ESSAYS ON THE ECONOMICS OF MEMBERSHIP-BASED

FREE SHIPPING PROGRAMS IN ONLINE MARKETPLACES

by

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To my family, Yue Dai, Jianxin Sun, Shengzhi Li

for their love and support throughout my life.

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The rapid growth of e-commerce and the importance of shipping in the context of online retailing have motivated online retailers to introduce the membership-based free shipping programs (MFS) programs in which retail platforms bear the shipping costs for purchases made by members that have paid an upfront fee. In spite of the popularity of such programs and the exemplary success of Amazon Prime, the mechanisms and implications of MFS have not been thoroughly investigated. In this dissertation, we study the economics of membership-based free shipping programs in online marketplaces from three distinct perspectives and provide insights to better leverage such programs in the online retailing industry.

In the first chapter, we examine the strategic implications of MFS. We find that the membership fee collected by a platform does not even cover the shipping cost. However, MFS can benefit the platform because of its positive impacts on price and demand. Consumers, on the other hand, are not necessarily better off, despite higher level of consumption. Moreover, MFS could hurt the society because it may overstimulate demand from low value transactions and thus incur social waste. Our results imply that MFS cannot be simply considered as a pure shipping cost transfer mechanism; online retailers who aim to benefit from it should take into consideration the strategic benefits of it.

In the second chapter, we identify the strategic relationship between an online retailer's consumer-side MFS adoption and its supplier-side business model shift from the agency model of selling, where a retailer allows a manufacturer to sell on the retailer site for a commission on the sale price, to the wholesale resale model, where the retailer buys from the manufacturer at a wholesale price and resells to consumers at a retail price. We find that such shift enhances the value of MFS to the retailer in the sense the retailer gains more from MFS and MFS is profitable to the retailer in a larger region of the parameter space under the agency model than the wholesale model. The retailer's gain from MFS comes at the expense of consumers and the society under the wholesale model, but the consumers and the society can also benefit from MFS under the agency model. The key driver of these results is that, under the wholesale model, MFS increases the severity of the double-marginalization problem because of larger retailer's marginal cost; however, under the agency model, MFS reduces the impact of marginalization at the manufacturer end because the manufacturer faces consumers with smaller purchasing cost on average.

In the last chapter, we focus on MFS in the context of platform competition. We would like to understand how MFS serves as an innovative marketing tool that grants unique competitive advantages and how competition in turn influences the adoption of MFS. By analyzing online retailers' MFS decisions in a competitive environment, we show that low shipping cost generally encourages the adoption of MFS that could benefit the adopter in terms of price, demand, and market share. Online retailers, however, are not necessarily better off with MFS. Particularly when shipping cost is attractive to induce MFS adoption on both sides but not low enough to justify the profitability, online retailers fall into prisoner's dilemma where they are forced to adopt MFS that ends up hurting them both. Moreover, our analysis suggests that MFS is more likely to appear in the presence of competition than in a monopoly scenario, which provides a reasonable explanation to firms' growing interest toward and the striking popularity of MFS.

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CHAPTER 1

INTRODUCTION

1.1 Strategic Implications of Online Retail Platforms' Membership-Based Free Shipping Programs

Online retail platforms (hereafter, platforms) that allow third-party sellers to sell their products on those platforms offer consumers enormous benefits, such as huge product selection and convenience. At the same time, shipping physical products to consumers is an indispensable but costly operation in online retailing because of the geographical separation of buyers and sellers/products. Industry experts often cite the shipping cost as the Achilles' heel of e-commerce that hinders its growth (Fierce Retail, 2014; Information Age, 2015). Shipping cost is also recognized as a key factor that affects online consumers' purchasing decisions and satisfaction (Rosen and Howard, 2000; Trocchia and Janda, 2003; Janda et al., 2002; Pyke et al., 2001), and consumers are known to not complete their purchases when the shipping cost is added to the price at the checkout point(comScore, 2012).

Recognizing the importance of shipping cost in online consumers' purchase decisions, platforms have recently introduced innovative programs related to shipping that seek to reduce the shipping cost burden on consumers. One such program is the membership-based free shipping (MFS). Examples of MFS programs include *Amazon Prime*, *ShopRunner*, Walmart.com's now defunct *ShippingPass*, and Walmart.com's recently introduced *Delivery Unlimited*. While these programs are not identical in every respect, a common element of these programs is that once a consumer becomes a member of the program by paying an upfront membership or subscription fee, the platform ships products for free to the member whenever she makes a purchase during the membership period. The popularity of MFS programs is evident from the size of the Amazon Prime program which currently has more than 100 million members in the United States, representing about 57% of Amazon customers (https://www.cirpllc.com).

Despite the popularity of MFS programs, industry experts are divided in their opinions about the effectiveness of these programs to increase platforms' profits (Time, 2011; CNET, 2015; The Motley Fool, 2016; MIT Technology Review, 2016). Some experts claim that MFS programs play a pivotal role in helping platforms deliver profits (CNET, 2015; The New York Times, 2015) and argue that platforms would lose money if there were no membership revenue (The Motley Fool, 2016). Those experts often compare MFS programs to the membership programs of wholesale clubs such as Costco, which derive bulk of their profits from membership fees rather than product sales; Costco's operating income in 2018 was $4.5 billion which included the $3.1 billion membership fee (Costco, 2018). On the contrary, other experts claim that unlimited free shipping costs significant amount of money to the platforms, hurting their bottom lines (CNET, 2016b; Independent, 2015; Market Watch, 2015). For instance, they point to Amazon's increasing shipping costs which accounted for 14 percent of its net sales in year 2017 (Statista, 2018). The value of MFS programs to consumers is also keenly debated. Since consumers pay an upfront fee to join these programs, figuring out if the membership is worth the fee is another issue for which there is no consensus among experts (CR Consumer Reports, 2016; CNET, 2016a; The Street, 2016). Furthermore, whether or not MFS programs improve the overall welfare of stakeholders in the system such as platform, sellers, and consumers, remains an unexplored question, though it has been reported that the free shipping programs exacerbate broader societal costs such as carbon footage, packaging waste, and driver safety (Buzz Feed News, 2018; Forbes, 2018; The New York Times, 2019).

In spite of the significant attention given to MFS programs in the popular press and their more than decade-long existence (Amazon introduced the Prime program in year 2005), there has been little academic research on this topic. Moreover, discussions in the popular press regarding the profitability of MFS programs to platforms or the potential benefit to consumers have revolved around shipping cost and membership fee, presumably because free shipping is at the core of these programs. However, the impacts of these programs go well beyond shipping as they have implications for various parties involved with these programs, such as the platform, the third-party sellers that sell via the platform, and consumers that buy in the platform. Assessing the benefits of MFS programs without accounting for their strategic impacts could lead to flawed conclusions and an incomplete understanding of these programs. In this chapter, we seek to articulate the strategic effects of MFS programs using a game-theoretical model. Specifically, we seek to answer the following research questions:

(1) For a platform, does the membership fee cover the shipping costs? Alternatively, for a member, does the shipping cost saving pay for the membership?

(2) Who benefits from the MFS program? Is it the platform, consumers, and/or the society?

We consider a dominant online platform where independent third-party sellers sell their products to consumers using an agency pricing model, i.e., sellers pay a percentage of sale price as commission to the platform. In return, the platform provides various value-added services to sellers, such as online storefronts, product review systems, and recommendation systems. Such a business model is ubiquitous in online retailing and is used by platforms such as Amazon, Walmart.com, and ShopRunner. For instance, Amazon sells a majority of its products and more than 90% of products in several product categories using the agency pricing model (Jiang and Srinivasan, 2011). In the absence of the MFS program, consumers pay not only the product price but also the shipping cost. If the platform implements the MFS program, then the platform pays the shipping cost for program members. We develop a game-theoretical model of this context with two sellers, each selling a single product, to assess the implications of the MFS program for the stakeholders by comparing the equilibrium outcomes in the presence of the MFS program with those in its absence.

The key findings and implications of our study are the following:

(i) The membership fee collected by the platform does not cover the cost it incurs in shipping products purchased by members during the membership period. Thus, solely from the perspective of shipping, the MFS program hurts the platform and benefits the members.

(ii) Despite the platform's shipping-related loss, the MFS program still benefits the platform when the shipping cost is less than a threshold value. The platform benefits the most from the MFS program when the shipping cost is moderate.

(iii) The MFS program hurts consumers overall. The MFS program hurts not only non-members but also members. The higher product price consumers pay under the MFS program compared to when there is no MFS program offsets the shipping cost related savings members enjoy.

(iv) Even though the MFS program increases the overall demand and the platform finds the program to be profitable, it is not necessarily social welfare-enhancing. The MFS program stimulates extra demand from members that have a low utility for the products. The society's gain from this extra demand could fall short of the shipping cost required to satisfy this demand under the MFS program, thus hurting the social welfare. Therefore, even when the other societal costs associated with extra demand are ignored, the MFS program could still hurt the society based on consumption benefits and shipping costs alone.

The findings suggest that the the MFS program is a strategic vehicle for the platform to benefit at consumers', and sometimes also at the society's, expense. We demonstrate that our findings are driven by several effects regarding how sellers and consumers respond to the MFS program. Hence, judging the MFS program purely as a cost transfer mechanism between the platform and the consumers can lead to misleading and incorrect conclusions. Finally, despite the similarity between the MFS programs of online retailers and the membership programs of physical stores such as Costco, the implications of these programs can be quite different and the differences could be attributed to the role of shipping which is likely to be more significant in online retailing than physical retailing.

1.2 Value of Membership-Based Free Shipping in Online Retailing: Impact of Upstream Pricing Model

Shipping products to consumers is an indispensable and a costly activity in online retailing (Fierce Retail, 2014; Information Age, 2015). Moreover, the shipping cost plays a pivotal role in online consumers' purchasing decisions and satisfaction (Rosen and Howard, 2000; Sawhney, 1999; Ernst and Young, 1999; Trocchia and Janda, 2003; Janda et al., 2002; Pyke et al., 2001). The consumers typically pay the shipping cost, though the sellers often absorb this cost when the transaction amount exceeds a threshold. A recent development related to shipping is the membership-based free shipping (MFS) program which seeks to mitigate the shipping cost burden of consumers.

While MFS is an innovation on the downstream consumer-side of online retailing, we have been witnessing a gradual shift in the upstream business model between the retailer and the suppliers. Large online retailers such as Amazon.com, Walmart.com, Sears.com, and Buy.com started with the reselling or *wholesale model* for most products, in which the retailers buy products at wholesale prices and subsequently resells them to consumers at retail prices. However, those retailers have now become platforms for third-party sellers, and they typically use the *agency model*, in which sellers sell their products directly to consumers for a commission on the sale price. (Seller Labs, 2016; The Wall Street Journal, 2010; Dealnews, 2013; Sears Holding, 2010). The significance of the agency model in current online retailing is evident from Amazon's recent disclosure that third-party sellers accounted for 58 percent of total physical gross merchandise sales on Amazon in 2018, up from just 3 percent in 1999, and this percentage has been steadily increasing.[1] The shift in the business model of online retailing has also drawn significant attention from industry experts who have argued the need for online retailers to align their strategies and operational practices to the agency model (Wired, 2015; Zhu and Furr, 2016; The Marketing Journal, 2017).

[1] https://www.statista.com/chart/18751/physical-gross-merchandise-sales-on-amazon-by-type-of-seller/

On surface, the upstream pricing model and the downstream MFS program seem unrelated to each other because each strategy seeks to achieve a different objective. The agency model shifts the retailer's focus to providing value-added services and transfers the key retailing function of product pricing to upstream third-party sellers. On the other hand, the MFS program seeks to eliminate shipping cost burden of downstream consumers, specifically program members. Moreover, while the online retailer incurs a direct additional cost, viz., members' shipping cost, when it offers a MFS program, there is no direct additional cost to the retailer when it accommodates third-party sellers on its site.[2] However, observations suggest that the MFS program is prevalent only among retailers that use the agency (or platform) model of selling. For instance, Amazon introduced the Prime program in 2005 by which time approximately 30% of its product sales by volume had been coming from third-party sellers.[3] While Walmart did not have a program similar to Amazon Prime when it was a reseller, it introduced its *ShippingPass* program after it became a marketplace by purchasing jet.com. ShopRunner has always been a marketplace operating under the pure agency model. On the contrary, we do not observe free shipping programs offered by online retailers who are resellers using the wholesale model. These observations raise the questions of whether a retailer achieves a higher benefit from the MFS program under the agency model than the wholesale model, and if so, why.

We answer those questions by analyzing a stylized game-theoretic model of a context in which a manufacturer sells his product to consumers via an online retailer, using either the agency model or the wholesale model. Under the agency model, the manufacturer sets the retail price and pays a percentage of the sale price as commission to the retailer. Under the wholesale model, the manufacturer sets the wholesale price, and the retailer sets the retail

[2]On the contrary, some argue that the retailers incur lower costs under the agency model than the wholesale model (Jiang et al., 2011; Digital Business Models, 2013).

[3]https://www.marketplacepulse.com/stats/amazon/amazon-percent-of-gross-merchandise-volume-by-third-party-sellers-157

price. In the absence of the MFS program, consumers bear the shipping cost for product delivery. If the retailer implements the MFS program, he pays the shipping cost for the members during the membership period. We use the scenario with no MFS program as the benchmark to assess the impact of the MFS program under the agency and wholesale models. We then compare the value of the MFS program under the two pricing models.

We show that the retailer indeed gains more from the MFS program under the agency model than the wholesale model, and the retailer finds the MFS program to be profitable in a larger region of the parameter space under the agency model compared to the wholesale model. The retailer's gain from the MFS program under the wholesale model comes solely at the expense of consumers; consumers pay higher prices under the MFS program while consuming, on average, the same amount whether or not the MFS program is adopted. In contrast, consumer surplus can be higher in the presence of the MFS program than in its absence under the agency model because MFS enhances the total demand. Non-members are always worse off with the MFS program than without under both pricing models as a result of negative externalities imposed by members' participation in the form of higher prices; interestingly, some members can also be hurt by the MFS program. Finally, society as a whole is always worse off, surprisingly, with the MFS program than without under the wholesale model, although the overall demand is unaffected by the MFS program. On the flip side, society can be better off with the MFS program under the agency model in certain conditions by virtue of the demand enhancement effect.

The benefits of the agency model over the wholesale model in a channel structure in many contexts are typically attributed to the problem of double-marginalization which is present in the wholesale model, but is absent in the agency model. Our results are driven not just by the presence or absence of double-marginalization, but by how the MFS program affects the severity of double-marginalization in the wholesale model and single marginalization in the agency model. The MFS program exacerbates the double-marginalization problem, measured as the reduction in the channel profit from double marginalization when compared to single marginalization, in the wholesale model. The MFS program transfers the shipping cost from the consumers to the retailer. This additional marginal cost on the retailer, on top of the wholesale price that the retailer incurs whether or not the MFS program exists, worsens the double-marginalization problem in the wholesale model. On the other hand, marginalization exists only at the manufacturer's end (i.e., single marginalization) in the agency model because the manufacturer sets the retail price. The MFS program eliminates the shipping cost incurred by the consumers which is analogous to reducing the marginal cost of the manufacturer. Effectively, the MFS program mitigates (single) marginalization at the manufacturer end. Together, these effects of MFS on marginalization in the two models drive the results of this chapter. This insight is new to the literature in that we are unaware of a study in which the benefits of a downstream strategy are affected by its impacts on the marginalization feature exhibited by the upstream pricing model.

Moreover, our findings make significant contributions to two research streams in online retailing, and offers several implications for practitioners. One, this research provides new insights into the strategic drivers of (retailer's) profitability from MFS programs and how a retailer's upstream pricing model can impact the value from downstream MFS strategies. Specifically, our results reveal that the MFS program might be regarded as an unprofitable strategy if it is evaluated based solely on the shipping cost incurred by the retailer in serving members and the membership fee she collects from them. However, the MFS program could be a profitable strategy for the retailer if the benefits from the strategic impacts of the program are accounted for. Similarly, on the consumer side, even though members realize savings via the MFS program in shipping cost, some members (and all non-members) are hurt by the MFS program. Finally, the possible negative impact of the MFS program on the society reveals that the MFS program cannot be viewed as a simple transfer of the shipping cost burden from consumers to the retailer with no societal impact; the impacts of the MFS program go beyond the transfer of the shipping cost. These findings demonstrate that viewing the MFS program solely through the shipping lens leads to incorrect conclusions about the program.

Two, the findings are new to the literature that studies the wholesale and agency models. The extant literature has generally examined how exogenous market characteristics such demand and competition affect the firms differently depending on the pricing model. However, the literature has not examined the role of shipping (or product distribution) under these models, possibly because shipping is a significant activity primarily in online retailing. More importantly, our findings provide insights into how the pricing model affects the value of an endogenous strategy such as the MFS program, which is under the control of the retailer. Our findings suggest that as the agency model becomes more widespread in online retailing in the form of platform selling, online platforms would find introduction of a MFS program to be more attractive. These insightful results extend our understanding of the drivers of the transformations occurring in online retailing.

1.3 Membership-Based Free Shipping Programs: A New Vehicle to Gain Competitive Advantage for Online Retailers?

Online retailing is growing three times faster than the overall retail industry (BusinessInsider, 2017). Within online retailing, the platform model of selling in which a retail platform, serving as a marketplace, offers products from third-party sellers for purchase for a commission has expanded significantly in recent years (The Marketing Journal, 2017). For example, about half of the sales of Amazon comes from third-party sellers (Statista, 2017). Other retailers, such as Walmart, have also adopted the platform model for their online operations. In the platform model of selling, the traditional marketing mix elements—product, price, promotion, and place, known as 4Ps (McCarthy, 1968)—may not be as useful to online retailers to gain competitive advantage or achieve differentiation. For instance, under platform selling, the product and pricing decisions are made by the upstream third-party sellers and thus not under the control of online retailers. The locational advantages brick-and-mortar retailers may enjoy generally do not exist for online retailers. Any technology-based value-added services, such as recommender systems, product reviews or seller rating features, and advertising and promotion activities are often easily replicated by competitors, thereby resulting in no long-term competitive edge and perhaps even more intense competition. Recognizing the possible limitations of traditional marketing efforts in online platforms, the marketing community has advocated the need for rethinking the marketing strategies for online retailing (DigitalTonto, 2013).

In recent years, online retail platforms have started competing through shipping programs. Product shipping or delivery is not a major concern for brick-and-mortar firms (except perhaps for large bulky items) and thus it has not been viewed as a significant element for differentiation by these firms. However, shipping is an indispensable part of online retailing for all (both large and small) physical products. In online retailing, shipping cost is the second highest cost component after the product purchase price (Fierce Retail, 2014; Information Age, 2015), and the shipping cost plays a pivotal role in consumers' purchasing decisions and satisfaction (Rosen and Howard, 2000; Sawhney, 1999; Ernst and Young, 1999; Trocchia and Janda, 2003; Janda et al., 2002; Pyke et al., 2001). Recognizing the importance of shipping in consumers' purchase process, online retail platforms have launched several innovations related to product shipping. One such innovation is membership-based free shipping (MFS). While the first such program, Amazon Prime, was launched more than a decade ago in 2005, there has been little research on the role of these programs in a competitive setting.

In this chapter, we examine the impact of MFS-based competition between online retail platforms and seek to answer two important but related research questions:

(1) Does the adoption of MFS program mitigate or intensify online retail platform competition?

(2) Does competition encourage the adoption of the MFS program by online retail platforms?

To address the above questions, we develop a game-theoretic model in which two retail platforms sell (imperfectly) substitutable products from a manufacturer. We examine the equilibrium outcomes when only one or both platforms offer an MFS program. Using the scenario with no MFS program as the benchmark, we evaluate the MFS program's impact on competition between retailers and whether competition encourages or suppresses the adoption of MFS.

We show that the shipping cost plays a critical role in determining the impact of MFS under retail competition. When the shipping cost is high, neither retail platform has an incentive to adopt MFS. When the shipping cost is moderate, one of the platforms adopts MFS but the other one does not. In this asymmetric adoption equilibrium, the platform that does not adopt MFS is worse off and the platform that adopts the MFS is better off compared to the benchmark case where neither adopts the MFS program. When the shipping cost is low, both platforms adopt MFS in the equilibrium. However, the platforms are not necessarily better off when they implement MFS compared to the benchmark case. In particular, when the shipping cost is not too low, both platforms are hurt when they adopt MFS than when they do not, akin to the prisoners' dilemma situation. We identify *price increasing, purchase enhancing, and market expansion* effects of the MFS program for the implementing retailer as primary drivers for our findings.

Furthermore, we show that competing retailers indeed have a higher incentive to adopt MFS than a monopoly retailer. The result is particularly interesting because a monopolist retailer will never adopt MFS if it is not profitable to him, but competing retailers sometimes adopt MFS even if it hurts them. The findings suggest that shipping programs can indeed be a new vehicle for online retailer platforms to compete with each other.

CHAPTER 2

STRATEGIC IMPLICATIONS OF ONLINE RETAIL PLATFORMS' MEMBERSHIP-BASED FREE SHIPPING PROGRAMS

2.1 Introduction

Online retail platforms (hereafter, platforms) that allow third-party sellers to sell their products on those platforms offer consumers enormous benefits, such as huge product selection and convenience. At the same time, shipping physical products to consumers is an indispensable but costly operation in online retailing because of the geographical separation of buyers and sellers/products. Industry experts often cite the shipping cost as the Achilles' heel of e-commerce that hinders its growth (Fierce Retail, 2014; Information Age, 2015). Shipping cost is also recognized as a key factor that affects online consumers' purchasing decisions and satisfaction (Rosen and Howard, 2000; Trocchia and Janda, 2003; Janda et al., 2002; Pyke et al., 2001), and consumers are known to not complete their purchases when the shipping cost is added to the price at the checkout point(comScore, 2012).

Recognizing the importance of shipping cost in online consumers' purchase decisions, platforms have recently introduced innovative programs related to shipping that seek to reduce the shipping cost burden on consumers. One such program is the membership-based free shipping (MFS). Examples of MFS programs include *Amazon Prime*, *ShopRunner*, Walmart.com's now defunct *ShippingPass*, and Walmart.com's recently introduced *Delivery Unlimited*. While these programs are not identical in every respect, a common element of these programs is that once a consumer becomes a member of the program by paying an upfront membership or subscription fee, the platform ships products for free to the member whenever she makes a purchase during the membership period. The popularity of MFS programs is evident from the size of the Amazon Prime program which currently has more than 100 million members in the United States, representing about 57% of Amazon customers (https://www.cirpllc.com).

Despite the popularity of MFS programs, industry experts are divided in their opinions about the effectiveness of these programs to increase platforms' profits (Time, 2011; CNET, 2015; The Motley Fool, 2016; MIT Technology Review, 2016). Some experts claim that MFS programs play a pivotal role in helping platforms deliver profits (CNET, 2015; The New York Times, 2015) and argue that platforms would lose money if there were no membership revenue (The Motley Fool, 2016). Those experts often compare MFS programs to the membership programs of wholesale clubs such as Costco, which derive bulk of their profits from membership fees rather than product sales; Costco's operating income in 2018 was $4.5 billion which included the $3.1 billion membership fee (Costco, 2018). On the contrary, other experts claim that unlimited free shipping costs significant amount of money to the platforms, hurting their bottom lines (CNET, 2016b; Independent, 2015; Market Watch, 2015). For instance, they point to Amazon's increasing shipping costs which accounted for 14 percent of its net sales in year 2017 (Statista, 2018). The value of MFS programs to consumers is also keenly debated. Since consumers pay an upfront fee to join these programs, figuring out if the membership is worth the fee is another issue for which there is no consensus among experts (CR Consumer Reports, 2016; CNET, 2016a; The Street, 2016). Furthermore, whether or not MFS programs improve the overall welfare of stakeholders in the system such as platform, sellers, and consumers, remains an unexplored question, though it has been reported that the free shipping programs exacerbate broader societal costs such as carbon footage, packaging waste, and driver safety (Buzz Feed News, 2018; Forbes, 2018; The New York Times, 2019).

In spite of the significant attention given to MFS programs in the popular press and their more than decade-long existence (Amazon introduced the Prime program in year 2005), there has been little academic research on this topic. Moreover, discussions in the popular press regarding the profitability of MFS programs to platforms or the potential benefit to consumers have revolved around shipping cost and membership fee, presumably because free shipping is at the core of these programs. However, the impacts of these programs go well beyond shipping as they have implications for various parties involved with these programs, such as the platform, the third-party sellers that sell via the platform, and consumers that buy in the platform. Assessing the benefits of MFS programs without accounting for their strategic impacts could lead to flawed conclusions and an incomplete understanding of these programs. In this paper, we seek to articulate the strategic effects of MFS programs using a game-theoretical model. Specifically, we seek to answer the following research questions:

(1) For a platform, does the membership fee cover the shipping costs? Alternatively, for a member, does the shipping cost saving pay for the membership? (2) Who benefits from the MFS program? Is it the platform, consumers, and/or the society?

We consider a dominant online platform where independent third-party sellers sell their products to consumers using an agency pricing model, i.e., sellers pay a percentage of sale price as commission to the platform. In return, the platform provides various value-added services to sellers, such as online storefronts, product review systems, and recommendation systems. Such a business model is ubiquitous in online retailing and is used by platforms such as Amazon, Walmart.com, and ShopRunner. For instance, Amazon sells a majority of its products and more than 90% of products in several product categories using the agency pricing model (Jiang and Srinivasan, 2011). In the absence of the MFS program, consumers pay not only the product price but also the shipping cost. If the platform implements the MFS program, then the platform pays the shipping cost for program members. We develop a game-theoretical model of this context with two sellers, each selling a single product, to assess the implications of the MFS program for the stakeholders by comparing the equilibrium outcomes in the presence of the MFS program with those in its absence.

The key findings and implications of our study are the following:

(i) The membership fee collected by the platform does not cover the cost it incurs in shipping products purchased by members during the membership period. Thus, solely from the perspective of shipping, the MFS program hurts the platform and benefits the members.

(ii) Despite the platform's shipping-related loss, the MFS program still benefits the platform when the shipping cost is less than a threshold value. The platform benefits the most from the MFS program when the shipping cost is moderate.

(iii) The MFS program hurts consumers overall. The MFS program hurts not only non-members but also members. The higher product price consumers pay under the MFS program compared to when there is no MFS program offsets the shipping cost related savings members enjoy.

(iv) Even though the MFS program increases the overall demand and the platform finds the program to be profitable, it is not necessarily social welfare-enhancing. The MFS program stimulates extra demand from members that have a low utility for the products. The society's gain from this extra demand could fall short of the shipping cost required to satisfy this demand under the MFS program, thus hurting the social welfare. Therefore, even when the other societal costs associated with extra demand are ignored, the MFS program could still hurt the society based on consumption benefits and shipping costs alone.

The findings suggest that the the MFS program is a strategic vehicle for the platform to benefit at consumers', and sometimes also at the society's, expense. We demonstrate that our findings are driven by several effects regarding how sellers and consumers respond to the MFS program. Hence, judging the MFS program purely as a cost transfer mechanism between the platform and the consumers can lead to misleading and incorrect conclusions. Finally, despite the similarity between the MFS programs of online retailers and the membership programs of physical stores such as Costco, the implications of these programs can be quite different and the differences could be attributed to the role of shipping which is likely to be more significant in online retailing than physical retailing.

2.2 Related Literature

The MFS programs are a recent phenomenon and academic research on this topic is limited. However, the MFS programs share a few characteristics with loyalty programs that are popular among brick-and-mortar retailers and in the airline industry. For instance, in loyalty programs as well as MFS programs, consumers need to sign up first for the program, and those who sign up as members enjoy benefits that non-members do not. Since the seminal works of (Klemperer, 1987) and (Farrell, 1987), researchers have examined the impacts of loyalty programs on brand loyalty, repeat-purchase patterns, and customer retention (Sharp and Sharp, 1997; Dowling and Uncles, 1997; Uncles et al., 2003; Yi and Jeon, 2003; Lewis, 2004; Ashley et al., 2016). These studies show that loyalty programs can lock in customers, increase switching cost, increase customer loyalty, and soften competition between firms. Our work differs from this stream of research along several dimensions. First, while a loyalty program is an ex-post reward mechanism in the sense that the reward amount is often proportional to how much the consumer has already spent at the firm, the MFS is a front-end subscription-based program that promises future savings. Second, loyalty programs generally offer free membership. Therefore, participation decisions of consumers are not necessarily strategic. However, since membership in MFS programs is not free, consumers have to assess the expected future benefits of the MFS program in relation to the membership fee they have to pay before making the joining decision. Finally, there is one dominant platform that the consumer can buy from in our model, and thus the question of whether the consumer remains loyal to the platform or switches to another platform does not arise in our context. Thus, our results are not driven by how MFS affects competition between platforms.

The MFS program is also related to the two-part tariff scheme in the sense that the membership fee can be considered as a lump-sum fee and the price as the per-unit charge (Oi, 1971; Littlechild, 1975; Yin, 2004; Reisinger, 2014). A principal finding of research in two-part tariff is that a discriminatory two-part tariff policy with price equal to marginal cost maximizes a monopoly's profit and that it is attractive even under competitive settings, compared to a linear pricing scheme. However, a key difference between the MFS programs and two-part tariff schemes is that a single firm jointly determines the optimal lump-sum fee and per-unit charge in a two-part tariff setting while the membership fee and purchase price are decided by different firms—the platform and sellers respectively—in the MFS program.

Some recent work has started to examine free shipping in the online retailing context. Wen and Lin (2017) study the impact of the MFS program when one of two competing retailers adopts the program. They show that the MFS program benefits both retailers by softening the price competition between them. Tan et al. (2015) compare two free shipping programs: free shipping with a minimum order quantity (referred to as *Contingent Free Shipping*) and free expedited shipping with a membership. They show that the free expedited shipping with membership benefits retailers when the value of expedited shipping is sufficiently high. A key difference between our model and the models used by these two papers is that they assume an exogenous fixed demand that is unaffected by the MFS program, but we endogenize the demand and show that the demand is indeed affected by the MFS program. In fact, this finding is consistent with the anecdotal observation that Amazon prime members consume more than non-members. Moreover, Tan et al. (2015) assess the free shipping programs from the order quantity perspective when consumers incur holding cost and focus on the trade-off between holding cost savings and utility from expedited shipping. In contrast, we seek to isolate and articulate the impacts of only free shipping—which is the core element of MFS programs—without benefits such as expedited shipping.

2.3 Model

We consider a dominant online platform R that allows third-party sellers to sell their products in it for a commission equal to α fraction of the sale price. We want to note that we also analyzed a model in which the platform acts as a reseller using the wholesale model and found qualitatively similar results. There is a mass of consumers that use the platform. A consumer visits R to shop for a product that could possibly satisfy her need whenever a consumption need arises. We consider a time period that consists of discrete shopping instances (normalized to 1). For example, the time period could be a year and each day in the year could be a shopping instance such that the time period has 365 shopping instances. A consumer may not have a consumption need in every shopping instance. Furthermore, even when she faces a consumption need, the intensity of the need and her product preference can differ across shopping instances. A consumer has two options when she visits the platform: either (i) buy the product that offers the maximum positive surplus, or (ii) not buy any product. The consumer will choose the second option if no product offers a positive surplus to her. There is a cost associated with shipping the product to the consumer if she buys. A consumer buys a maximum of one unit of one product in a shopping instance. The fixed and marginal production costs are assumed to be zero for all products.

Consumer Utility and Consumer Segments. Consumers are heterogeneous in their *shopping frequency* in the sense that some consumers face consumption need and visit the platform more frequently than others during the time period we consider. For instance, the head of a household that has more family members is more likely to shop more often than one that has fewer family members in his household. We assume σ fraction of the consumers are *infrequent shoppers* and the probability that a consumption need arises for an infrequent shopper in a shopping instance is γ_l. The rest, $(1-\sigma)$ fraction, of the consumer population are *frequent shoppers* with the corresponding probability of having a consumption need at a shopping instance being γ_h, where $\gamma_l < \gamma_h$. The shopping frequency defines the consumer type in our model.

The consumer utility for a product at a shopping instance depends on her base valuation, which represents the value she derives from an ideal product that meets her need perfectly, and the misfit cost if the product does not meet her need perfectly at that instance. A consumer's base valuation and misfit cost can vary across shopping instances. We assume a consumer's base valuation at a shopping instance, conditional on her having a consumption need, is low, v_l, with probability θ, and high, v_h, with probability $(1-\theta)$, where $v_l < v_h$. We can consider the base valuation as the intensity of the consumption need. For example, the need could be an essential one in one shopping instance but a non-essential one (i.e., a want/desire) in another instance for the same consumer. In the case of essential need, the consumer would likely have a high valuation and buy a product to satisfy the need. On the other hand, in case of a non-essential need, she is more likely to have a low valuation and may purchase a product only if she finds a product that is sufficiently close to her preference.

To model consumer's preference or misfit cost, we assume, for simplicity, that the platform offers two products that are imperfect substitutes from two different sellers. We denote the two products as A and B. For notational brevity, we refer to the respective sellers also as A and B. We use a typical horizontal product differentiation model for the misfit cost. In particular, we assume that products A and B are located at positions 0 and 1 of a unit line, respectively. A consumer's location at a shopping instance is equally likely to be any point along the line. The distance between a consumer and a product measures the degree of misfit of the product to the consumer. Notice that when the degree of misfit between a consumer and product A is λ, $\lambda \in [0,1]$, the degree of misfit between the consumer and product B is $(1-\lambda)$. The misfit cost is the degree of misfit times a unit misfit cost t. Note that neither the base valuation (v_l and v_h) nor the degree of misfit (λ) are idiosyncratic types of consumers; on the other hand, the shopping frequency is.

The cost to ship the product to the consumer at any shopping instance during the period is s, regardless of who pays for it. This is reasonable in a context where the shipping is done by an independent logistics provider. (In the model extension section, we do examine the case where the consumers' shipping cost could be different from the actual shipping cost.) We examine this context in order to focus on the strategic impacts related to who pays for shipping. We consider two scenarios that differ with respect to who bears the shipping cost. In the scenario in which the platform does not offer the MFS program, consumers incur the shipping cost. In the scenario in which the platform offers the MFS program, the platform bears the shipping cost of members, but non-members bear the shipping cost themselves. Thus, conditional on a consumer having a consumption need, if she has a base valuation v, is located at λ, and bears the shipping cost, then her net utility from products A and B is as follows:

$$U_A = \quad v - \lambda t - p_A - s \ , \tag{2.1}$$

$$U_B = \quad v - (1-\lambda)t - p_B - s \ . \tag{2.2}$$

where p_A and p_B respectively denote the the prices of A and B. Clearly, if the platform bears the shipping cost for the consumer, then the shipping cost term will not be part of the net utility expressions given in Equations 2.1 and 2.2.

A consumer knows whether she has a consumption need at a particular shopping instance, and if there is a need, she also knows her base valuation and her location on the Hotelling line before making the purchase decision at that shopping instance. Neither the platform nor the sellers know the type of an individual consumer, whether a consumer has a need at a specific instance, her base valuation nor the consumer's location. However, the sellers and the platform know the distributions of consumers' shopping frequency, base valuation, and location. Figure 2.1 illustrates the model setup.

Timing of the Game. The sequence of events is as follows. In stage 1, the platform announces a (per-member) membership fee M at the beginning of the period and commits to bearing the member's shipping costs during the period. In stage 2, consumers decide whether to participate in the MFS program, also at the beginning of the period. In stage 3, the platform announces the commission rate α. In stage 4, sellers choose their prices simultaneously and, in stage 5, consumers who face a consumption need visit the platform and make their purchase decisions, and all parties realize their payoffs. In the case where the

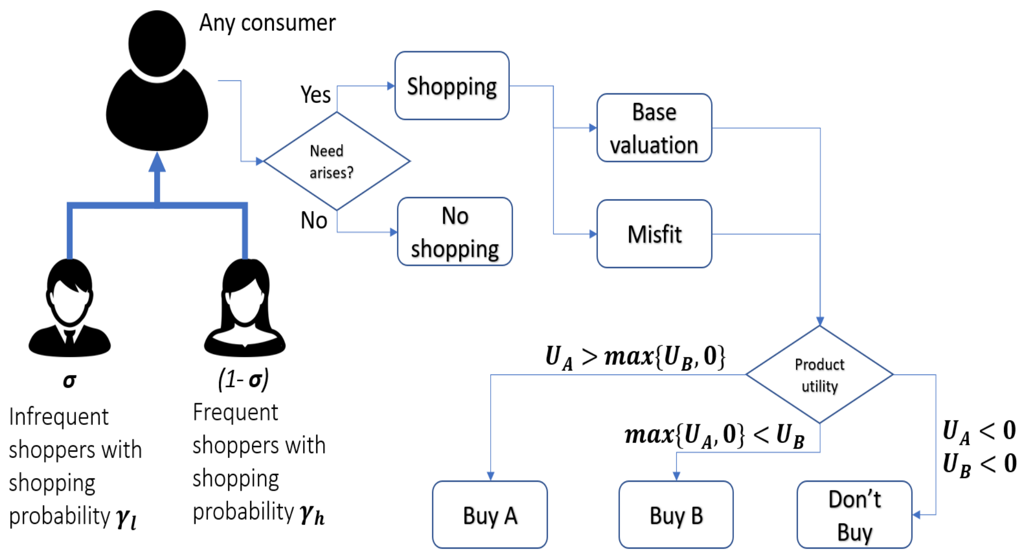

Figure 2.1: Model Setup

platform does not offer the MFS program, stage 1 and stage 2 are irrelevant and the game starts from stage 3.

All players are risk neutral. Table 2.1 summarizes the main notation used in the paper. We use the subscript i, $i \in \{A, B\}$, to denote sellers/products and the superscript j, $j \in \{b, m\}$, to denote the program scenarios—no MFS (b) and MFS (m).

2.3.1 No MFS (Benchmark Scenario)

In this section, we derive the subgame perfect equilibrium for the scenario without the MFS program. If a consumer has a consumption need, a base valuation v_h, and is located at λ, she will buy product A if $U_A > U_B$ and will buy product B otherwise. Thus, using Equation 2.1, we can verify that she will buy product A if $\lambda < \frac{t-p_A^b+p_B^b}{2t}$ and product B otherwise. On the other hand, if the same consumer has a base valuation v_l, then she will buy product A if $\lambda < \frac{v_l-p_A^b-s}{t}$, buy product B if $\lambda > 1 - \frac{v_l-p_B^b-s}{t}$, and will not buy any product otherwise.

Table 2.1: Summary of Notation 1

Notation	Definition	Values
σ	fraction of infrequent shoppers	$\sigma \in (0,1)$
γ_l	shopping frequency of an infrequent shopper	$\gamma_l > 0$
γ_h	shopping frequency of a frequent shopper	$\gamma_h > \gamma_l$
v_l	low base valuation	$v_l > 0$
v_h	high base valuation	$v_h > v_l$
θ	probability that a consumer's base valuation is v_l	$\theta \in (0,1)$
λ	degree of misfit between a consumer and product A	$\lambda \in (0,1)$
t	unit misfit cost	$t > 0$
s	unit shipping cost	$v_l > s > 0$
i	index for sellers/products	$i \in \{A,\ B\}$
j	index for program scenarios	$k \in \{b,\ m\}$
α_i^j	commission rate for seller i in scenario j	$\alpha_i^j \in (0,1)$
U_i^j	net utility derived by a consumer from product i in scenario j	
π_R^j	expected profit of platform in scenario j	
π_i^j	expected profit of seller i in scenario j	
p_i^j	retail price of product i in scenario j	$p_i^j \geq 0$
M^j	membership fee in scenario j	
D_h^j	purchase frequency (demand) of frequent shoppers in scenario j	$D_{h,j}^k > 0$
D_l^j	purchase frequency (demand) of infrequent shoppers in scenario j	$D_{l,j}^k > 0$
D_i^j	expected demand for seller i in scenario j	$D_i^j > 0$
CS^j	consumer surplus in scenario j	
SW^j	social welfare in scenario j	

In stage 4, sellers choose prices to maximize their expected profits given as follows:

$$\arg\max_{p_A^b} \ \pi_A^b = \quad (\sigma\gamma_l + (1-\sigma)\gamma_h)[\theta\frac{v_l - p_A^b - s}{t} + (1-\theta)\frac{t - p_A^b + p_B^b}{2t}]p_A^b(1-\alpha_A^b) \ , \quad (2.3)$$

$$\arg\max_{p_B^b} \ \pi_B^b = \quad (\sigma\gamma_l + (1-\sigma)\gamma_h)[\theta\frac{v_l - p_B^b - s}{t} + (1-\theta)\frac{t - p_B^b + p_A^b}{2t}]p_B^b(1-\alpha_B^b) \ . \quad (2.4)$$

In Equation 2.3, $(\sigma\gamma_l + (1-\sigma)\gamma_h)$ denotes the the expected number of consumers that visit the platform, and $[\theta\frac{v_l - p_A^b - s}{t} + (1-\theta)\frac{t-p_A^b+p_B^b}{2t}]$ denotes the expected demand for product A from a shopper that visits the platform. Analogously, we have the expected demand for product B in Equation 2.4. Since the sellers do not know the consumer type, the realized valuation nor the preference of any individual consumer, each seller computes his expected demand as the product of the likelihood of a consumer buying his product conditional on vising the platform and the likelihood of a consumer visiting the platform. We refer to the expected demand from each consumer type—frequent shoppers or infrequent shoppers—as the type's *purchase frequency* hereafter. Solving the first-order conditions for the sellers' maximization problems, we obtain the optimal retail prices.

In stage 3 of the game, the platform determines the commission rates α_A^b and α_B^b by solving the model below.

$$\begin{aligned}
\arg\max_{\alpha_A^b,\alpha_B^b}\ \pi_R^b = \quad & (\sigma\gamma_l + (1-\sigma)\gamma_h)[\theta\frac{v_l - p_A^b - s}{t} + (1-\theta)\frac{t - p_A^b + p_B^b}{2t}]p_A^b\alpha_A^b \\
& +(\sigma\gamma_l + (1-\sigma)\gamma_h)[\theta\frac{v_l - p_B^b - s}{t} + (1-\theta)\frac{t - p_B^b + p_A^b}{2t}]p_B^b\alpha_B^b\ , \\
\text{subject to} \qquad & \pi_A^b \geq \mu,\ \pi_B^b \geq \mu\ .
\end{aligned}$$

The constraints in the above model denotes the individual rationality (IR) restrictions that ensure the reservation profit for the sellers to sell through the platform. Solving the platform's maximization problem, we obtain the optimal commission rates.

Lemma 1. *In the absence of the MFS program, in equilibrium, commission rates α_A^{b*} and α_B^{b*}, retail prices p_A^{b*} and p_B^{b*}, purchase frequency of frequent shoppers D_h^{b*} and purchase frequency of infrequent shoppers D_l^{b*} are as follows.*

$$\alpha_A^{b*} = \alpha_B^{b*} = \ 1 - \frac{2t(1+3\theta)^2\mu}{(1+\theta)[t(1-\theta)+2\theta(v_l - s)]^2(\sigma\gamma_l + (1-\sigma)\gamma_h)}\ ,$$

$$p_A^{b*} = p_B^{b*} = \ \frac{2\theta(v_l - s) + t(1-\theta)}{1+3\theta}\ , \tag{2.5}$$

$$D_h^{b*} = \ \frac{(1+\theta)[2\theta(v_l - s) + t(1-\theta)](1-\sigma)\gamma_h}{t(1+3\theta)}\ , \tag{2.6}$$

$$D_l^{b*} = \frac{(1+\theta)[2\theta(v_l - s) + t(1-\theta)]\sigma\gamma_l}{t(1+3\theta)} . \tag{2.7}$$

PROOF. All proofs are in the appendix unless indicated otherwise.

Using Lemma 1, we compute the equilibrium platform profit π_R^{b*}, consumer surplus CS^{b*}, and social welfare SW^{b*} in the No MFS scenario, where we define the social welfare as the summation of sellers' profits, platform profit, and consumer surplus. We provide the expressions for these in the appendix. We verify that an increase in shipping cost s reduces the equilibrium prices because the sellers will expect a smaller demand when the shipping cost is higher. The purchase frequency of each type also decreases in s even though sellers set a lower price because the reduction in price does not offset the increase in shipping cost. Anticipating less demand and lower prices due to a higher shipping cost, the platform lowers the commission rates if shipping gets more costly in order to provide the reservation profit to sellers. Consequently, the platform's profit decreases in s.

2.4 Analysis of the MFS Program

We first derive the subgame perfect equilibrium for the scenario with the MFS program. If the platform implements the MFS program, it can induce one of two possible equilibria: (i) only frequent shoppers become members, or (ii) both frequent shoppers and infrequent shoppers become members. We note that the case where no consumer becomes a member is identical to the benchmark, and we assume that the platform would not implement the MFS program in this case. Furthermore, the case where only infrequent shoppers become members cannot be an equilibrium because if an infrequent shopper finds it profitable to become a member so will a frequent shopper because a frequent shopper would expect to save more in shipping cost by joining the MFS program than an infrequent shopper. In this paper, we focus on the equilibrium in which only frequent shoppers join the MFS program as this scenario is more likely in practice than the one in which all consumers join the MFS program. We performed the analysis for the equilibrium where both frequent and infrequent shoppers join the program and found the insights presented in this paper to hold in that equilibrium as well. Further, we note that Amazon has been increasing its membership fee for the Prime program over time, which disincentives a consumer that shops less frequently in Amazon from joining the Prime program.

In stage 5 of the game under the MFS program, a member's purchase decision can vary from that of a non-member because a member does not bear the shipping cost whereas a non-member does. A non-member's purchase decision rule remains the same as that under the benchmark scenario. On the other hand, if the consumer is a member, she will buy product A if $\lambda < \frac{t-p_A^m+p_B^m}{2t}$ and product B otherwise if her base valuation is v_h; if the base valuation is v_l, then she will then buy product A if $\lambda < \frac{v_l-p_A^m}{t}$, buy product B if $\lambda > 1-\frac{v_l-p_B^m}{t}$, and will not buy any product otherwise.

In stage 4, the expected seller profits depend on the size and the composition of the membership base. If ω fraction of frequent shoppers and none of the infrequent shoppers become members, the sellers' pricing problems are formulated as:

$$\begin{aligned}
\arg\max_{p_A^m}\ \pi_A^m = \ & [(\sigma\gamma_l + (1-\omega)(1-\sigma)\gamma_h)(\theta\frac{v_l - p_A^m - s}{t} + (1-\theta)\frac{t - p_A^m + p_B^m}{2t}) \\
& +\omega(1-\sigma)\gamma_h(\theta\frac{v_l - p_A^m}{t} + (1-\theta)\frac{t - p_A^m + p_B^m}{2t})]p_A^m(1-\alpha_A^m)\ , \\
\arg\max_{p_B^m}\ \pi_B^m = \ & [(\sigma\gamma_l + (1-\omega)(1-\sigma)\gamma_h)(\theta\frac{v_l - p_B^m - s}{t} + (1-\theta)\frac{t - p_B^m + p_A^m}{2t}) \\
& +\omega(1-\sigma)\gamma_h(\theta\frac{v_l - p_B^m}{t} + (1-\theta)\frac{t - p_B^m + p_A^m}{2t})]p_B^m(1-\alpha_B^m)\ .
\end{aligned}$$

Solving the first-order conditions, we get the equilibrium prices under the belief that ω fraction of frequent shoppers only join the MFS program:

$$p_A^{m*}(\omega) = p_B^{m*}(\omega) = \frac{t(1-\theta) + 2\theta(v_l - s) + \theta\dfrac{s(1-\sigma)\omega\gamma_h}{\sigma\gamma_l + (1-\sigma)\gamma_h}}{1+3\theta}\ .$$

In stage 3 of the game, the platform determines the commission rates $\alpha_A^m(\omega)$ and $\alpha_B^m(\omega)$ by solving the model below.

$$
\begin{aligned}
\arg \max_{\alpha_A^m(\omega),\alpha_B^m(\omega)} \quad \pi_R^m = \quad & (\sigma\gamma_l + (1-\omega)(1-\sigma)\gamma_h)[\theta\frac{v_l - p_A^{m*}(\omega) - s}{t} \\
& +(1-\theta)\frac{t - p_A^{m*}(\omega) + p_B^{m*}(\omega)}{2t}]p_A^{m*}(\omega)\alpha_A^m(\omega) \\
& +\omega(1-\sigma)\gamma_h[\theta\frac{v_l - p_A^{m*}(\omega)}{t} \\
& +(1-\theta)\frac{t - p_A^{m*}(\omega) + p_B^{m*}(\omega)}{2t}](p_A^{m*}(\omega)\alpha_A^m(\omega) - s) \\
& +(\sigma\gamma_l + (1-\omega)(1-\sigma)\gamma_h)[\theta\frac{v_l - p_B^{m*}(\omega) - s}{t} \\
& +(1-\theta)\frac{t - p_B^{m*}(\omega) + p_A^{m*}(\omega)}{2t}]p_B^{m*}(\omega)\alpha_B^m(\omega) \\
& +\omega(1-\sigma)\gamma_h[\theta\frac{v_l - p_B^{m*}(\omega)}{t} \\
& +(1-\theta)\frac{t - p_B^{m*}(\omega) + p_A^{m*}(\omega)}{2t}](p_B^{m*}(\omega)\alpha_B^m(\omega) - s) \\
& +M^m(\omega)(1-\sigma)\ , \\
\text{subject to} \quad & \pi_A^m(\omega) \geq \mu,\ \pi_B^m(\omega) \geq \mu\ .
\end{aligned}
$$

In stage 2, a consumer will join the program only if her expected (purchase-related) surplus gain by joining the MFS program compared to not joining is not less than the membership fee, $M^m(\omega)$. The expected surplus gain would depend on the consumer's belief about how many consumers would join the program. Moreover, for the equilibrium to sustain, the platform's belief about the size of the membership base when it sets the membership fee should be consistent with the consumers' belief as well.

For a frequent shopper, the expected surplus with the membership under the belief that ω fraction of frequent shoppers only join the program is given by:

$$
\begin{aligned}
\gamma_h[& \int_0^{\frac{v_l - p_A^{m*}(\omega)}{t}} \theta(v_l - p_A^{m*}(\omega) - \lambda t)d\lambda + \int_0^{\frac{t - p_A^{m*}(\omega) + p_B^{m*}(\omega)}{2t}} (1-\theta)(v_h - p_A^{m*}(\omega) - \lambda t)d\lambda \\
+ & \int_0^{\frac{v_l - p_B^{m*}(\omega)}{t}} \theta(v_l - p_B^{m*}(\omega) - \lambda t)d\lambda + \int_0^{\frac{t - p_B^{m*}(\omega) + p_A^{m*}(\omega)}{2t}} (1-\theta)(v_h - p_B^{m*}(\omega) - \lambda t)d\lambda]\ .
\end{aligned}
$$

The expected surplus for a frequent shopper without the membership under the same belief is given by:

$$\gamma_h[\int_0^{\frac{v_l-p_A^{m*}(\omega)-s}{t}} \theta(v_l - p_A^{m*}(\omega) - \lambda t - s)d\lambda + \int_0^{\frac{t-p_A^{m*}(\omega)+p_B^{m*}(\omega)}{2t}} (1-\theta)(v_h - p_A^{m*}(\omega) - \lambda t - s)d\lambda$$
$$+ \int_0^{\frac{v_l-p_B^{m*}(\omega)-s}{t}} \theta(v_l - p_B^{m*}(\omega) - \lambda t - s)d\lambda + \int_0^{\frac{t-p_B^{m*}(\omega)+p_A^{m*}(\omega)}{2t}} (1-\theta)(v_h - p_B^{m*}(\omega) - \lambda t - s)d\lambda] \ .$$

We can compute the expected surplus for an infrequent shopper with and without the membership by replacing γ_h with γ_l in the above expressions.

Therefore, for a frequent shopper, the expected surplus gain by joining the MFS program as compared to not joining under the belief that ω fraction of frequent shoppers would join the MFS program is given by:

$$\begin{aligned}\Delta SP(\omega) = \ & s\gamma_h[(1-\sigma)(t(1-\theta^2) - s\theta(1+\theta(4\omega-1)) + 2\theta(1+\theta)v_l)\gamma_h \\ & +\sigma((1-\theta)(t+t\theta-s\theta) + 2\theta(1+\theta)v_l)\gamma_l] \\ & [t(1+3\theta)(\sigma\gamma_l + (1-\sigma)\gamma_h)]^{-1} > 0 \ .\end{aligned}$$

Under this belief, the platform would set the membership fee to an amount that is slightly less than $\Delta SP(\omega)$; any fee less than this amount only reduces the platform's profit and any fee higher than this amount implies that the fraction of the frequent shoppers would find it profitable join the program is not ω which would contradict the belief. When the platform sets the membership fee $M^m(\omega)$ to be slightly less than $\Delta SP(\omega)$, a frequent shopper that is deciding whether to join the MFS program will find that joining is better than not joining. Furthermore, we can show that an infrequent shopper's surplus gain from joining the MFS program is less than the membership fee. Thus, regardless of the belief about the fraction of frequent shoppers that would join the program, when the platform sets the membership fee based on that belief, an individual frequent shopper's decision would be to join the program (with probability one) and an individual infrequent shopper's decision would be to not join the program (with probability one). Since this result holds for any arbitrary frequent shopper and infrequent shopper, the belief that only a fraction (less than one) of frequent shoppers joins the program cannot be sustained in the equilibrium, i.e., when only frequent shoppers are part of the membership, the only equilibrium is one in which all frequent shoppers join the program. Further, we can show that:

$$\frac{\partial \Delta SP}{\partial \omega} = -\frac{4s^2\theta^2(1-\sigma)\gamma_h^2}{t(1+3\theta)(\sigma\gamma_l + (1-\sigma)\gamma_h)} < 0 \ .$$

which implies that if the platform sets a membership fee under the belief that all frequent shoppers would join the program, a frequent shopper that has any other belief would indeed join the program because the platform would have set a smaller fee than this consumer's expected surplus gain. Therefore, if only frequent shoppers join the MFS program, in equilibrium, the platform would set a membership fee equal to $\Delta SP(\omega = 1)$ minus a negligibly small value, and all and only frequent shoppers would become members.

Lemma 2. *If the platform implements the MFS program (with only frequent shoppers as members), in equilibrium, the membership fee M^{m*}, commission rates α_A^{m*} and α_B^{m*}, retail prices p_A^{m*} and p_B^{m*}, purchase frequency of frequent shoppers D_h^{m*} and purchase frequency of infrequent shoppers D_l^{m*} are as follows.*

$$M^{m*} = \frac{s[t(1-\theta) - s\theta + \theta(2v_l - p_A^{m*} - p_B^{m*})]\gamma_h}{t} \ ,$$

$$\alpha_A^{m*} = \alpha_B^{m*} = 1 - \frac{2t(1+3\theta)^2(\sigma\gamma_l + (1-\sigma)\gamma_h)\mu}{(1+\theta)[(t(1-\theta)+2\theta v_l)(1-\sigma)\gamma_h + (t(1-\theta)+2\theta(v_l - s))\sigma\gamma_l]^2} \ ,$$

$$p_A^{m*} = p_B^{m*} = \frac{(t(1-\theta)+2\theta v_l)(1-\sigma)\gamma_h + (t(1-\theta)+2\theta(v_l-s))\sigma\gamma_l}{(1+3\theta)(\sigma\gamma_l + (1-\sigma)\gamma_h)} \ , \qquad (2.8)$$

$$
\begin{aligned}
D_h^{m*} = \ & [(1+\theta)(2v_l\theta + t(1-\theta))(1-\sigma)\gamma_h \\
& +(t(1-\theta^2) + 2\theta(v_l + v_l\theta + 2s\theta))\sigma\gamma_l](1-\sigma)\gamma_h \\
& [t(1+3\theta)(\sigma\gamma_l + (1-\sigma)\gamma_h)]^{-1} \ ,
\end{aligned}
\tag{2.9}
$$

$$
\begin{aligned}
D_l^{m*} = \ & [(t(1-\theta^2) + 2\theta(v_l(1+\theta) - s - 3s\theta))(1-\sigma)\gamma_h \\
& +(1+\theta)(2\theta(v_l - s) + t(1-\theta))\sigma\gamma_l]\sigma\gamma_l \\
& [t(1+3\theta)(\sigma\gamma_l + (1-\sigma)\gamma_h)]^{-1} \ .
\end{aligned}
\tag{2.10}
$$

Using Lemma 2, we compute the equilibrium platform profit π_R^{m*}, consumer surplus CS^{m*}, and social welfare SW^{m*}. These are provided in the appendix. We verify that the equilibrium prices and commission rates decrease in the shipping cost s, as in the benchmark scenario. It is intuitive that the non-members', i.e., infrequent shoppers', purchase frequency decreases in s, as in the benchmark scenario. On the other hand, in contrast to the benchmark case, the members', i.e., frequent shoppers', purchase frequency increases in s under the MFS program. The reason is that an increase in shipping cost leads to a decrease in prices. However, the price decrease does not offset the increase in the shipping cost for the infrequent shoppers and therefore, the infrequent shopper segment's demand decreases in the shipping cost. In contrast, frequent shoppers do not have to pay for shipping; hence, their demand increases in the shipping cost.

Proposition 1. *If the platform implements the MFS program with only frequent shoppers as members, in equilibrium, the platform's revenue from the membership fee is less than the shipping cost it incurs.*

Proposition 1 shows that the platform essentially subsidizes the shipping cost of its members by charging each a membership fee that is less than the shipping cost it would incur for purchases made by the member. This result sharply contrasts with the Costco model where the membership revenue is the main driver of the profit (Scuttlebutt Investor, 2017).

However, Proposition 1 is consistent with data from Amazon's Prime program, which are shown in Figure 2.2. The figure shows Amazon's revenue from Prime memberships during the years 2006-2016 (recall that Amazon introduced the Prime program in 2005). We note that the revenues shown in the figure include only the portion of the membership fee that is attributed to the free shipping benefit because the prime program includes benefits other than free shipping as well. The figure also shows the shipping costs incurred by Amazon to serve the members. We make the following observations from this figure: (i) the shipping cost is higher than the revenue in every year, and (ii) the gap between revenue and shipping cost, which represents the shipping cost subsidy to members has been steadily increasing, from \$317 million in 2006 to \$7.19 billion in 2016. We note that the number of Prime members also increased during this period, and the subsidy grew along with it. Proposition 1 provides theoretical support to the argument that Amazon is hurt by the Prime program, when the program is evaluated solely based on membership revenue and shipping costs. However, the following result demonstrates that this conclusion may be unwarranted.

Proposition 2. *If the platform implements the MFS program with only frequent shoppers as members, the platform equilibrium profit is higher compared to the no MFS benchmark, if and only if* $s < s^{m*}$*, where*

$$s^{m*} = \frac{4(1+\theta)(t(1-\theta)+2\theta v_l)(\sigma\gamma_l+(1-\sigma)\gamma_h)}{(1+\theta(10+13\theta))(1-\sigma)\gamma_h+(1+\theta(14\theta+17\theta))\sigma\gamma_l}.$$

Proposition 2 shows that the platform would be hurt by the MFS program only when the shipping cost is high. Clearly, the platform's shipping subsidy to members, demonstrated by Proposition 1, would be prohibitively high if the shipping cost is high. However, when the shipping cost is not high, despite the shipping subsidy, the platform benefits from the MFS program. We identify three strategic impacts of the MFS program which contribute to the higher platform profit with the MFS program compared to the benchmark scenario, when s is not high.

Source: https://www.statista.com/chart/6527/amazon-shipping-costs/

Figure 2.2: Shipping Subsidy of Amazon

First, by comparing Equation 2.5 and Equation 2.8, we find that the retail prices are higher when the platform implements the MFS program than when it does not. Sellers recognize that members incur a smaller purchase cost compared to when there is no MFS program because they do not incur the shipping cost. Consequently, sellers increase their prices and extract some of the members' savings in the shipping cost when the platform implements the MFS program. This finding is noteworthy in light of the popular press reports which note that Amazon encouraged third-party sellers to inflate their prices after it introduced the Prime program (GeekWire, 2014). We denote this impact of the MFS program on the prices as the *price increasing* effect. The price increasing effect of the MFS program can be quantified as:

$$\Delta p_i^* = p_i^{m*} - p_i^{b*} = \frac{2s\theta(1-\sigma)\gamma_h}{(1+3\theta)(\sigma\gamma_l + (1-\sigma)\gamma_h)} > 0. \tag{2.11}$$

Second, by comparing Equation 2.6 and Equation 2.9, we find that the purchase frequency of members of the MFS program is higher compared to when there is no MFS program. On the other hand, by comparing Equation 2.7 and Equation 2.10, we find that the purchase frequency of non-members is lower. The non-members purchase less because of the price increasing effect discussed previously. The members purchase more despite the price increasing effect because the shipping cost savings offset the price increase, as indicated by Equation 2.11. While the impacts on the two groups—members and non-members—are in opposite directions, we find that the net impact of the MFS program on the overall purchase frequency is positive. We denote this impact of the MFS program on the overall purchase frequency of consumers as the *demand enhancement* effect. We quantify the demand effects as follows.

$$\Delta D_h^* = \quad D_h^{m*} - D_h^{b*} = \frac{2s\theta(1-\sigma)\gamma_h((1+\theta)(1-\sigma)\gamma_h + (1+3\theta)\sigma\gamma_l)}{t(1+3\theta)(\sigma\gamma_l + (1-\sigma)\gamma_h)} > 0 \ ,$$

$$\Delta D_l^* = \quad D_l^{m*} - D_l^{b*} = -\frac{4s\theta^2(1-\sigma)\sigma\gamma_l\gamma_h}{t(1+3\theta)(\sigma\gamma_l + (1-\sigma)\gamma_h)} < 0 \ ,$$

$$\Delta D^* = \quad \Delta D_h^{m*} + \Delta D_l^{m*} = \frac{2s\theta(1+\theta)(1-\sigma)\gamma_h}{t(1+3\theta)} > 0 \ .$$

It is worthwhile to note that an Amazon Prime member spends an average of $1,400 a year on Amazon while a non-member spends only $600 (https://www.cirpllc.com). Even though the higher shopping frequency of a member compared to a non-member could partly explain this difference in spending, Proposition 2 shows that the differential impacts of the MFS program on members and non-members could be a key contributor to it as well.

Third, as a result of the two effects mentioned above, the platform charges a higher commission rate when it implements the MFS program than when it does not. We denote the impact of MFS on the platform's commission rates as the *commission rate increasing* effect and quantify it as the following.

$$\begin{aligned}
\Delta\alpha_i^* = \quad & \alpha_i^{m*} - \alpha_i^{b*} \\
= \quad & \frac{8t(1+3\theta)^2\mu s\theta(1-\sigma)\gamma_h}{(1+\theta)(\sigma\gamma_l + (1-\sigma)\gamma_h)} \\
& [(1-\sigma)(t(1-\theta)+\theta(2v_l - s))\gamma_h + \sigma(t(1-\theta)+2\theta(v_l - s))\gamma_l] \\
& [(t(1-\theta)+2\theta(v_l - s))^2[(1-\sigma)(t(1-\theta)+2\theta v_l)\gamma_h \\
& +\sigma(t(1-\theta)+2\theta(v_l - s))\gamma_l]^2]^{-1} > 0.
\end{aligned}$$

All the above explained effects of the MFS program are positive for the platform; however, the platform is not always better off with the MFS program because of the shipping subsidy revealed by Proposition 1. To further explain Proposition 2, we decompose the platform profit under the MFS program into three components: commission revenue received from the sellers (CR), membership fee paid by subscribing consumers (MF), and absorbed shipping cost (SC). Clearly, CR is higher if the platform implements the MFS program than if it does not because the price increasing effect, the demand enhancement effect, and the commission rate increasing effect of the MFS program improve the overall commission and revenue. Thus, in light of Proposition 1, whether the platform benefits from the the MFS program depends on whether the increase in the commission revenue, $CR^{m*} - \pi_R^{b*}$, compensates the shipping cost subsidy to members, $SC^{m*} - MF^{m*}$. When the shipping cost is smaller than s^{m*} given in Proposition 2, the subsidy is smaller than the increase in the commission revenue, and the platform benefits from the MFS program. However, when the shipping cost is above s^{m*}, the platform is hurt by the MFS program.

We quantify the value of the MFS program to the platform as $\Delta\pi_R^* = \pi_R^{m*} - \pi_R^{b*}$. The following result shows how the value of the MFS program to a platform is affected by the shipping cost.

Proposition 3. *The value of the MFS program to the platform increases in s when $s < s^{m*}/2$ and decreases in s when $s > s^{m*}/2$.*

Proposition 3 shows that the value of the MFS program to the platform follows an inverted U-shape with respect to s and that the value is highest when the shipping cost is equal to $s^{m*}/2$. The dynamics of the three components of platform profit—CR, MF, and SC, with respect to the shipping cost s determine how the value of the MFS program is affected by s. The following derivatives explain these dynamics.

$$\begin{aligned}\frac{\partial(CR^* - \pi_R^{b*})}{\partial s} &= -\frac{8\theta^2(1+\theta)(1-\sigma)\gamma_h(2\sigma\gamma_l + (1-\sigma)\gamma_h)}{t(1+3\theta)^2(\sigma\gamma_l + (1-\sigma)\gamma_h)} \times s \\ &\quad + \frac{4\theta(1+\theta)(1-\sigma)(t(1-\theta) + 2\theta v_l)\gamma_h}{t(1+3\theta)^2} \\ \frac{\partial(SC^* - MF^*)}{\partial s} &= \frac{\theta(1-\sigma)\gamma_h}{t} \times s\end{aligned}$$

We observe that the shipping subsidy offered by the platform to members is increasing in s in a convex fashion, i.e., $\frac{\partial(SC^* - MF^*)}{\partial s}$ is positive and increasing in s. The convexity arises because an increase in the shipping cost increases the demand from members (Recall the discussion following Lemma 2). Therefore, an increase in the shipping cost not only increases the subsidy each time a member makes a purchase but also increases the purchase frequency of members. On the other hand, the benefit from the program in the form of increase in the commission revenue is increasing in s in a concave fashion i.e., $\frac{\partial(CR^* - \pi_R^{b*})}{\partial s}$ is positive and decreasing in s. The quadratic nature of the platform's value from the MFS program implies that the value is highest when $s = s^{m*}/2$. We can also verify that the the value is zero when $s = 0$. The primary implication of Proposition 3 is that the platform finds the

MFS program to be most attractive at moderate values of the shipping cost. Thus, the MFS program is likely to be most valuable in the context of online marketplaces selling physical goods where the shipping cost plays a role and it is neither excessive nor inconsequential. More importantly, even though we do not consider any cost to implement the MFS program, if there is an implementation cost, the platform will implement the MFS program only when the shipping cost is neither too high nor too low.

Proposition 4. *If the platform implements the MFS program with only frequent shoppers as members, the equilibrium consumer surplus is less than that in the no MFS benchmark.*

Proposition 4 reveals that consumers as a whole are worse off when the platform implements the MFS program than when it does not. The non-members are worse off with the MFS program because of the price increasing effect; non-members not only pay higher prices but also consume less when the platform implements the MFS program than when it does not. The reduction in non-members' surplus has implications for members as well and the platform. For members, it seems that they should be better off when the platform implements the MFS program than when it does not because the members choose between two options—joining and not joining the MFS program—that gives them a higher expected surplus. However, we find that even members are actually worse off under the MFS program compared to the benchmark. The explanation for this finding is the following.

Consider a frequent shopper deciding whether to join the program. Because of the adverse effect of the program on non-members, she will expect to suffer a loss in surplus if she does not join the program. On the other hand, by joining the program, she will expect a positive purchase-related surplus gain. The expected surplus gain when she joins the program as opposed to the surplus loss when she does not provides her an incentive to join the program. Recognizing this incentive, the platform charges a membership fee that is just less than the difference in surplus between joining and joining, which is equal to the surplus gain from joining plus the surplus loss from not joining. That is, the platform extracts more than just the savings a consumer would enjoy by joining the program compared to when no one joins the program; it also extracts an additional amount equal to the loss in surplus if she does not join the program. Consequently, even the members end up being hurt with the MFS program compared to the benchmark. Essentially, the platform exploits the differential impacts of the MFS program on the two consumer types and forces frequent shoppers to choose between two options—joining and not joining—, both options hurt them compared to when there is no MFS program but joining hurts them less.

Recalling our earlier discussion of frequent shoppers' decisions to participate in the MFS program, any belief about the size of the membership base, including the scenario where no one participates, would make a frequent shopper willing to participate. So joining the MFS program is the best response for a frequent shopper. Meanwhile, Proposition 4 shows that members become worse off because of the participation of their peers due to the price increasing effect. Hence, even though every single frequent shopper acts in the best interest of herself, collectively all of them are hurt by the MFS program. Thus, the participation in the MFS program is effectively a prisoner's dilemma.

Proposition 5. *If the platform implements the MFS program with only frequent shoppers as members, in equilibrium, the social welfare is higher than that in the no MFS benchmark if and only if $s < \overline{s}^m$, where*

$$\overline{s}^m = \frac{2(1+\theta)(t(1-\theta)+2\theta v_l)(\sigma\gamma_l+(1-\sigma)\gamma_h)}{(1+\theta)(1+5\theta)(1-\sigma)\gamma_h+(1+\theta(10+13\theta))\sigma\gamma_l} .$$

As shown in Proposition 5, the impact of the MFS program on social welfare can be positive or negative, similar to that on the platform profit. The possible negative impact of MFS on the social welfare is somewhat surprising given that the MFS program enhances the overall demand, which enhances the consumption utility. The reason for the possible adverse impact of the MFS program on the social welfare lies in the nature of additional demand generated by the MFS program. We note that the social welfare is affected by the (purchasing) consumers' gross utility (i.e., valuation minus the misfit cost, excluding product prices which simply transfer wealth from one party to another within the society) and the cost of satisfying the demand from these consumers. The only cost in satisfying the demand in our context relates to shipping. The MFS program increases the total gross utility of consumers, driven solely by the additional demand generated by the MFS program. However, if the shipping cost is higher than the threshold given in Proposition 5, then the cost required to satisfy this demand offsets additional utility it generates. We illustrate this possibility using Figure 2.3.

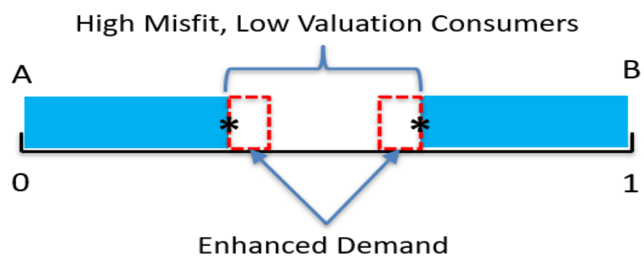

Figure 2.3: Illustration of Possible Negative Societal Impact of the MFS Program

In Figure 2.3, consider the marginal consumers that are indifferent between buying and not buying when there is no MFS program, indicated as '*'. These consumers have a low valuation for the product. They are farther away from the product they are indifferent between buying and not buying, and, hence have a higher misfit cost, compared to other low valuation buyers that buy. Essentially, these marginal consumers have a low gross utility for the products. If they have to bear the shipping cost, as in the no MFS case, they do not find it profitable to buy either product. On the contrary, under the MFS program, if these consumers are members, they do not incur the shipping cost and they will buy the product that is closer to them. In fact, even some members that are farther than these marginal consumers could end up buying a product under the MFS program, but they would not buy any product in the absence of the MFS program. These consumers are those that constitute the demand enhancement effect among members, as indicated in Figure 2.3. These consumers generate very low additional utility because of their low valuation and high misfit costs. However, the flip side is that the same shipping cost is required to fulfill their demand as that from consumers that have high valuation and low misfit cost. The MFS program removes the shipping cost from the consideration of members when they make the purchase decisions, but the society still incurs this cost. When the shipping cost is high, the MFS program stimulates demand from low-valuation members even when their misfit cost is high, at the expense of the platform and society which incur the shipping cost. This could lead to a smaller social welfare when the platform implements the MFS program than when it does not.

We point out that our analysis of social welfare does not account for potential hidden societal costs such as additional carbon footage, packaging waste, and driver safety (Buzz Feed News, 2018; Forbes, 2018; The New York Times, 2019) that could arise from demand enhancement. When these costs are also accounted for, the potential negative impacts on social welfare could be even more severe.

Table 2.2: Summary of Propositions 2 - 5

	(1)	(2)	(3)
	$s < \overline{s}^m$	$\overline{s}^m < s < s^{m*}$	$s^{m*} < s$
Platform Profit	$\uparrow$	$\uparrow$	$\downarrow$
Consumer Surplus	$\downarrow$	$\downarrow$	$\downarrow$
Social Welfare	$\uparrow$	$\downarrow$	$\downarrow$

Notes: $\uparrow$ ($\downarrow$) indicates a higher (lower) value under MFS compared to the benchmark.

Table 2.2 summarizes the implications of the MFS program on key stakeholders. When the shipping cost is low, i.e., $s < \overline{s}^m$, as in column (1), the platform and society benefit from the MFS program at the expense of consumers. When the shipping cost is high, i.e., $s > s^{m*}$, as in column (3), no stakeholder is better off with the MFS program. On the other hand, when the shipping cost is moderate such that $\overline{s}^m < s < s^{m*}$, as in column (2), while the platform benefits from the MFS program, consumers and the society are hurt. While a dominant platform would implement the MFS program as long as the shipping cost is not high, it is not possible to induce the platform to implement the MFS program through any side payment from one player to another within the system if the shipping cost is high.

2.5 Model Extensions

In this section, we extend our model in two directions by changing our model setup and assumptions to demonstrate the robustness of the key results. We present only the result regarding the impact of the MFS program on the platform for brevity.

2.5.1 MFS in Conjunction with Contingent Free Shipping (CFS)

Although our focus is on free shipping only with membership, another popular free shipping scheme that has been widely adopted by online retailers is contingent free shipping (CFS). Under CFS, the platform offers free shipping to consumers if the order amount exceeds a certain threshold. Given its prevalence in online retailing, understanding the impact of MFS on top of CFS is an important question. Accordingly, we model CFS as the benchmark scenario in this extension and assess the value of MFS in conjunction with CFS.

Under CFS, any consumer enjoys free shipping if she buys two units of the product. Conditional on the consumer having a consumption need for the product in a shopping instance, we assume that the consumer can make use of a second unit of the same product with probability ϵ and can make use of a maximum of one unit with probability $1 - \epsilon$. We model the consumer's base valuation for the first unit as in the main model, i.e., a consumer's base valuation at a shopping instance, conditional on her having a consumption need, is v_l, with probability θ and v_h with probability $(1 - \theta)$. To model the diminishing utility of the second unit, we let the base valuation for the second unit be ρ fraction of that of the first unit. Moreover, a consumer would possibly buy the second unit only when her base valuation for the first unit is high.

When there is no MFS, assuming a consumer has a consumption need, she will buy the second unit if her valuation for the first unit is v_h and $\rho v_h - p_i^b + s > 0$. Note that the savings in shipping cost plays a role in the consumer's decision to buy the second unit. The same condition holds for a non-member as well under the MFS program. On the contrary, if the consumer joins the MFS program, she will buy the second unit if her valuation for the first unit is v_h and $\rho v_h - p_i^m > 0$. Note that the shipping cost does not play a role for a member because she gets free shipping whether she buys one unit or two units. As the main purpose of this extension is to check whether the results from our main model are robust to model variations, we restrict our attention to the scenario where the likelihood of purchasing two units is not too high relative to purchasing one unit, conditional on the event that a consumption need arises. Specifically, we assume $\epsilon < \theta/3$. All other aspects remain identical to those in the main model. We note that the CFS model reduces to our main model if $\epsilon = 0$.

We derive the equilibrium under CFS and under MFS+CFS in the appendix. We present the impact of the MFS program when the platform already has CFS in place as the following result.

Proposition 6. *If the platform implements the MFS program in conjunction with CFS and only frequent shoppers join the program, in equilibrium, the platform profit is higher compared to the CFS benchmark if $s < \dot{s}$ where*

$$\begin{aligned}
\dot{s} = &\ \frac{4(\theta - \epsilon(1-\theta))(1+\theta+2\epsilon(1-\theta))((1-\theta)(t+2\epsilon\rho v_h)+2\theta v_l)(\sigma\gamma_l+(1-\sigma)\gamma_h)}{\eta_1(1-\sigma)\gamma_h+\eta_2\sigma\gamma_l}\ , \\
\eta_1 = &\ \theta+\theta^2(10+13\theta)-8\epsilon^3(1-\theta)^3-4\epsilon^2(1-\theta)^2(3+19\theta)-\epsilon(1-\theta)(3+\theta(26+27\theta)), \\
\eta_2 = &\ \theta+\theta^2(14+17\theta)-8\epsilon^2(1-\theta)^2(1+11\theta)-\epsilon(1-\theta)(3+\theta(34+27\theta))\ .
\end{aligned}$$

Proposition 6 reveals the condition under which the MFS program is beneficial on top of CFS. Proposition 6 is qualitatively similar to Proposition 1, and, in fact, if $\epsilon = 0$, then these two Propositions become identical. The result demonstrates that even when the platform has CFS in place which could generate additional revenue compared to when it does not have CFS, implementing the MFS program is profitable if the shipping cost is not too large. This is because the strategic effects of the MFS program identified in main model such as demand enhancement continue to exist in the presence of CFS as well.

2.5.2 Shipping Fee versus Shipping Cost

In the main model, we assume that a consumer's shipping cost (and a platform's when it pays for members) is identical to the actual shipping cost that is equal to the shipping cost charged possibly by the independent logistics provider. However, in reality, consumers may pay a seller a shipping fee which could be different from the actual shipping cost incurred by the seller. That is, sellers could potentially charge consumers a 'shipping fee' that is different from the 'shipping cost'. In this extension, we assume that seller i chooses a shipping fee, which is denoted as f_i, even though she incurs the shipping cost s when a consumer pay for shipping. Because sellers can now strategically partition the total transaction (purchase) cost into product price and shipping fee, we assume that the platform charges a commission on the total cost of the transaction minus the actual shipping cost to avoid any gaming behavior related to setting the shipping fee; otherwise, sellers could set the product price close to zero to avoid paying any commission. All other aspects remain identical to those in the main model. In particular, when the platform bears the shipping cost for a member, it incurs a cost of s. In all other cases, sellers charge a shipping fee.

Proposition 7. *Assume that sellers set a shipping fee in addition to price. If the platform implements the MFS program and only frequent shoppers join the membership, in equilibrium, the platform profit is higher compared to the no MFS benchmark if and only if $s < \ddot{s}$, where*

$$\ddot{s} = \frac{2t(1-\theta) + 4\theta v_l}{1+5\theta}.$$

Proposition 7 shows that the overall effect of the MFS program on the platform remains qualitatively the same as in the main model. As before, sellers charge a higher retail price when the platform implements the MFS program.

$$p_i^{m*} - p_i^{b*} = \frac{t(1-\theta)+2\theta v_l}{1+3\theta} - \frac{t(1+\theta)+2\theta(v_l - s)}{1+3\theta} = \frac{2s\theta}{1+3\theta} > 0 \ .$$

Moreover, we find that the platform still benefits from the demand enhancement effect of the MFS program. Although non-members buy the same amount as their transaction cost remains the same, members buy more due to free shipping. Therefore, the overall demand is always higher under the MFS program, as shown below.

$$\Delta D_h^{m*} = D_h^{m*} - D_h^{b*} = \frac{2s\theta(1+\theta)(1-\sigma)\gamma_h}{t(1+3\theta)} > 0 \ ,$$

$$\Delta D_l^{m*} = D_l^{m*} - D_l^{b*} = 0 \ ,$$

$$\Delta D^{m*} = \Delta D_h^{m*} + \Delta D_l^{m*} = \frac{2s\theta(1+\theta)(1-\sigma)\gamma_h}{t(1+3\theta)} > 0 \ .$$

Also, the total transaction cost for a non-member (i.e., the product price plus the shipping fee) remains the same when there is no MFS program and when there is.

$$p_i^{b*} + f_i^{b*} = p_i^{m*} + f_i^{m*} = \frac{t(1-\theta)+s(1+\theta)+2\theta v_l}{1+3\theta} \ .$$

At the same time, sellers charge a shipping fee that is lower than the shipping cost under the MFS program, as shown below.

$$f_i^{m*} - s = \frac{s(1+\theta)}{1+3\theta} - s = -\frac{2s\theta}{1+3\theta} < 0 \ .$$

The lower shipping fee compared to the cost is the result of the attempt to mitigate the transaction cost heterogeneity between members and non-members. Members and non-members differ in terms of transaction cost because members do not have to pay for shipping but non-members do. The higher the consumer heterogeneity, the more difficult it is for each seller to extract the surplus via a uniform retail price to both consumer groups. Therefore, sellers charge a lower shipping fee when the MFS program is offered compared to no MFS so as to make members and non-members less heterogeneous with regards to the total transaction cost. Essentially, sellers partially subsidize non-members' shipping while the platform fully subsidizes members' shipping under the MFS program.

Finally, the platform charges a higher commission rate and the commission revenue is higher with the MFS program than without. Consequently, the platform finds the MFS program valuable when the shipping subsidy is compensated by the increase in the commission revenue. This requires the shipping cost to be lower than the threshold given in the Proposition.

2.6 Conclusion and Implications

We examine the membership-based free shipping (MFS) programs offered by some online marketplaces in which a retail platform bears the shipping costs for purchases made by members that have paid an upfront fee, but non-members bear the shipping costs themselves. We identify several strategic effects of the MFS program on sellers' pricing strategies, consumer demand, and consumers' participation decisions. All these effects provide us with a deeper understanding of the program, going beyond the conventional view that MFS programs are solely a shipping cost transfer mechanism. The findings provide the following important managerial implications.

(i) If the platform implements the MFS program, even though the platform could profit from the MFS program, the platform effectively subsidizes the shipping costs of its members even after accounting for the membership dues. Therefore, assessing the success of the MFS program to the platform solely based on the shipping cost and the membership fee can be misleading; an assessment that ignores the strategic effects may label the program as a failure even though the program is actually profitable.

(ii) Neither a low shipping cost nor a high shipping cost offers the highest profit gain from the MFS program to the platform. The platform gains the most when the shipping cost is moderate. Consequently, if the platform incurs a fixed cost to implement the program, then a low shipping cost is neither a prerequisite nor a guarantee for the platform to benefit from the MFS program. Thus, the MFS program is suitable primarily for platforms that sell physical goods for which shipping costs are neither inconsequential nor excessive.

(iii) Analogous to the result for the platform, concluding that members of the MFS program gain from it just because they realize more savings in shipping cost than the membership fee they pay is also incorrect because these savings may be extracted away in the form of higher retail prices. On the other hand, when individual consumers make participation decisions based on their own self interests, the platform can exploit the prisoners' dilemma faced by consumers when the MFS program is implemented.

(iv) Despite the stimulation of consumer demand by the MFS program, more demand could hurt the society because consumer surplus from the additional demand could be offset by excessive shipping cost required to satisfy the extra demand. That is, the MFS program may not be social welfare enhancing.

(v) Finally, the implications of membership programs can be quite different in online and physical retailing because of the role played by product shipping in online retailing.

Taken together, the implications suggest that the the MFS program is generally a vehicle for the platform to benefit at consumers' and possibly the society's expense.

We also show that the impact of the MFS program on the platform profit does not change even if we assume the program is offered in the presence of a free-shipping option for bundled purchases without membership, or sellers are capable of setting the shipping fee for customers who are not members. That said, our study is not without limitations. First, we assume the platform that contemplates offering a membership-based free shipping program has no competitor in the marketplace. This assumption, although limiting, does not conflict with the reality. Currently Amazon has a monopolistic power in online retailing business (In These Times, 2019). Second, we assume that the sellers do not resort to price discrimination with the help of this program even though platform would have the ability to distinguish members from non-members. Third, the platform can reap additional benefits through cross-selling enabled by the membership program. For instance, Amazon offers exclusive discounts on variety of other services, such as Amazon Music Unlimited and Twitch Prime. Hence, the platform can earn additional revenue via other purchases. We can speculate that the platform would gain more from the MFS program if it can also benefit through other means. We leave the analysis of all these scenarios to future research.

CHAPTER 3

VALUE OF MEMBERSHIP-BASED FREE SHIPPING IN ONLINE RETAILING: IMPACT OF UPSTREAM PRICING MODEL

3.1 Introduction

Shipping products to consumers is an indispensable and a costly activity in online retailing (Fierce Retail, 2014; Information Age, 2015). Moreover, the shipping cost plays a pivotal role in online consumers' purchasing decisions and satisfaction (Rosen and Howard, 2000; Sawhney, 1999; Ernst and Young, 1999; Trocchia and Janda, 2003; Janda et al., 2002; Pyke et al., 2001). The consumers typically pay the shipping cost, though the sellers often absorb this cost when the transaction amount exceeds a threshold. A recent development related to shipping is the membership-based free shipping (MFS) program which seeks to mitigate the shipping cost burden of consumers. Amazon's *Prime* program, Walmart's now defunct *Shipping Pass* program and the recently introduced *Delivery Unlimited* program, and the free shipping program of online marketplace *ShopRunner*[1] are some examples of MFS programs. The core feature of MFS programs is that once a consumer becomes a member of the program by paying an upfront membership fee, products are shipped for free to the member whenever she makes a purchase during the membership period.[2]

While MFS is an innovation on the downstream consumer-side of online retailing, we have been witnessing a gradual shift in the upstream business model between the retailer and the suppliers. Large online retailers such as Amazon.com, Walmart.com, Sears.com, and Buy.com started with the reselling or *wholesale model* for most products, in which the retailers buy products at wholesale prices and subsequently resells them to consumers at

[1]https://www.shoprunner.com/memberfaq/

[2]The MFS programs have evolved significantly in their scale and scope. For instance, while the program by ShopRunner offers only free shipping, the Amazon Prime program provides additional membership benefits. However, free shipping for members remains at the core of MFS programs.

retail prices. However, those retailers have now become platforms for third-party sellers, and they typically use the *agency model*, in which sellers sell their products directly to consumers for a commission on the sale price. (Seller Labs, 2016; The Wall Street Journal, 2010; Dealnews, 2013; Sears Holding, 2010). The significance of the agency model in current online retailing is evident from Amazon's recent disclosure that third-party sellers accounted for 58 percent of total physical gross merchandise sales on Amazon in 2018, up from just 3 percent in 1999, and this percentage has been steadily increasing.[3] The shift in the business model of online retailing has also drawn significant attention from industry experts who have argued the need for online retailers to align their strategies and operational practices to the agency model (Wired, 2015; Zhu and Furr, 2016; The Marketing Journal, 2017).

On surface, the upstream pricing model and the downstream MFS program seem unrelated to each other because each strategy seeks to achieve a different objective. The agency model shifts the retailer's focus to providing value-added services and transfers the key retailing function of product pricing to upstream third-party sellers. On the other hand, the MFS program seeks to eliminate shipping cost burden of downstream consumers, specifically program members. Moreover, while the online retailer incurs a direct additional cost, viz., members' shipping cost, when it offers a MFS program, there is no direct additional cost to the retailer when it accommodates third-party sellers on its site.[4] However, observations suggest that the MFS program is prevalent only among retailers that use the agency (or platform) model of selling. For instance, Amazon introduced the Prime program in 2005 by which time approximately 30% of its product sales by volume had been coming from third-party sellers.[5] While Walmart did not have a program similar to Amazon Prime when

[3]https://www.statista.com/chart/18751/physical-gross-merchandise-sales-on-amazon-by-type-of-seller/

[4]On the contrary, some argue that the retailers incur lower costs under the agency model than the wholesale model (Jiang et al., 2011; Digital Business Models, 2013).

[5]https://www.marketplacepulse.com/stats/amazon/amazon-percent-of-gross-merchandise-volume-by-third-party-sellers-157

it was a reseller, it introduced its *ShippingPass* program after it became a marketplace by purchasing jet.com. ShopRunner has always been a marketplace operating under the pure agency model. On the contrary, we do not observe free shipping programs offered by online retailers who are resellers using the wholesale model. These observations raise the questions of whether a retailer achieves a higher benefit from the MFS program under the agency model than the wholesale model, and if so, why.

We answer those questions by analyzing a stylized game-theoretic model of a context in which a manufacturer sells his product to consumers via an online retailer, using either the agency model or the wholesale model. Under the agency model, the manufacturer sets the retail price and pays a percentage of the sale price as commission to the retailer. Under the wholesale model, the manufacturer sets the wholesale price, and the retailer sets the retail price. In the absence of the MFS program, consumers bear the shipping cost for product delivery. If the retailer implements the MFS program, he pays the shipping cost for the members during the membership period. We use the scenario with no MFS program as the benchmark to assess the impact of the MFS program under the agency and wholesale models. We then compare the value of the MFS program under the two pricing models.

We show that the retailer indeed gains more from the MFS program under the agency model than the wholesale model, and the retailer finds the MFS program to be profitable in a larger region of the parameter space under the agency model compared to the wholesale model. The retailer's gain from the MFS program under the wholesale model comes solely at the expense of consumers; consumers pay higher prices under the MFS program while consuming, on average, the same amount whether or not the MFS program is adopted. In contrast, consumer surplus can be higher in the presence of the MFS program than in its absence under the agency model because MFS enhances the total demand. Non-members are always worse off with the MFS program than without under both pricing models as a result of negative externalities imposed by members' participation in the form of higher prices; interestingly, some members can also be hurt by the MFS program. Finally, society as a whole is always worse off, surprisingly, with the MFS program than without under the wholesale model, although the overall demand is unaffected by the MFS program. On the flip side, society can be better off with the MFS program under the agency model in certain conditions by virtue of the demand enhancement effect.

The benefits of the agency model over the wholesale model in a channel structure in many contexts are typically attributed to the problem of double-marginalization which is present in the wholesale model, but is absent in the agency model. Our results are driven not just by the presence or absence of double-marginalization, but by how the MFS program affects the severity of double-marginalization in the wholesale model and single marginalization in the agency model. The MFS program exacerbates the double-marginalization problem, measured as the reduction in the channel profit from double marginalization when compared to single marginalization, in the wholesale model. The MFS program transfers the shipping cost from the consumers to the retailer. This additional marginal cost on the retailer, on top of the wholesale price that the retailer incurs whether or not the MFS program exists, worsens the double-marginalization problem in the wholesale model. On the other hand, marginalization exists only at the manufacturer's end (i.e., single marginalization) in the agency model because the manufacturer sets the retail price. The MFS program eliminates the shipping cost incurred by the consumers which is analogous to reducing the marginal cost of the manufacturer. Effectively, the MFS program mitigates (single) marginalization at the manufacturer end. Together, these effects of MFS on marginalization in the two models drive the results of this paper. This insight is new to the literature in that we are unaware of a study in which the benefits of a downstream strategy are affected by its impacts on the marginalization feature exhibited by the upstream pricing model.

Moreover, our findings make significant contributions to two research streams in online retailing, and offers several implications for practitioners. One, this research provides new insights into the strategic drivers of (retailer's) profitability from MFS programs and how a retailer's upstream pricing model can impact the value from downstream MFS strategies. Specifically, our results reveal that the MFS program might be regarded as an unprofitable strategy if it is evaluated based solely on the shipping cost incurred by the retailer in serving members and the membership fee she collects from them. However, the MFS program could be a profitable strategy for the retailer if the benefits from the strategic impacts of the program are accounted for. Similarly, on the consumer side, even though members realize savings via the MFS program in shipping cost, some members (and all non-members) are hurt by the MFS program. Finally, the possible negative impact of the MFS program on the society reveals that the MFS program cannot be viewed as a simple transfer of the shipping cost burden from consumers to the retailer with no societal impact; the impacts of the MFS program go beyond the transfer of the shipping cost. These findings demonstrate that viewing the MFS program solely through the shipping lens leads to incorrect conclusions about the program.

Two, the findings are new to the literature that studies the wholesale and agency models. The extant literature has generally examined how exogenous market characteristics such demand and competition affect the firms differently depending on the pricing model. However, the literature has not examined the role of shipping (or product distribution) under these models, possibly because shipping is a significant activity primarily in online retailing. More importantly, our findings provide insights into how the pricing model affects the value of an endogenous strategy such as the MFS program, which is under the control of the retailer. Our findings suggest that as the agency model becomes more widespread in online retailing in the form of platform selling, online platforms would find introduction of a MFS program to be more attractive. These insightful results extend our understanding of the drivers of the transformations occurring in online retailing.

3.2 Related Literature

Broadly, our study is related to studies that have examined the impacts of shipping fees and free-shipping (Capon and Kuhn, 1982; Dolan, 1987; Morwitz et al., 1998; Nunes, 2000). This stream of research concludes that although free-shipping can increase consumer retention rate and order incidences, it is often unprofitable to online retailers (Lewis, 2006; Lewis et al., 2006). Our research is more closely related to the two contemporary studies that have examined separate issues related to membership-based free shipping programs in online marketplaces. Tan et al. (2015) compare two shipping programs—free shipping with a minimum order quantity, and free and expedited shipping with membership—for a monopoly retailer. They show that expedited free shipping with membership benefits the retailer when the value of expedited shipping to consumers (e.g., savings in holding cost) is sufficiently high, but the program hurts the society. Wen and Lin (2017) study the impact of a MFS program in a competitive setting in which one of two competing retailers adopts the program. They show that the MFS program benefits both retailers by softening the price competition between them. Both these studies consider a single-level channel structure—one without a manufacturer—in which the retailer sets the retail price. The research question that we examine—the impact of the upstream pricing model on the value of the MFS program—is fundamentally different from the research questions examined by those two studies. Therefore, consistent with our research question, and in contrast to the earlier studies, we examine a two-level channel structure with a retailer and a manufacturer. We consider the wholesale model as well as the agency model for the upstream relationship between the retailer and the manufacturer. Also, unlike these prior studies, we allow the purchase frequencies of consumers to be heterogeneous but as well as endogenous in our setup. Consequently we show several strategic effects of free shipping such as demand enhancement and negative externality imposed by members on non-members, which play key roles in determining the impacts of MFS under the two pricing models, but these effects of the MFS program are absent in the other two studies.

Our work is also related to the studies that have examined the differential impacts of the agency model and wholesale model in supply chains. The rapid growth of online platforms and digital products has led to an emerging body of literature on agency pricing, particularly for digital products (Hao and Fan, 2014; Tan et al., 2016; Tan and Carrillo, 2017; Hao et al., 2017; Geng et al., 2018). The primary focus of this literature stream is how external factors such as retailer competition, market uncertainty, cost structure, and demand influence a retailer's choice of the pricing model. Jiang et al. (2011) assume the agency model is inherently more cost efficient than the wholesale model for the retailer, but show that the uncertainty about demand affects the choice of the pricing model. Johnson (2017) shows revenue-sharing is attractive to firms that set the revenue shares, which provides a potential explanation for why dominant retailers switch from the wholesale model to the agency model. Foros et al. (2017) consider a market with competition between upstream suppliers and competition between retailers. They find that the relative intensity of competition between the two groups determines a retailer's preferred pricing model. Hagiu and Wright (2015) find that the levels of marketing efforts of sellers (the retailer in the wholesale model and third-party sellers in the agency model) are different under the two pricing models and therefore, the resulting marketing efforts could influence the retailer's choice of the pricing model, and Hagiu and Wright (2019) examine whether a manufacturer or sales agents should undertake costly marketing efforts. Abhishek et al. (2015) compare the profitability of the wholesale and agency models when online markets coexist with offline channels. They find that although the agency model is more efficient than the wholesale model, e-tailers' preference over the two pricing models depends on whether sales in the electronic channel stimulates or suppresses demand in the traditional channel. The implications of such spillovers are further examined by Yan et al. (2018) from the perspective of retailing inefficiency. Kwark et al.

(2017) conclude that publicly available third-party information in online marketplaces has different effects under the two pricing models for different product types (e.g., whether product quality or product fit dominates in consumers' evaluation of products), and thus product type and uncertainty about product attributes impact the retailer's choice of the business model. Tian et al. (2018) find that upstream competition between suppliers critically affects an intermediary's choice of the business model. Some more recent studies (Yan et al., 2019; Zennyo, 2020; Wei et al., 2020) also provide useful insights on this topic from various perspectives such as information asymmetry, demand volume, and market leadership. Our research builds on this literature in the following way. While the prior literature has focused on how exogenous market characteristics, such as competition and demand, affect a retailer under the wholesale and agency pricing models, our research addresses the question of how the value of free shipping programs, which is generally under the control of the retailer, is affected by the pricing model.

Our research exhibits some aspects that resemble, and yet depart from, the studies on multi-sided platforms (Armstrong, 2006; Caillaud and Jullien, 2003; Parker and Van Alstyne, 2005; Rochet and Tirole, 2003). This stream of research considers intermediaries that facilitate transactions between two or more distinct groups of entities to create value in an efficient way. The studies in this stream focus on markets that exhibit same-side and cross-side network effects. On the other hand, we consider a retail marketplace where products that do not exhibit such network effects.[6] While the marketplace we study could be viewed as a platform in that it facilitates transactions between sellers and consumers, online retailers are not regarded as multi-sided platforms (Rochet and Tirole, 2006; Rysman, 2009) because they lack the key features of multi-sided platforms, such as network effects.

[6]There is only one seller in the main model, which makes the issue of the cross-network effect on consumers irrelevant. There is also no same-side network effect on consumers as the utility derived from the purchase of a product does not depend on how many other consumers purchased the product.

3.3 Model

We examine a pure online retailing context in which a manufacturer (namely, a third-party seller) M sells his products with the help of a retailer R.[7] We consider a time period that consists of discrete shopping instances. For example, the time period could be a year and each day in the year could be a shopping instance such that the time period has 365 shopping instances. The manufacturer sells a product, which could be the same or different across shopping instances.[8] The retailer uses either the wholesale model or the agency model during the period. Under the wholesale model, the retailer buys the product from the manufacturer at a wholesale price and resells it to consumers at a retail price. Under the agency model, the manufacturer sells the product directly to consumers using the retailer, and the retailer charges a commission equal to α fraction of the sale price. The intensity of need for the product for a consumer can vary across shopping instances in the sense that she may not assign the same valuation, nor does she have the same preference at every shopping instance. A consumer purchases a product at a shopping instance only if the net utility from purchasing the product is positive at that instance. This model ensures that no consumer—neither a member nor a non-member of the MFS program when it exists—buys a product at all shopping instances. She buys a maximum of one unit of a product in a shopping instance. The fixed and marginal production costs of products are assumed to be zero for the manufacturer.

[7]We consider an extension in which the retailer sells products from $K > 1$ competing manufacturers in Section 7.1 and show that the qualitative results of the main model carry over to this extension.

[8]The restriction of single product in a shopping instance is for expositional clarity and is not critical to our analysis or findings. In case of $n > 1$ products, if the products are symmetric with respect to the consumer valuations, then the retailer's and manufacturer's profits under each pricing model will simply be n times those given in the paper, and therefore, the results regarding the comparisons of the two pricing models will not change qualitatively. Even in the case of asymmetric valuations of the n products, the retailer's and manufacturer's profits under each pricing model will be an aggregation of the profits of individual products. While the profit expressions will be more complex than those given in the paper, the qualitative results regarding the comparisons of the two pricing models are unlikely to be different.

Consumer Utility and Consumer Types. The consumer utility for the product at any shopping instance depends on her base valuation, v, which represents the value she derives from an ideal product that meets her need perfectly, and the misfit cost if the product does not meet her need perfectly at that instance. We assume a consumer's base valuation at a shopping instance is either high, i.e., $v{=}v_h$, or low, i.e., $v{=}v_l$, where $v_h > v_l$. Consumers are heterogeneous with respect to the likelihood that their base valuation is high (or low). We let θ denote the probability that $v{=}v_h$, and refer to θ as consumer type. We assume θ is uniformly distributed on [0,1]. This heterogeneity is related to the intensity of consumers' need or desire for purchase during the period. Hence, a consumer with a high θ is more likely to purchase than a consumer with a low θ at any shopping instance.

We use a typical horizontal product differentiation model (Hotelling, 1929) to capture a consumer's preference or fit with the product at a shopping instance. In particular, we assume that the product sold through the retailer is located at position 0 of a unit line that goes from -0.5 to $+0.5$. A consumer's location at any shopping instance is equally likely to be any point along the unit line. The distance between a consumer and a product measures the degree of misfit of the product to the consumer. When a consumer's location is λ, the misfit cost is the degree of misfit times a unit misfit cost t, which is equal to $\mid \lambda \mid t$.

The cost to ship a product to a consumer at any shopping instance during the period is s, regardless of who pays for it. This is reasonable in a context where the shipping is handled by an independent logistics provider. We abstract away details regarding logistics and inventory management in order to isolate the impact of the pricing model (wholesale versus agency) on the value of the MFS program. A similar approach is used by Wen and Lin (2017). We consider two scenarios that differ with respect to who bears the shipping cost. In the scenario in which the retailer does not offer the MFS program, consumers incur the shipping cost. In the scenario in which the retailer offers the MFS program, the retailer bears the cost to ship products to members, but non-members bear the shipping cost themselves.

Thus, for any shopping instance, we can formulate the net utility of a product for a consumer of type θ, who is located at λ, and bears the shipping cost s, as follows:

$$U(v(\theta), \lambda) = \ \ v(\theta) - \mid \lambda \mid t - s - p \ . \tag{3.1}$$

where $v(\theta)$ captures the base valuation of the consumer and p denotes the retail price of the product at the shopping instance. Clearly, if the retailer bears the shipping cost for the consumer, then the shipping cost will not be part of the net utility expression given in Equation 3.1. We assume that each consumer knows her (realized) base valuation and her (realized) location on the Hotelling line before making a purchase decision.

We assume $t > \frac{3v_h}{2} - \frac{v_l}{2} + s$ so that at any shopping instance there exist consumers (i.e., those whose preferences are located far from the product) that do no buy. Furthermore, in order to ensure a positive demand under both high and low base valuation scenarios under both pricing models, with and without MFS, we assume that $5v_l - 3v_h + \frac{s(s(6s - 3v_h + v_l) - 2tf)}{tf + s(v_h - v_l)} > 0$. The left side of the condition denotes the demand of low-valuation non-members in the scenario where the retailer uses the wholesale model and adopts MFS, as this scenario yields the lowest demand in our setup. The sellers (the manufacturer and the retailer) do not know an individual consumer's (realized) base valuation nor her (realized) location. However, they know the base valuation distribution and location distribution.

Timing of the Game. The game sequence depends on the pricing model as well as the existence of the MFS program. The game sequence at any shopping instance is the following. When there is no MFS program, under the wholesale model, in stage 1, the manufacturer sets the wholesale price w. In stage 2, the retailer sets the retail price p. In stage 3, consumers make their purchase decisions, and all parties realize their payoffs. If the retailer does not offer the MFS program, under the agency model, in stage 1, the retailer announces the commission rate α. In stage 2, the manufacturer sets the retail price p. In stage 3, consumers make their purchase decisions, and all parties realize their payoffs.

The sequence of events when the retailer offers the MFS program has two additional stages which occur at the beginning of the period. In the first of these two stages, the retailer announces a membership fee M and commits to bearing members' shipping cost for all shopping instances during the period. In the next stage, consumers decide whether to participate in the MFS program by paying the membership fee.

We assume that the retailer incurs a per period MFS program administration cost that is quadratic in the number of members. That is, the MFS cost to the retailer is given by $f\cdot$(number of members)^2. This cost includes the cost to manage the program, the cost related to handling potential product returns, and other costs such as those related to negotiating fulfillment contracts with the manufacturer, arranging logistics, and allocating warehouse spaces. We assume the MFS program administration cost f is not too small; specifically, $f > \dfrac{s(5v_l - 3v_h - 2s)}{4t}$.[9] The sole purpose of this cost in our model is to ensure interior solutions (namely, not all consumers join the MFS program when it is offered) under the agency as well as wholesale models. We let μ denote the manufacturer's reservation profit for the period to sell via R under the agency model. For a fair comparison of the two models, we assume that the reservation profit is equal to the profit the manufacturer earns if it were to use the wholesale model.[10] Without loss of generality, we normalize the number of consumers and the number of shopping instances in time period under consideration to one in the analysis, but still the realization of base valuation and location remains probabilistic.

[9] Relaxation of this constraint simply leads to an equilibrium in which all consumers become members of the MFS program in the agency model. However, our results regarding the impacts of the pricing model do not change qualitatively in this boundary equilibrium. For derivation of this condition, please refer to proof of Lemma 4 in the appendix.

[10] A similar approach is used by Tian et al. (2018). In reality, the manufacturer might choose either the wholesale or agency model after observing the commission rate charged by the retailer, so his payoffs should be identical to make it indifferent between the two pricing models, as suggested by Zennyo (2020). However, we note that the exact value of the reservation profit does not play a role in the value of MFS to the retailer, defined as the retailer's profit under MFS minus the retailer's profit under no MFS, under the agency model.

We note that our model is applicable to an online retailing context that has the following characteristics. The retailer sells a physical product that requires some cost to ship. The product does not exhibit network effects, either on the consumer side or on the producer side. Thus, an individual consumer's valuation of the product is not influenced by the number of consumers that buy the product. In the same vein, the number of consumers has no influence on the manufacturer's production cost. Analogously, the number of manufacturers has no impact on production cost or consumer valuations. Furthermore, the retailer is free to adopt either the wholesale model or the agency model with the upstream manufacturer. Table 3.1 summarizes the main notation used in the paper.

Table 3.1: Summary of Notation 2

Parameters	Definition	Range
v_l	low base valuation at a shopping instance	$v_l > 0$
v_h	high base valuation at a shopping instance	$v_h > v_l$
θ	consumer type (probability that a consumer's base valuation is v_h)	$\theta \sim U[0,1]$
λ	location of a consumer at any shopping instance	$\lambda \sim U[-0.5, 0.5]$
t	unit misfit cost	$t > 0$
s	cost to ship the product at any shopping instance	$v_l > s > 0$
μ	reservation profit of the manufacturer	$\mu > 0$
f	MFS program administration cost multiplier	$f > 0$
Decision Variables		
α	commission rate	$\alpha \in (0,1)$
w	wholesale price of the product	$w \geq 0$
p	retail price of the product	$p \geq 0$
M	membership fee to join the MFS program	
Variables of Interest		
U	net utility from purchase for a consumer	
D_{θ^m}	demand from consumer type θ as a member	$D_{\theta^m} > 0$
D_{θ^n}	demand from consumer type θ as a non-member	$D_{\theta^n} > 0$
D	overall demand	$D > 0$
π_M	expected profit of the manufacturer	
π_R	expected profit of the retailer	
CS	consumer surplus	
SW	social welfare	

3.4 MFS program under the Wholesale Model

We first derive the subgame perfect equilibrium when there is no MFS program in place, followed by the subgame perfect equilibrium when the retailer implements the MFS program. We then compare the key quantities under the two equilibria to characterize the impact of the MFS program under the wholesale model. We use the superscript ij for decision variables in different scenarios, where $i \in \{w, a\}$ indicates the business model—wholesale (w) or agency (a), and $j \in \{b, m\}$ refers to the MFS program status—no MFS (b) or MFS (m).

3.4.1 No MFS (Benchmark) under the Wholesale Model

In stage 3 of the game, when a consumer visits the retail platform, she will buy the product if and only if her net utility is non-negative. Thus, using Equation 3.1, we can determine that a consumer with a base valuation of v for the product will make the purchase only if she is located at $\mid \lambda \mid < \dfrac{v - p^{wb} - s}{t}$.

In stage 2 of the game, given the wholesale price w^{wb}, the retailer sets the retail price to maximize his expected profit by solving the following optimization model:

$$\arg\max_{p^{wb}} \ \pi_R^{wb} = \ (p^{wb} - w^{wb})\Big(\int_0^1 \int_{-\frac{v_h - p^{wb} - s}{t}}^{\frac{v_h - p^{wb} - s}{t}} \theta d\lambda d\theta + \int_0^1 \int_{-\frac{v_l - p^{wb} - s}{t}}^{\frac{v_l - p^{wb} - s}{t}} (1-\theta) d\lambda d\theta \Big) \ . \qquad (3.2)$$

In Equation 3.2, the first double integral captures the expected demand from the high base valuation consumer and the second double integral refers to the expected demand from the low base valuation consumer. Solving the retailer's maximization problem, we obtain the optimal retail price as a function of the wholesale price in stage 2 of the game.

In stage 1 of the game, the manufacturer maximizes his profit by solving the following model:

$$\arg\max_{w^{wb}} \pi_M^{wb} = w^{wb}\Big(\int_0^1 \int_{-\frac{v_h - p^{wb} - s}{t}}^{\frac{v_h - p^{wb} - s}{t}} \theta d\lambda d\theta + \int_0^1 \int_{-\frac{v_l - p^{wb} - s}{t}}^{\frac{v_l - p^{wb} - s}{t}} (1-\theta) d\lambda d\theta \Big) . \tag{3.3}$$

Lemma 3. *Under the wholesale model, in the absence of the MFS program, the equilibrium wholesale price w^{wb*}, retail price p^{wb*}, demand D_θ^{wb*} from consumer type θ, and total demand D^{wb*}, are as follows.*

$$w^{wb*} = \frac{v_h + v_l - 2s}{4} , \tag{3.4}$$

$$p^{wb*} = \frac{3(v_h + v_l - 2s)}{8} , \tag{3.5}$$

$$D_\theta^{wb*} = \frac{5v_l - 3v_h - 2s + 8\theta(v_h - v_l)}{4t} , \tag{3.6}$$

$$D^{wb*} = \frac{v_h + v_l - 2s}{4t} . \tag{3.7}$$

Using Lemma 3, we compute the equilibrium manufacturer profit (π_M^{wb*}), retailer profit (π_R^{wb*}), consumer surplus (CS^{wb*}) and social welfare (SW^{wb*}) and provide them in the appendix. We observe from Lemma 3 that an increase in shipping cost reduces both the wholesale price and the retail price because the manufacturer as well as the retailer will expect the demand to decrease when shipping cost increases, *ceteris paribus.* The demand from each consumer also decreases in s even though the retailer lowers the price in response to an increase in shipping cost. Consequently, the overall demand as well as the retailer's and the manufacturer's profits decrease in s.

3.4.2 MFS Program under the Wholesale Model

When the MFS program is in place, a consumer's purchase decision in the last stage of the game depends on her membership status—whether she is a member of the MFS program or not—in addition to her base valuation and location. A non-member's purchase decision rule remains the same as that in the benchmark. Specifically, she will buy the product if and only if $\mid \lambda \mid < \dfrac{v - p^{wm} - s}{t}$. On the other hand, if the consumer is a member, she will buy the product if and only if $\mid \lambda \mid < \dfrac{v - p^{wm}}{t}$.

When the retailer sets the price, his expected profit depends on the expected size and the composition of the membership base. The retailer will rationally expect that if a consumer of type θ participates in the MFS program, then all consumers that have a type greater than θ will also participate in the program. This is because a consumer with a higher θ would buy more frequently and would find participation to be more profitable than a consumer with a low θ, given the membership fee. We denote the type of the marginal consumer who is indifferent between joining and not joining the MFS program as $\hat{\theta}^{wm}$. Then, the size of the membership base would be equal to $(1 - \hat{\theta}^{wm})$. Therefore, the retailer solves the following model to set the retail price.

$$\begin{aligned}
\arg\max_{p^{wm}} \ \pi_R^{wm} = \ & \Big(\int_0^{\hat{\theta}^{wm}} \int_{-\frac{v_h - p^{wm} - s}{t}}^{\frac{v_h - p^{wm} - s}{t}} \theta d\lambda d\theta + \int_0^{\hat{\theta}^{wm}} \int_{-\frac{v_l - p^{wm} - s}{t}}^{\frac{v_l - p^{wm} - s}{t}} (1-\theta) d\lambda d\theta \Big) (p^{wm} - w^{wm}) \\
& + \Big(\int_{\hat{\theta}^{wm}}^{1} \int_{-\frac{v_h - p^{wm}}{t}}^{\frac{v_h - p^{wm}}{t}} \theta d\lambda d\theta + \int_{\hat{\theta}^{wm}}^{1} \int_{-\frac{v_l - p^{wm}}{t}}^{\frac{v_l - p^{wm}}{t}} (1-\theta) d\lambda d\theta \Big) (p^{wm} - w^{wm} - s) \\
& + MF^{wm} - f(1 - \hat{\theta}^{wm})^2 \ .
\end{aligned}$$

where $MF^{wm} = (1 - \hat{\theta}^{wm}) M^{wm}$ is the total membership fee collected by the retailer from participating consumers and M^{wm} is the membership fee. Solving the retailer's maximization problem, we obtain the optimal retail price as a function of the wholesale price under the MFS program.

In the stage where the manufacturer sets the wholesale price, the manufacturer solves the following model.

$$\arg\max_{w^{wm}} \ \pi_M^{wm} = \Bigg(\int_0^{\hat{\theta}^{wm}} \int_{-\frac{v_h - p^{wm} - s}{t}}^{\frac{v_h - p^{wm} - s}{t}} \theta d\lambda d\theta + \int_0^{\hat{\theta}^{wm}} \int_{-\frac{v_l - p^{wm} - s}{t}}^{\frac{v_l - p^{wm} - s}{t}} (1-\theta) d\lambda d\theta$$

$$+ \int_{\hat{\theta}^{wm}}^{1} \int_{-\frac{v_h - p^{wm}}{t}}^{\frac{v_h - p^{wm}}{t}} \theta d\lambda d\theta + \int_{\hat{\theta}^{wm}}^{1} \int_{-\frac{v_l - p^{wm}}{t}}^{\frac{v_l - p^{wm}}{t}} (1-\theta) d\lambda d\theta \Bigg) w^{wm} \ .$$

In the preceding stage, a consumer participates in the MFS program if and only if her expected (future) surplus gain by participating is not less than the membership fee, M^{wm}. For a consumer with type θ, the expected surplus with the membership is given by:

$$\int_{-\frac{v_h - p^{wm}}{t}}^{\frac{v_h - p^{wm}}{t}} \theta(v_h - p^{wm} - t \mid \lambda \mid) d\lambda + \int_{-\frac{v_l - p^{wm}}{t}}^{\frac{v_l - p^{wm}}{t}} (1-\theta)(v_l - p^{wm} - t \mid \lambda \mid) d\lambda \ . \tag{3.8}$$

The expected surplus for the same consumer without the membership is given by:

$$\int_{-\frac{v_h - p^{wm} - s}{t}}^{\frac{v_h - p^{wm} - s}{t}} \theta(v_h - p^{wm} - s - t \mid \lambda \mid) d\lambda + \int_{\frac{v_l - p^{wm} - s}{t}}^{\frac{v_l - p^{wm} - s}{t}} (1-\theta)(v_l - p^{wm} - s - t \mid \lambda \mid) d\lambda \ . \tag{3.9}$$

We can verify that the difference 3.8 - 3.9 is increasing in θ, implying that if a consumer of type θ participates in the MFS program, then consumers that have a type higher than θ will also participate in the program. Therefore, we can write the membership fee M^{wm} as the difference 3.8 - 3.9 for the indifferent consumer with type $\hat{\theta}^{wm}$. Then, we can restate the retailer's problem in stage 1 in terms of choosing the optimal $\hat{\theta}^{wm}$.

Lemma 4. *If the retailer implements the MFS program under the wholesale model, the equilibrium membership fee M^{wm*}, membership base $(1-\hat{\theta}^{wm*})$, wholesale price w^{wm*}, retail price*

p^{wm*}, *demand from consumer type* θ *with a membership* $D^{wm*}_{\theta>\hat{\theta}^{wm}}$, *demand from consumer type* θ *without a membership* $D^{wm*}_{\theta<\hat{\theta}^{wm}}$, *and total demand* D^{wm*} *are as follows.*

$$M^{wm*} = \frac{s(5v_l - 3v_h - 6s + 8(s + v_h - v_l)\hat{\theta}^{wm*})}{4t} ,$$

$$1 - \hat{\theta}^{wm*} = \frac{s(v_h + v_l - 6s)}{8(tf + s(v_h - v_l))} ,$$

$$w^{wm*} = \frac{v_h + v_l - 2s}{4} = w^{wb*} , \tag{3.10}$$

$$p^{wm*} = \frac{2s + 3(v_h + v_l) - 8s\hat{\theta}^{wm*}}{8} = p^{wb*} + (1 - s)\hat{\theta}^{wm*} , \tag{3.11}$$

$$D^{wm*}_{\theta<\hat{\theta}^{wm}} = \frac{5v_l - 3v_h - 10s + 8\theta(v_h - v_l) + 8s\hat{\theta}^{wm*}}{4t} = D^{wb*}_{\theta} - \frac{2s(1 - \hat{\theta}^{wm*})}{t} , \tag{3.12}$$

$$D^{wm*}_{\theta\geq\hat{\theta}^{wm}} = \frac{5v_l - 3v_h - 2s + 8\theta(v_h - v_l) + 8s\hat{\theta}^{wm*}}{4t} = D^{wb*}_{\theta} + \frac{2s\hat{\theta}^{wm*}}{t} , \tag{3.13}$$

$$D^{wm*} = \frac{v_h + v_l - 2s}{4t} = D^{wb*} . \tag{3.14}$$

Using Lemma 4, we compute the equilibrium manufacturer profit (π_M^{wm*}), retailer profit (π_R^{wm*}), consumer surplus (CS^{wm*}) and social welfare (SW^{wm*}) and provide them in the appendix. We also verify that $0 < \hat{\theta}^{wm*} < 1$. By comparing Lemma 3 with Lemma 4, we identify interesting similarities and differences between the equilibria in the presence of the MFS program and in its absence. One striking similarity is that the wholesale price and total demand are identical in the two equilibria. The intuition for this result is the following. The MFS program directly affects the consumers (members, specifically) and the retailer by transferring the burden of shipping cost from members to the retailer, but it does not directly affect the manufacturer. The retailer accounts for the shipping cost transfer by adjusting his profit margin such that the demand under MFS is the same as that in the benchmark; specifically, while the retailer sets a low price in the benchmark to compensate for the shipping cost incurred by consumers, he sets a high price under the MFS program to account for the shipping cost transferred to him. Anticipating this behavior from the retailer, the manufacturer sets the same wholesale price as in the benchmark under the MFS program and induces the same overall demand in both cases.

We note that the above finding is analogous to the classic economic finding that demonstrates the equivalence between producer tax and consumer tax in terms of equilibrium demand, producer surplus, and consumer surplus (Gans et al., 2011). Shipping cost in our context can be viewed as a tax on transactions. In the absence of the MFS program, the consumer bears this tax whereas in the presence of the MFS program, the retailer bears the tax for members. Regardless of who bears this cost, the entity that sets the price that consumers pay (the retailer in our context) adjusts the price so as to induce the same demand in the equilibrium. However, we note that our context also differs from a typical tax on transactions. For instance, we have two groups of consumers—members and non-members—under the MFS program and the party that bears the shipping cost varies across these two groups whereas the consumers are treated uniformly in the tax analogy. Therefore, although the transfer of shipping cost does not affect the overall demand under the wholesale model, consumer surplus is different with and without MFS due to heterogeneity among consumers.

While the retail price decreases with the shipping cost in the benchmark, it can increase or decrease with the shipping cost under the MFS program. An increase in shipping cost has two effects on the retailer under the MFS program. The direct effect is that it increases the retailer's cost of shipping to members. The indirect effect is that it decreases the wholesale price. While the first effect exerts an upward pressure on the retail price, the second effect exerts a downward pressure, *ceteris paribus*. Therefore, whether the equilibrium retail price increases or decreases with the shipping cost depends on which of these two effects dominates. Consequently, an increase in shipping cost can cause demand from a consumer to increase or decrease.

We find that the size of membership base is concave in s and achieves the maximum value at $s = \dfrac{\sqrt{6tf(6tf + v_h^2 - v_l^2)} - 6tf}{6(v_h - v_l)}$. When the shipping cost is small, the impact of and the benefit from the MFS program to the retailer is not significant. Consequently, the retailer does not have much incentive to induce low consumer types to join the program. On the other hand, when the shipping cost is large, the shipping cost burden becomes more dominant relative to the potential benefit from low consumer types. Thus, the membership base is largest when the shipping cost is neither too small nor too large.

3.4.3 Impact of the MFS Program under the Wholesale Model

Proposition 8. *Under the wholesale model, the retailer's profit is higher with the MFS program than without, i.e., $\pi_R^{wm*} > \pi_R^{wb*}$, if and only if $s < \dfrac{v_h + v_l}{6}$.*

Proposition 8 reveals that under the wholesale model, the MFS program is profitable to the retailer only if the shipping cost is not too excessive. When the shipping cost is very high, the increase in revenue does not offset the increase in the shipping cost burden even for the consumer with the highest consumer type. Therefore, it is unprofitable for the retailer to induce any consumer to join the program. A closer examination of the drivers of Proposition 1 reveals several more granular insights regarding the impact of the MFS program under the wholesale model. We explain these insights by isolating the impact of MFS on various components of the retailer profit. We decompose the retailer profit under the MFS program, excluding program administration cost, into three components: (i) retailer's net revenue from sales (**NR**) which is equal to demand times profit margin, where profit margin is defined as retail price minus wholesale price, (ii) total membership fee paid by members (**MF**), and (iii) absorbed shipping cost (**SC**). We note that in the absence of the MFS program, the retailer's profit comprises of NR only, which is equal to π_R^{wb*}.

By comparing Equation 3.10 with Equation 3.5, we find that the retail price is higher under the MFS program compared to the benchmark. Meanwhile, the MFS program does not have any effect on the wholesale price as mentioned in the discussion following Lemma 4. Thus, the MFS program enhances the retailer's profit margin. We denote this impact of

MFS on the retailer's profit margin as the *profit-margin increasing* effect. The magnitude of the profit-margin increasing effect under the MFS program in the wholesale model can be calculated as:

$$\Delta PM^{w*} = \quad (p^{wm*} - w^{wm*}) - (p^{wb*} - w^{wb*}) = s(1 - \hat{\theta}^{wm*}) > 0 \ . \tag{3.15}$$

From the above expression, it is clear that an increase in the size of the membership base increases the magnitude of the profit-margin increasing effect of the MFS program.

The MFS program has opposite effects on the demands from a member and a non-member. By comparing Equation (3.13) with Equation (3.6), we find that the demand from a member is greater under the MFS program compared to the benchmark. On the other hand, by comparing Equation (3.12) with Equation (3.6), we observe that the demand from a non-member is smaller under the MFS program compared to the benchmark. The non-members purchase less under the MFS program because the MFS program pushes up the retail price, which increases their overall cost of purchase. The members purchase more under the MFS program despite the increase of the retail price because this increase does not offset the savings they realize in shipping cost, which decreases their overall purchase cost. While the impacts of the MFS program on the two groups—members and non-members—are in opposite directions, the increase in the demand from members is offset by the decrease in the demand from non-members, resulting in no impact on the overall demand as shown below:

$$\Delta D^{w*} = D^{wm*} - D^{wb*} = 0 \ . \tag{3.16}$$

Thus, the total demand is unaffected by the MFS program under the wholesale model. Since profit margin is higher, the net revenue, NR^{wm*} is higher under the MFS program compared to the benchmark.

The retailer also enjoys a new source of revenue in the form of membership fee, MF, under the MFS program, but the gain from MF comes at the expense of shipping cost burden, SC.

Corollary 1. *The revenue earned from membership fees is less than the burden of shipping cost incurred by the retailer in the wholesale model, i.e., $MF^{wm*} < SC^{wm*}$.*

Corollary 1 reveals that the retailer ends up subsidizing the members' shipping cost because the total membership fee collected by the retailer is less than the total shipping cost borne by it. An important implication of this finding is that the MFS program will be deemed to be a failure for the retailer and a success for the members if the argument is made solely based on the membership fee and the shipping cost. However, Proposition 1 and the analysis related to consumer surplus discussed in Section 6 show that this line of reasoning and any conclusion based on it could be misleading.

The above findings show that under the wholesale model, the sole cause for the retailer's benefit from the MFS program is the increased profit margin he enjoys under the MFS program. More importantly, the increased profit margin is solely the result of a higher retail price charged under the MFS program compared to the benchmark (recalling that the wholesale price is unaffected by the MFS program). While the retailer gives back some of the price increase in the form of shipping subsidy to members, he retains all the price increase from non-members.

3.5 MFS Program under the Agency Model

As in the wholesale model, we follow the backward induction procedure to derive the subgame perfect equilibria in the absence and in the presence of MFS under the agency model. We leave the details of derivation to the appendix and provide a brief sketch of the derivation in this section.

3.5.1 No MFS (Benchmark) under the Agency Model

Consumer decision rule in the last stage of the game remains the same as in the benchmark under the wholesale model. In stage 2 of the game, the manufacturer chooses the retail price

p^{ab} given the commission rate α^{ab} by solving the following model:

$$\arg\max_{p^{ab}} \ \pi_M^{ab} = \Big(\int_0^1 \int_{-\frac{v_h-p^{ab}-s}{t}}^{\frac{v_h-p^{ab}-s}{t}} \theta d\lambda d\theta + \int_0^1 \int_{-\frac{v_l-p^{ab}-s}{t}}^{\frac{v_l-p^{ab}-s}{t}} (1-\theta) d\lambda d\theta\Big) p^{ab}(1-\alpha^{ab}) \ .$$

In stage 1 of the game, the retailer determines the commission rate α^{ab} by solving the model below.

$$\arg\max_{\alpha^{ab}} \ \pi_R^{ab} = \Big(\int_0^1 \int_{-\frac{v_h-p^{ab}-s}{t}}^{\frac{v_h-p^{ab}-s}{t}} \theta d\lambda d\theta + \int_0^1 \int_{-\frac{v_l-p^{ab}-s}{t}}^{\frac{v_l-p^{ab}-s}{t}} (1-\theta) d\lambda d\theta\Big) p^{ab}\alpha^{ab} \ ,$$

$$\text{subject to} \qquad \pi_M^{ab} \geq \mu = \pi_M^{wb*} = \pi_M^{wm*} \ .$$

The constraint in the above model denotes the individual rationality (IR) restriction that ensures the reservation wage for the manufacturer to sell via the online retailer.

Lemma 5. *Under the agency model, in the absence of the MFS program, the equilibrium commission rate α^{ab*}, retail price p^{ab*} and demand D_θ^{ab*} from consumer type θ , and total demand D^{ab*} are as follows.*

$$\alpha^{ab*} = 1 - \frac{8t\mu}{(v_h+v_l-2s)^2} \ , \tag{3.17}$$

$$p^{ab*} = \frac{v_h+v_l-2s}{4} \ , \tag{3.18}$$

$$D_\theta^{ab*} = \frac{3v_l - v_h - 2s + 4\theta(v_h-v_l)}{2t} \ , \tag{3.19}$$

$$D^{ab*} = \frac{v_h+v_l-2s}{2t} \ . \tag{3.20}$$

Using Lemma 5, we compute the equilibrium manufacturer profit (π_M^{ab*}), retailer profit (π_R^{ab*}), consumer surplus (CS^{ab*}) and social welfare (SW^{ab*}) and provide them in the appendix. We also verify that $0 < \alpha^{ab*} < 1$. It is intuitive that the equilibrium commission rate decreases in the manufacturer's reservation profit, because as the value of the outside option for the manufacturer increases, the retailer has to leave more surplus so that the manufacturer does not drop out. An increase in shipping cost reduces the equilibrium retail price because the manufacturer expects less demand from consumers, *ceteris paribus*. The demand from any consumer also decreases in s. Consequently, the overall demand decreases in s and the retailer decreases the commission rate when s increases so as to satisfy the (IR) constraint.

3.5.2 MFS Program under the Agency Model

The consumer decision rule in the last stage of the game, given the retail price, remains the same as in the MFS program under the wholesale model. Thus, a consumer's purchase decision in any shopping instance depends on her membership status. Denoting the indifferent consumer type as $\hat{\theta}^{am}$, the manufacturer solves the following model to choose the retail price.

$$\arg\max_{p^{am}} \; \pi_M^{am} = \Bigg(\int_0^{\hat{\theta}^{am}} \int_{-\frac{v_h - p^{am} - s}{t}}^{\frac{v_h - p^{am} - s}{t}} \theta d\lambda d\theta + \int_0^{\hat{\theta}^{am}} \int_{-\frac{v_l - p^{am} - s}{t}}^{\frac{v_l - p^{am} - s}{t}} (1-\theta) d\lambda d\theta$$

$$+ \int_{\hat{\theta}^{am}}^{1} \int_{-\frac{v_h - p^{am}}{t}}^{\frac{v_h - p^{am}}{t}} \theta d\lambda d\theta + \int_{\hat{\theta}^{am}}^{1} \int_{-\frac{v_l - p^{am}}{t}}^{\frac{v_l - p^{am}}{t}} (1-\theta) d\lambda d\theta \Bigg) p^{am} (1 - \alpha^{am}) \; .$$

Knowing how much the manufacturer will charge as the retail price, the retailer solves the following model to choose the commission rate in the preceding stage.

$$\arg\max_{\alpha^{am}} \; \pi_R^{am} = \Big(\int_0^{\hat{\theta}^{am}} \int_{-\frac{v_h - p^{am} - s}{t}}^{\frac{v_h - p^{am} - s}{t}} \theta d\lambda d\theta + \int_0^{\hat{\theta}^{am}} \int_{-\frac{v_l - p^{am} - s}{t}}^{\frac{v_l - p^{am} - s}{t}} (1-\theta) d\lambda d\theta\Big) p^{am} \alpha^{am}$$

$$+\Big(\int_{\hat{\theta}^{am}}^{1} \int_{-\frac{v_h - p^{am}}{t}}^{\frac{v_h - p^{am}}{t}} \theta d\lambda d\theta + \int_{\hat{\theta}^{am}}^{1} \int_{-\frac{v_l - p^{am}}{t}}^{\frac{v_l - p^{am}}{t}} (1-\theta) d\lambda d\theta\Big)(p^{am}\alpha^{am} - s)$$

$$+MF^{am} - f(1-\hat{\theta}^{am})^2 \;,$$

$$\text{subject to} \qquad \pi_M^{am} \geq \mu = \pi_M^{wb*} = \pi_M^{wm*} \;.$$

Following the logic provided for the wholesale model, in stage 1 of the game, the retailer will set the membership fee M^{am} as the difference between the marginal member's expected surplus with the membership and without the membership.

For the marginal member, the expected surplus with the membership can be calculated as:

$$\theta \int_{-\frac{v_h - p^{am}}{t}}^{\frac{v_h - p^{am}}{t}} (v_h - p^{am} - t\lambda) d\lambda + (1-\theta) \int_{-\frac{v_l - p^{am}}{t}}^{\frac{v_l - p^{am}}{t}} (v_l - p^{am} - t\lambda) d\lambda$$

The expected surplus for the same consumer without the membership can be calculated as:

$$\theta \int_{-\frac{v_h - p^{am} - s}{t}}^{\frac{v_h - p^{am} - s}{t}} (v_h - p^{am} - s - t\lambda) d\lambda + (1-\theta) \int_{-\frac{v_l - p^{am} - s}{t}}^{\frac{v_l - p^{am} - s}{t}} (v_l - p^{am} - s - t\lambda) d\lambda$$

Lemma 6. *If the retailer implements the MFS program under the agency model, the equilibrium membership fee M^{am*}, membership base $(1 - \hat{\theta}^{am*})$, commission rate α^{am*}, retail price*

p^{am*}, *demand from consumer* θ *with the membership* $D^{am*}_{\theta \geq \hat{\theta}^{am}}$, *and demand from consumer* θ *without the membership* $D^{am*}_{\theta < \hat{\theta}^{am}}$, *and total demand* D^{am*} *are as follows.*

$$
\begin{aligned}
M^{am*} &= \frac{s(3v_l - v_h - 2s + 2(s + 2v_h - 2v_l)\hat{\theta}^{am*})}{2t}, \\
1 - \hat{\theta}^{am*} &= \frac{s(v_h + v_l - 4s)}{4tf - 2s(s - 2v_h + 2v_l)}, \\
\alpha^{am*} &= 1 - \frac{8t\mu}{(v_h + v_l - 2s\hat{\theta}^{am*})^2}, \qquad (3.21) \\
p^{am*} &= \frac{v_h + v_l - 2s\hat{\theta}^{am*}}{4} = p^{ab*} + \frac{s(1 - \hat{\theta}^{am*})}{2}, \qquad (3.22) \\
D^{am*}_{\theta < \hat{\theta}^{am}} &= \frac{3v_l - v_h - 4s + 4\theta(v_h - v_l) + 2s\hat{\theta}^{am*}}{2t} = D^{ab*}_{\theta} - \frac{s(1 - \hat{\theta}^{am*})}{t}, \qquad (3.23) \\
D^{am*}_{\theta \geq \hat{\theta}^{am}} &= \frac{3v_l - v_h + 4\theta(v_h - v_l) + 2s\hat{\theta}^{am*}}{2t} = D^{ab*}_{\theta} + \frac{s\hat{\theta}^{am*}}{t}, \qquad (3.24) \\
D^{am*} &= \frac{v_h + v_l - 2s\hat{\theta}^{am*}}{2t} = D^{ab*} + \frac{s(1 - \hat{\theta}^{am*})}{t}. \qquad (3.25)
\end{aligned}
$$

Using Lemma 6, we compute the equilibrium manufacturer profit (π^{am*}_M), retailer profit (π^{am*}_R), consumer surplus (CS^{am*}) and social welfare (SW^{am*}) and provide them in the appendix. We also verify that $0 < \hat{\theta}^{am*} < 1$ and $0 < \alpha^{am*} < 1$. We find that the retail price set by the manufacturer is not the same with the MFS program and without the MFS program under the agency model. Furthermore, total demands are also different under the MFS program and the benchmark in the agency model. These findings are in sharp contrast to those under the wholesale model. Similar to the MFS program under the wholesale model, the retail price can increase or decrease with the shipping cost, as the optimal membership base that determines the retail price is non-monotonic in s. Consequently, an increase in the shipping cost can cause demand from any consumer as well as the overall demand to increase or decrease. Furthermore, as in the wholesale model, we find that the size of membership base is concave in s and achieves the maximum value at $s = \dfrac{\sqrt{2tf(32tf + (7v_h - 9v_l)(v_h + v_l))} - 8tf}{7v_h - 9v_l}$.

3.5.3 Impact of MFS under the Agency Model

Proposition 9. *Under the agency model, the retailer's profit is higher with the MFS program than without, i.e.,* $\pi_R^{am*} > \pi_R^{ab*}$ *if and only if* $s < \dfrac{v_h + v_l}{4}$.

A comparison of Proposition 8 and Proposition 9 shows that the impact of the MFS program on the retailer's profit is qualitatively similar under the wholesale and agency models. A closer examination of the impact of MFS under the agency model reveals that while some of the underlying drivers of the impact are the same under the two models, there is also an important difference. To understand this difference, we again decompose the retailer profit, not accounting for the program administration cost, under the MFS program into three components: retailer's net revenue received from the manufacturer as commission fee (**NR**); total membership fee paid by subscribing consumers (**MF**); and absorbed shipping cost (**SC**).

By comparing Equation 3.22 with Equation 3.18, we find that the retail price charged by the manufacturer is higher under the MFS program compared to the benchmark. Clearly, the manufacturer recognizes that some fraction of the consumers, viz., members, incur a smaller overall cost of purchase under the program compared to the benchmark because they do not incur the shipping cost anymore. The manufacturer then extracts a part of the extra surplus these consumers enjoy under the MFS program in the form of a higher price. This finding is noteworthy in light of the report in the popular press that Amazon has been accused of encouraging third-party sellers to inflate their prices after it introduced the the Prime program (GeekWire, 2014). This increase in the retail price is similar to the one we identified under the wholesale model. The retailer, being the first mover in the game, extracts the higher price enjoyed by the manufacturer under the MFS program, by adjusting the commission rate and leaving the same surplus to the manufacturer as in case without the MFS program. Thus, the retailer enjoys an increase in the profit margin in the agency model as in the wholesale model. The magnitude of the profit-margin increasing effect under the agency model can be calculated as:

$$\Delta PM^{a*} = \ p^{am*}\alpha^{am*} - p^{ab*}\alpha^{ab*} > p^{am*}\alpha^{ab*} - p^{ab*}\alpha^{ab*} = \frac{s(1-\hat{\theta}^{am*})\alpha^{ab*}}{2} > 0\ . \tag{3.26}$$

The retailer enjoys an additional benefit from the MFS program under the agency model that does not exist under the wholesale model. By comparing Equation (3.24) with Equation (3.19), we find that the demand from a member is higher in the presence of the MFS program compared to the benchmark. On the other hand, comparing Equation (3.23) with Equation (3.19), we find that the demand from a non-member is smaller in the presence of the MFS program compared to the benchmark. The impact of the MFS program on each of the two groups—members and non-members—is qualitatively identical under the wholesale and agency models. However, unlike the wholesale model, we find that the impact of the MFS program on the overall demand is always positive. Thus, while the total demand is unaffected by MFS under the wholesale model, it increases with MFS under the agency model. We denote this impact of the MFS program on the overall demand as the *demand enhancement* effect. We quantify the demand enhancement effect as follows.

$$\Delta D^{a*} = D^{am*} - D^{ab*} = \frac{s(1-\hat{\theta}^{am*})}{t} > 0\ . \tag{3.27}$$

Both the profit-margin increasing effect and the demand enhancement effect contribute to the higher commission revenue, NR, for the retailer under the MFS program compared to the benchmark. Furthermore, as in the wholesale model, the retailer enjoys an additional stream of revenue in the form of membership fees collected, MF under MFS, which the retailer does not have in the benchmark, and also incurs the shipping cost of the members which the retailer does not have to incur in the benchmark. We show below the membership fees collected does not cover the cost of shipping burden incurred by the retailer even under the agency model.

Corollary 2. *The revenue earned from membership fees is less than the burden of shipping cost incurred by the retailer in the agency model, i.e.,* $MF^{am*} < SC^{am*}$.

As in the wholesale model, an important implication of the above finding is that success or failure of the MFS program cannot be assessed solely based on the membership fee and shipping cost in the agency model.

The above findings show that under the agency model, two effects contribute to the retailer's benefit from the MFS program: the increased profit margin and the enhanced total demand. In summary, the analysis of this section shows that the qualitative impacts of the MFS on the retailer are largely similar under both wholesale and agency models. For example, under both models, the MFS program is profitable to the retail platform only when shipping cost is not too high, and the retailer subsidizes shipping cost of members by charging a membership fee that is smaller than the average shipping cost savings enjoyed by members. Some of the drivers of the impact are also the same under both models. For instance, the MFS program always leads to a profit-margin increasing effect. Therefore, a key question is whether the retailer has the same incentives to adopt MFS under the agency and wholesale models. We answer this question next.

3.6 Value of MFS under the Two Pricing Models

We examine the value of the MFS program to the retailer under each pricing model (wholesale and agency) based on the retailer's profit gain when he implements the MFS program compared to the benchmark under the same business model. We define the retailer's profit gain from the MFS program under the wholesale model and the agency model, respectively, as $\Delta\pi_R^{w*} = \pi_R^{wm*} - \pi_R^{wb*}$ and $\Delta\pi_R^{a*} = \pi_R^{am*} - \pi_R^{ab*}$. The following result provides a key finding of our study—that is, the MFS program is more valuable to the retailer under the agency model than the wholesale model.

Proposition 10. *The retailer's profit gain from the implementation of the MFS program is greater under the agency model than the wholesale model, i.e.,* $\Delta\pi_R^{a*} \geq \Delta\pi_R^{w*}$.

Proposition 10 is a main result of this paper. It shows that the MFS program is more valuable to the retailer under the agency model than the wholesale model. On the surface, one might think this result is intuitive because of the well-known double-marginalization problem that exists in the wholesale model but not in the agency model. However, this intuition does not capture the more subtle relationships between the MFS program and the pricing model. Specifically, the driving force behind Proposition 3 is not just the presence or absence of double-marginalization, but how the MFS program affects the severity of double-marginalization problem in the wholesale model and the single marginalization in the agency model. We quantify the degree of the double-marginalization problem as the total channel profit, i.e., the sum of retailer's and manufacturers' profits, when the double marginalization is present (as in the wholesale model) and when it is absent (as in the agency model). The MFS program aggravates the double-marginalization problem in the wholesale model because the MFS program transfers the shipping cost from the consumers to the retailer. The shipping cost is an additional marginal cost on the retailer, on top of the wholesale price that the retailer incurs whether or not the MFS program exists, which worsens the double-marginalization problem in the wholesale model. On the other hand, marginalization exists only at the manufacturer end in the agency model because the manufacturer sets the retail price based on his marginal cost (which is normalized to zero). The MFS eliminates the shipping cost incurred by the consumers. A reduction in consumer's transaction cost is analogous to reducing the marginal cost of the manufacturer. Effectively, the MFS program mitigates (single) marginalization at the manufacturer's end. Together, these effects of MFS on marginalization in the two models drive Proposition 3.

To gain further insights into Proposition 10, we decompose the retailer's profit gain from the MFS program by isolating how the MFS program affects different components of profit gain under the two models. Clearly, the MFS program affects the retailer's profit margin, demand, and shipping cost subsidy. Furthermore, all these components and the MFS program cost, are affected by the size of the membership base, which is different under the two models.

Corollary 3. *When the retailer implements the MFS program,*

(i) the size of the membership base is larger under the agency model than the wholesale model, i.e., $1 - \hat{\theta}^{am*} > 1 - \hat{\theta}^{wm*}$*;*

(ii) the shipping subsidy to members is higher under the agency model than the wholesale model, i.e., $SC^{am*} - MF^{am*} > SC^{wm*} - MF^{wm*}$*;*

(iii) the profit-margin increasing effect is higher under the agency model than the wholesale model, i.e., $\Delta PM^{a*} > \Delta PM^{w*}$*;*

(iv) the demand enhancement effect is higher under the agency model than the wholesale model, i.e., $\Delta D^{a*} > \Delta D^{w*}$*.*

The retailer induces more consumers to become members of the MFS program under the agency model than the wholesale model. The primary reason for this finding is that for every consumer type, the surplus gain from joining the MFS program compared to not joining is lower under the wholesale model than the agency model. This is driven by the fact that, under the wholesale model, the retailer will pass on some of the shipping cost burden he will bear under MFS while setting the retail price; on the other hand, under the agency model, the manufacturer which sets the retail price under does not suffer from the shipping cost burden under the MFS program. As a result, the retailer induces only a smaller number of consumers to join the MFS program under the wholesale model than the agency model.

A larger membership base has both a positive impact and a negative impact on the retailer's profit gain from the MFS program. As we observed in Corollary 1 and Corollary 2, the retailer subsidizes the members' shipping costs. An increase in the membership base exacerbates the retailer's loss from the subsidy. On the other hand, the retailer's profit margin increases because of the MFS program. An increase in the membership base enhances this benefit to the retailer by increasing the demand. That is, the demand enhancement effect, which is present in the agency model but not in the wholesale model, arises from two sources: (i) a higher reduction in members' overall cost of purchase in the agency model compared to the wholesale model, and (ii) a larger membership base in the agency model compared to the wholesale model. Corollary 3(ii)-3(iv) confirm these positive and negative effects of a larger membership under the agency model compared to the wholesale model.

An implication of Corollary 3(i)-3(iv) is that a higher profit gain from the MFS program for the retailer under the agency model relative to the wholesale model comes solely from a higher (net) revenue increase the retailer enjoys from the MFS program under the agency model than the wholesale model, contributed by both (i) the profit margin increase that is higher under the agency model and (ii) the demand increase the retailer enjoys from the MFS program under the agency model. Furthermore, as shown in Proposition 9, the demand enhancement under the agency model comes only from members. Therefore, in conclusion, we find that a higher profit gain the retailer enjoys from the MFS program under the agency model than the wholesale model is essentially the result of a higher profit margin, a higher demand from members of the MFS program, and a larger MFS membership base in the agency model relative to the wholesale model.

Proposition 11. *The MFS program is profitable to the retailer*

(i) under both pricing models if $s < \dfrac{v_h + v_l}{6}$*,*

(ii) under only the agency model if $\dfrac{v_h + v_l}{6} \leq s < \dfrac{v_h + v_l}{4}$*, and*

(iii) under neither business model if $\dfrac{v_h + v_l}{4} \leq s$*.*

Proposition 11 shows that the retailer would implement the MFS program in a larger region of the parameter space under the agency model compared to the wholesale model.

In other words, there exist scenarios where MFS is unprofitable to the retailer under the wholesale model but profitable under the agency model. Figure 3.1 demonstrates the higher profit gain from MFS under the agency model (given in Proposition 10) and the expansion effect of the agency model (given in Proposition 11).

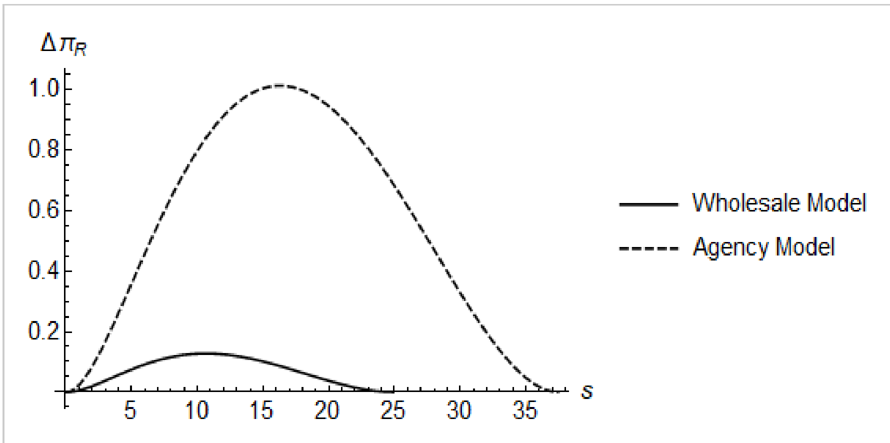

Figure 3.1: Retailer Profit Gain Comparison with respect to Shipping Cost
Notes: $f = 5,\ v_l = 50,\ v_h = 100,\ t = 100$

The last two propositions show that the agency model provides more incentive to an online retailer to adopt the MFS program. Intuitively, the wholesale model constrains the retailer from reaping the full benefit of the MFS program. The MFS program simply transfers the shipping cost—which is a type of transaction cost—from the consumers to the retailer. Under the wholesale model, the retailer sets a low retail price when consumers incur the shipping cost and a high retail price when it incurs the shipping cost. Effectively, the retailer is unable to alter the overall demand with the help of the MFS program compared to the benchmark under the wholesale model even though members do not incur any shipping cost in the presence of the MFS program but they do in its absence. On the other hand, under the agency model, the manufacturer does not face the burden of shipping cost under the MFS program while setting the retail price. That is, by removing the shipping cost altogether from the transaction between the manufacturer and the consumers, the MFS program boosts up the demand and the membership base in the agency model. Thus, by giving up the pricing power to the manufacturer, the retailer is able to reap the full benefits of the MFS program under the agency model.

We have shown in the preceding analysis and results that the MFS program delivers a higher profit gain under the agency model than under the wholesale model. We have also provided comprehensive explanation for the result based on how the MFS program affects demand, profit margin, and the severity of double and single marginalization under the two models. However, the two pricing models also differ on two fundamental characteristics. First, who moves first—whether the retailer or the manufacturer—is different under the two models. While the upstream manufacturer moves first by setting the wholesale price under the wholesale model, the retailer moves first by setting the commission rate under the agency model. Second, while the manufacturer offers a linear wholesale price contract under the wholesale model, the retailer offers an ad-valorem commission rate contract (i.e., revenue-sharing contract). Naturally, the question arises whether the differences between these two models along the above two characteristics could provide an explanation for our findings. We answer this question by examining the impact of the MFS program under the consignment model and a model akin to the franchise model, as investigated by Johnson (2017).

Consignment Mode

In the consignment model, the retailer first sets the wholesale price and then the manufacturer sets the retail price. Therefore, the consignment model is analogous to the wholesale model, but the retailer has the first-mover advantage as in the agency model. We compare the retailer's profit gain from the MFS program under the consignment model and the wholesale model (as discussed in Section 3) to examine how a change in the first mover affects the profit gain. We use superscript c to denote the consignment model.

Corollary 4. *The retailer's profit gain from the MFS program under the consignment model is equal to that under the wholesale model, i.e.,* $\Delta\pi_R^{c*} = \Delta\pi_R^{w*}$.

Corollary 4 shows that the retailer actually achieves the same level of profit gain under the consignment model and the wholesale model. An examination of the analysis suggests that although the wholesale price is higher with the MFS program than without under the consignment model, which is different from the wholesale model case, the retail prices in fact are identical if the retailer implements the MFS program across the two pricing models. Meanwhile, the equilibrium membership base are of the same size as well. Hence, the MFS program under the consignment model fails to induce any demand enhancement either. Interestingly, we find that the manufacturer's profit is not affect by the implementation of the MFS program under the consignment model, which is similar to what we found in the wholesale model. Thus, we can conclude that most of the equilibrium outcomes including the consumer composition, overall demand, manufacturer profit and retailer profit gain from the MFS program are not sensitive to who moves first.

Franchise Mode

In the franchise model, the retailer sets the commission rate (i.e., uses the revenue-sharing contract) as in the agency model, but also sets the retail price as in the wholesale model. Thus, the key difference between the wholesale model and the franchise model is that the linear wholesale price contract is replaced with the revenue-sharing contract.[11] We use superscript f to denote the franchise model.

[11]In a traditional franchise model, the manufacturer sets the commission rate, but this model is rarely used in online retailing where the retailers are dominant players. Our main purpose of this analysis is to theoretically understand the key driving force of MFS. Therefore, we only use the term "franchise model" loosely in this analysis.

Corollary 5. *The retailer's profit gain from the MFS program under the franchise model (i) is less than that under the agency model, i.e.,* $\Delta\pi_R^{f*} \leq \Delta\pi_R^{a*}$*; and (ii) is less than that under the wholesale model, i.e.,* $\Delta\pi_R^{w*} > \Delta\pi_R^{f*}$*, if and only if* $28s^2 - 20s(v_h + v_l) + 3(v_h + v_l)^2 < 0$.

Corollary 5(i) shows the retailer always benefits more from the MFS program under the agency model than under the franchise model, despite the fact that both of them have the revenue-sharing feature. This result suggests the retailer's higher profit gain from MFS under the agency model than under the wholesale model cannot be purely attributed to the revenue-sharing contract. In fact, as indicated by Corollary 5(ii), the MFS program can yield a lower gain under revenue-sharing than under the wholesale model under some conditions.

Overall, the results related to the value of the MFS program under the consignment model and the franchise model show that the retailer's higher profit gain from MFS in the agency model is not a result of the retailer having the first-mover advantage or the revenue-sharing contract. Instead, the key driving force is the separation of price setting and shipping burden to two different parties. That is, while the agency model transfers the retail price setting authority to the manufacturer from the retailer, the MFS program puts the shipping cost burden to the retailer, transferring from the consumer. Thus, the MFS program under the agency model alleviates the consumers' shipping burden and enables the retailer to realize the full demand and profit margin potential. The other models do not have this distinct feature, thereby limiting the potential benefit of the MFS program to the retailer.

3.7 Impacts of MFS on Consumers and Society

The preceding analysis focused on how the pricing model affects the impact of MFS on the retailer. However, the other stakeholders in this marketplace such as the manufacturer, consumers, and society could all be affected by the MFS program. In this section, we examine the impacts of the MFS program on these stakeholders under the two pricing models.

It is straightforward to verify that the MFS program does not have any impact on the manufacturer either under the wholesale model or the agency model. Under the wholesale model, both the wholesale price and the demand are the same with and without the MFS program. Under the agency model, the retailer makes the manufacturer indifferent with and without the MFS program by paying the same reservation wage.

The following result presents the impact of the MFS program on consumers.

Proposition 12. *When the retailer implements the MFS program, compared to when it does not,*

(a) the overall consumer surplus is lower in the wholesale model, i.e., $CS^{wm*} < CS^{wb*}$*;*

(b) the overall consumer surplus is higher in the agency model, i.e., $CS^{am*} > CS^{ab*}$*, if and only if* $s^2(8s + 5v_h - 11v_l) + 4tf(v_h + v_l - 2s) < 0$*;*

(c) non-members are worse off in both the wholesale model and the agency model, i.e., $CS^{wm*}_{\theta<\hat{\theta}^{wm}} < CS^{wb*}_{\theta<\hat{\theta}^{wm}}$ *and* $CS^{am*}_{\theta<\hat{\theta}^{am}} < CS^{ab*}_{\theta<\hat{\theta}^{am}}$*;*

(d) in each model, members are better off if their type is higher than a threshold value, i.e., $CS^{wm*}_{\theta\geq\hat{\theta}^{wm}} > CS^{wb*}_{\theta\geq\hat{\theta}^{wm}}$ *if and only if* $\theta > \theta^{wm*}$ *and* $CS^{am*}_{\theta\geq\hat{\theta}^{am}} > CS^{ab*}_{\theta\geq\hat{\theta}^{am}}$ *if and only if* $\theta > \theta^{am*}$*, where the exact expressions of* θ^{wm*} *and* θ^{am*} *are given in the proof.*

Proposition 12(a) reveals that consumers as a whole are worse off with the MFS program than without in the wholesale model. Clearly, non-members will be worse off with the MFS program because they end up paying a higher retail price and consuming less when the MFS program is implemented and when it is not. We refer to the reduction in surplus of non-members when some consumers decide to join the MFS program as the *negative externality* effect imposed by members on non-members. This negative externality effect has counter-intuitive implications for members as well as the retail platform. For members, it seems that they can be better off with the MFS program than without, because the extent of retail price increase given by Equation (3.15) is only a fraction of their savings in shipping cost, resulting in a net reduction in their purchase cost. However, this intuition turns out to be not necessarily correct because we find that even some members are actually worse off with the MFS program compared to the benchmark. The explanation for this surprising finding is the following. The members' benefit in the form of net savings in purchase cost comes at the expense of an upfront membership fee they pay to the retail platform. Consider a consumer deciding whether to join the program. Because of the negative externality effect, the consumer will expect to suffer a loss in surplus if she does not join the program. On the other hand, by joining the program, she will expect to achieve savings in purchase cost or a positive purchase-related surplus. Therefore, the positive difference in the consumer's expected surplus when she joins the program and when she does not, which is equal to the expected savings in purchase cost by joining plus the expected loss in surplus by not joining, provides her an incentive to join the program. Recognizing this incentive of the consumer, the retailer charges a membership fee that is just less than this difference in surplus, which accounts for not only the purchase-related savings enjoyed by the consumer but also the loss in surplus arising from the negative externality effect if she does not join the program. Consequently, some members with valuation close to the marginal member end up being hurt under the MFS program compared to the benchmark. Essentially, under the MFS program, the negative externality effect imposed by the program enables the retailer to force these members to choose between two options—joining and not joining—, both of which hurt them but joining hurts them less, thereby inducing them to choose joining over not joining. Interestingly, although some members with high valuation could be better off with the MFS program, the overall consumer surplus is always lower due to the relatively larger extent of price increase and the absence of demand enhancement under the wholesale model.

Proposition 12(b), on the other hand, suggests that the overall consumer surplus can be higher with the MFS program compared to the benchmark under the agency model, even though the surplus of any individual consumer, either a member or an non-member, is affected by the MFS program qualitatively in the same way under both agency and wholesale models. This remarkable distinction is because of the relatively smaller extent of price increase and the presence of demand enhancement under the agency model, which enhances the surplus enjoyed by consumers.

Proposition 13. *When the retailer implements the MFS program, compared to when it does not,*

(a) social welfare is lower under the wholesale model, i.e., $SW^{wm*} \leq SW^{wb*}$*;*

(b) social welfare is higher under the agency model, i.e., $SW^{am*} > SW^{ab*}$*, if and only if* $4v_h^2 - 23sv_h + 25sv_l - 4v_l^2 - 8tf > 0$.

Proposition 13(a) suggests that society is always worse off when the retail platform implements the MFS program than when it does not in the wholesale model. This is a noteworthy result in light of Equation (3.16), which shows that the MFS program does not have any impact on the overall demand under the wholesale model. Thus, it may seem that social welfare should remain the same as MFS does not change either valuations or costs; however, it turns out to be not the case. The explanation for this seemingly counter-intuitive finding is as follows. Although the overall demand is unaffected by the MFS program, demand from each consumer segment—members and non-members— is influenced in a distinctive manner. When the retailer implements the MFS program, members actually consume more, while non-members consume less than the benchmark. On one hand, the increase in demand from members comes from high-misfit cost transactions—that is, those shopping instances in which members do not consume when they have to incur the shipping cost but consume when they do not incur the shipping cost. On the other hand, the decrease in demand from non-members comes from relatively low-misfit cost transactions—that is, those shopping instances in which non-members consume when there is no MFS program but do not consume when there is the MFS program because of the higher retail price under the MFS program.

Essentially, the implementation of the MFS program in the wholesale model leads to demand substitution between non-members and members while keeping the overall demand identical to that when there is no MFS program. Specifically, the MFS program replaces some relatively low-misfit cost transactions by non-members with high-misfit transactions by members. This demand substitution diminishes the overall social welfare. We verified that this result holds even if the program administration cost is excluded from consideration, implying that the MFS program cost is not the driver of the impact of MFS on the social welfare. Furthermore, this result demonstrates the conventional wisdom that the social welfare is unaffected by the shifting the cost from one player to another does not hold in the MFS program context because of the intricate strategic effects of the MFS program.

Interestingly, Proposition 13(b) suggests that the impact of the MFS program on social welfare under the agency model can be positive or negative. The positive impact on social welfare is relatively straightforward to understand. Clearly, demand enhancement resulting from the MFS program contributes to the positive impact. The enhanced demand improves social welfare as long as the social cost of satisfying the additional demand, i.e., shipping cost plus the program administration cost, is small enough. On the other hand, if the social cost is too high, then the benefit from the demand enhancement effect is offset by the cost required to satisfy the additional demand. In other words, the additional utility enjoyed by members from increased demand may not compensate the additional cost incurred by the retailer (and the society eventually), so society could be hurt in satisfying the additional demand from the members.

3.8 Model Extensions

In this section, we extend our model in several directions by varying some of our basic assumptions. The primary purpose of the analysis in this section is to examine the robustness of the key results of the main model. Accordingly, we focus only on the MFS program's impact on the retailer in this section.

3.8.1 Manufacturer Competition in the Marketplace

In the main model, we consider a context in which one manufacturer sells via the online retailer. In this extension, we assume there are K manufacturers indexed by $i = 1, ..., K$ ($K \geq 2$) in the market selling through the retailer. Each manufacturer sells a product. These products are competing in the sense, at any shopping instance, consumers evaluate the net utility offered by each product and buy the product that offers the highest positive net utility. We adopt a circular model (Salop, 1979) to represent consumers' preference towards products that are symmetrically distributed along the unit circle. This setup also implies that there is a positive cross-side network effect on consumers because an increase in K reduces the consumers' misfit costs, *ceteris paribus*. To capture competition, we assume that the model parameters are such that the market is fully covered when the valuation is v_h, while the market is not fully covered when the valuation is v_l, as in the main model.[12] All other aspects remain identical to those in the main model.

Proposition 14. *In the marketplace with K competing manufacturers,*

(a) the retailer's profit gain from implementing the MFS program is higher in the agency model than the wholesale model, i.e., $\Delta\pi_R^{a*} > \Delta\pi_R^{w*}$;

(b) the difference in profit gain increases with K, that is $\dfrac{\partial(\Delta\pi_R^{a*} - \Delta\pi_R^{w*})}{\partial K} > 0$.

Proposition 14(a) demonstrates that the key result of this paper that the value of the MFS program to the retailer is higher in the agency model than the wholesale model carries over to

[12] If the market is not fully covered in both v_h and v_l scenarios, there is no competition among the manufacturers. In that case, this extension reduces to a context with K independent manufacturers, and consequently the model can be separated into K independent models where each resembles our main model with one manufacturer.

the competitive manufacturers setting. Moreover, Proposition 14(b) reveals that the relative incentive to implement the MFS program under the agency model (compared to the wholesale model) increases as the number of competing manufacturers increases. Proposition 14(b) suggests that a more intense competition in the marketplace (when measured using the number of competitors) provides more impetus to the retailer to adopt the MFS program when the retailer uses the agency model as compared to the wholesale model. The main drivers of the enhanced attractiveness of the MFS program in the competitive manufacturer setting under the agency model than the wholesale model remain the same as in the main model.

3.8.2 Membership-Based Price Discrimination

In the main model, we assume consumers pay the same price regardless of their membership status when the retailer implements the MFS program under both the wholesale model and the agency model. In reality, the seller (viz., the retailer in the wholesale model and the manufacturer in the agency model) could charge different prices to members and non-members, i.e., the seller could price discriminate consumers based on their membership status. In fact, it has been alleged that Amazon charges its Prime members more than the non-members for the same product (ConsumerAffairs, 2014). Such practice can be interpreted as an example of behavior-base price discrimination (BBPD) strategies, which have been discussed extensively by prior literature (Fudenberg and Tirole, 2000; Choe et al., 2018; Chen et al., 2019). These studies differ in aspects related to nature of the game (static one short versus dynamic multi-period) and type of price discrimination (third-degree or first-degree), among others. Moreover, some of these studies also examine the consumer strategies to avoid loss from discrimination. Our focus is on third-degree price discrimination enabled purely by the MFS program. In other words, price discrimination in our model would have not been an issue if the retail platform had not chosen to implement the MFS program.

Furthermore, in our setting, consumers are not able to use identity management strategies to prevent being price discriminated (Taylor, 2004; Villas-Boas, 2004; Acquisti and Varian, 2005). More importantly, while the price discrimination literature has largely focused on the impacts of price discrimination, we focus in this section on the value of the MFS program under two different pricing models when price discrimination is also a strategic choice of the retailer.

Ignoring the legality of such price discrimination practices, in this extension, we examine the case where price discrimination is possible based on MFS program membership status. When the retailer announces the MFS program, he either credibly commits to no price discrimination in the future or is unable to do so. The scenario when the retailer credibly commits to no price discrimination is identical to that considered in our main analysis, *ceteris paribus*. If the retailer is unable to make such a commitment, the consumers will rationally expect sellers to charge different prices to members and non-members and account for such potential price discrimination while making their participation decision. We keep all model aspects, except the commitment announcement at the time of announcing the MFS program, the same as in the main model.

Lemma 7. *(a) In the wholesale model, the retailer will commit to no price discrimination based on consumers' membership status when he implements the MFS program.*

(b) In the agency model, the retailer will not always commit to no price discrimination based on membership status when he implements the MFS program.

The primary driver of the Lemma 7(a) is that when the retailer is unable to credibly commit to no price discrimination, he cannot induce any consumer to join the program under the wholesale model. Clearly, the consumers will rationally expect that the retail platform will charge a higher price to members than non-members when the retailer cannot commit. Under the wholesale model, a potential member will expect that the difference in prices for members and non-members to be more than the shipping cost. Consequently, every consumer expects a smaller expected surplus if she becomes a member than if she does not, even if the membership is offered for free. The inability to attract any consumer into the MFS program reduces the scenario with the MFS program to the benchmark scenario of no MFS program. On the other hand, when the retailer is able to commit to no price discrimination, the results of the main wholesale model applies. Therefore, under the conditions stated in Proposition 1 (i.e., when $s < \frac{v_h + v_l}{6}$), the retailer will commit to no price discrimination and implement the MFS program. When $s \geq \frac{v_h + v_l}{6}$, the retailer will not implement the MFS program and hence the question of commitment would not arise.

In sharp contrast to the wholesale model, it is not always profitable for the retailer to make the commitment to not to price discriminate under the agency model. Specifically, the retailer will price discriminate if the profit gain with price discrimination exceeds the profit gain without price discrimination given. When the shipping cost is not high (i.e., when the condition given in Lemma 7 holds), the retailer prefers to implement the MFS program with commitment of no price discrimination. When the shipping cost is high, the retailer prefers to implement the MFS program without such a commitment if the MFS program is profitable. Figure 3.2 illustrates Lemma 7. In this figure, the retailer implements the MFS program with no price discrimination when the shipping cost is less than approximately 28, implements the MFS program with no commitment regarding price discrimination when the shipping cost is between 28 and 44 (approximately), and does not implement the MFS program otherwise. Essentially, the ability to price discriminate expands the region where the retailer prefers to implement the MFS program in the agency model. The higher profit the retailer can enjoy when it can price discriminate makes the MFS program attractive even when the shipping cost is high, even though the MFS program may not be profitable if price discrimination is not possible. On the other hand, even when price discrimination is possible, it is in the retailer's best interest to make the commitment to not to price discriminate when the shipping cost is low. The reason for this finding is that consumers do not expect a significant savings in shipping cost (i.e., surplus gain) by joining the MFS program. Without a commitment from the retail platform to no price discrimination, the expected surplus gain becomes even smaller. Consequently, the inability to attract many members into the MFS program when price discrimination is possible makes commitment (and hence a larger membership base) preferable for the retailer. Lemma 7(b) reveals that when shipping cost is low, price discrimination cannot be a significant tool to derive value from the MFS program under the agency model.

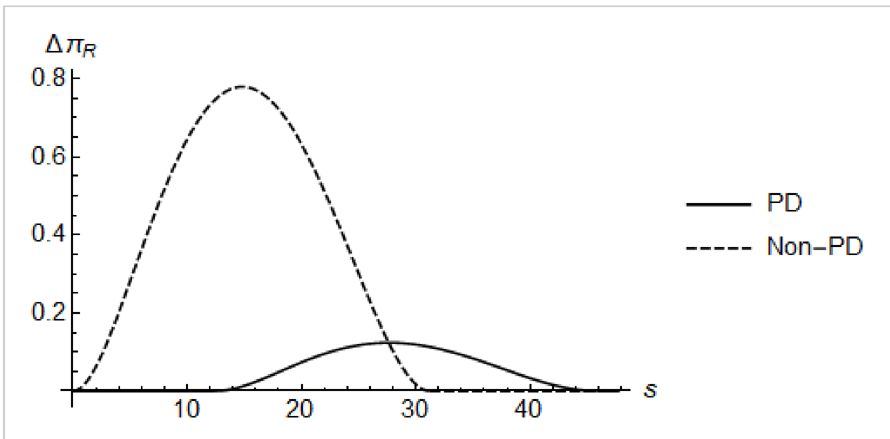

Figure 3.2: Retailer Profit Gains with Price Discrimination (PD)
and without Price Discrimination (Non-PD) under the Agency Model
$v_l = 50,\ v_h = 75,\ t = 100,\ f = 5$

Proposition 15. *When the retailer has the ability to commit (or not commit) to price discrimination based on membership status,*

(a) the retailer's profit gain from implementing the MFS program is higher under the agency model than under the wholesale model.

(b) the retailer implements the MFS program in a larger region of the parameter space in the agency model compared to when price discrimination is not possible.

Proposition 15(a) confirms that the key result of the main model holds even when the retailer has the ability to price discriminate consumers based on membership status. Furthermore, Proposition 15(b) reveals that the ability to price discriminate and make appropriate commitment to that effect makes the MFS even more attractive under the agency model compared to the wholesale model for the retailer.

3.8.3 Perks in addition to Free Shipping under MFS

In the main model, we focus on the core element of the MFS program as a shipping cost-absorption mechanism. In practice, the retailer could offer other perks in addition to free shipping to induce consumers to join the program. For example, other than two-day free shipping, Amazon Prime membership offers unlimited streaming of movies and TV shows, access to ad-free music, and cloud space for photo storage, among others. Hence, a consumer's program participation decision may be affected by those perks that come with the membership. In this sub section, we consider the scenario in which the MFS program offers additional perks besides free shipping. In particular, we assume that a consumer's valuation of these perks, denoted as γ, during the membership period follows a uniform distribution with support $[0, \Gamma]$, and that it is independent of the consumer's base product valuation and location. We normalize the retail platform's marginal cost to offer these perks to zero.[13] Furthermore, we assume that the key factor in a consumer's decision to participate in the MFS program is the surplus gain from the purchase of products with free shipping rather than the additional perks of the program. Thus, we assume that even when a consumer enjoys the maximum value of Γ from additional perks, she may not necessarily join the MFS program.

Proposition 16. *When the retailer implements the MFS program with additional perks,*

(a) its profit gain is higher under the agency model than under the wholesale model, i.e., $\Delta\pi_R^{a*} > \Delta\pi_R^{w*}$,

[13] Since most of the perks are information goods, this assumption is reasonable. Alternatively, we can assume a fixed cost that would be the same under the two business models.

(b) the difference in profit gain increases with the highest valuation toward additional perks, i.e., $\dfrac{\partial(\Delta\pi_R^{a*} - \Delta\pi_R^{w*})}{\partial\Gamma} > 0$.

The result shows that when the retailer offers additional perks along with free shipping in the MFS program, the attractiveness of the program under the agency model relative to the wholesale model is enhanced. Furthermore, the MFS model becomes more attractive under the agency model relative to the wholesale model as the (highest) consumer valuation for these perks increases. Anecdotal observations regarding the Amazon Prime program's expanding scope in terms of additional perks seem to be consistent with Proposition 16(b). The additional perks could potentially allow Amazon to reap more benefits from the Prime program because of the strategic effects we have identified in this paper.

3.8.4 Lower Shipping Cost for Retailer compared to Consumers

In the main model, we assume the shipping cost remains the same regardless of who is paying for it. However, one could argue that the shipping cost incurred by the retailer (under the MFS program) could be lower than that incurred by consumers (without the MFS program or if they are non-members). In reality, Amazon and other large online retailers pre-negotiate contracts with logistics providers that offer the retailers a discounted shipping cost, which will be typically lower than the cost charged to consumers. To model such possibility, we consider the shipping cost incurred by the retailer to be γs instead of s, where $\gamma \in (0, 1]$, for shipping to members under the MFS program. Other aspects remain the same as in the main model.

Proposition 17. *When the retailer incurs discounted shipping cost while implementing the MFS program, its profit gain under the agency model is higher than the wholesale model, i.e.,* $\Delta\pi_R^{a*} \geq \Delta\pi_R^{w*}$.

Proposition 17 shows that the retailer's profit gain from the MFS program is higher under the agency model than the wholesale model. We find that when the retailer enjoys a discount on the shipping cost under the MFS program, the MFS program may provide some demand enhancement even under the wholesale model, unlike the main model where such demand enhancement because of the MFS program does not exist. This is because the discounted shipping cost allows the retailer to set a lower retail price when the MFS program exists than when it does not if the discount is steep enough. As a result, the exacerbated double-marginalization caused by the MFS program is alleviated to some extent; however, the wholesale model still cannot compete with the agency model on demand enhancement, as the agency model enables the retailer to enjoy the maximum demand enhancement. Therefore, the agency model remains superior to the wholesale model regarding the value of the MFS program even in the scenario where the retailer might incur less shipping cost than consumers.

3.9 Conclusion

Membership-based free shipping (MFS) and the shift towards agency model of selling are two recent innovations in the online retailing context. Using a game theoretic model, we show that the retailer's profit gain from the MFS program is higher under the agency model than the wholesale model. Furthermore, the retailer finds it profitable to implement the MFS program in a larger region of the parameter space under the agency model than under the wholesale model. Moreover, our results suggest that consumers as a whole are worse off with the MFS program under the wholesale model but they can be better off under agency model. While the society is always worse off with the MFS program under the wholesale model, it is better off with the agency model if the societal cost is not too high. The results demonstrate that viewing the MFS program as a simple shipping cost transfer mechanism would fail to uncover the intricate strategic impacts of the program and could lead to incorrect conclusions about the program's impacts on various stakeholders.

The primary implication of our findings is that they posit a potential strategic relationship between the adoption of the consumer-side MFS program and the shift in the supplier-side pricing model to agency. The question of whether the growth of the MFS program is a result of a shift to the agency model is an empirical question; however, our theoretical analysis predict a positive relationship between the upstream pricing model and the adoption of downstream MFS program. The findings also provide a potential explanation for why the scope of MFS programs such as Amazon Prime has been expanding to include numerous additional perks. The analysis suggests that these additional perks could serve to enhance the fundamental strategic MFS program benefits, related to profit from sale of products rather than profit from additional perks, derived by a retail platform. While the MFS program has the additional benefit of enabling the retail platform to price discriminate based on membership status, we show that it is not always profitable for the retailer to practice price discrimination. This result is consistent with Amazon's public announcement to not price discriminate following the public outcry about instances of price discrimination by Amazon. Finally, our findings present a potential implication for the future of online retailing. The complementary relationship between agency model and MFS program suggests that it is quite possible that as more online retailers adopt the marketplace or platform model of selling and allow third-party sellers to sell using their platforms, MFS programs could become more ubiquitous.

As one of the first studies in MFS, we focused on the core aspect of MFS in this chapter. Clearly, the current research can be extended in different directions to provide more comprehensive insights into the economics of MFS programs. Clearly, there is a need to empirically establish if a causal relationship exists between MFS and pricing model strategies adopted by a dominant retailer and empirically test our theoretical insights. On the modeling side, one of the key limitations of the current model is that it does not account for features such as expedited shipping and discount in return for slower shipping to defray the consumers' shipping cost. Furthermore, the model and analysis does not consider factors such as network effects and fulfillment mechanisms that could affect the cost and valuation structure. We leave an examination of these factors to future research.

CHAPTER 4

MEMBERSHIP-BASED FREE SHIPPING PROGRAMS: A NEW VEHICLE TO GAIN COMPETITIVE ADVANTAGE FOR ONLINE RETAILERS?

4.1 Introduction

Online retailing is growing three times faster than the overall retail industry (BusinessInsider, 2017). Within online retailing, the platform model of selling in which a retail platform, serving as a marketplace, offers products from third-party sellers for purchase for a commission has expanded significantly in recent years (The Marketing Journal, 2017). For example, about half of the sales of Amazon comes from third-party sellers (Statista, 2017). Other retailers, such as Walmart, have also adopted the platform model for their online operations. In the platform model of selling, the traditional marketing mix elements - product, price, promotion, and place, known as 4Ps (McCarthy, 1968) - may not be as useful to online retailers to gain competitive advantage or achieve differentiation. For instance, under platform selling, the product and pricing decisions are made by the upstream third-party sellers and thus not under the control of online retailers. The locational advantages brick-and-mortar retailers may enjoy generally do not exist for online retailers. Any technology-based value-added services, such as recommender systems, product reviews or seller rating features, and advertising and promotion activities are often easily replicated by competitors, thereby resulting in no long-term competitive edge and perhaps even more intense competition. Recognizing the possible limitations of traditional marketing efforts in online platforms, the marketing community has advocated the need for rethinking the marketing strategies for online retailing (DigitalTonto, 2013).

In recent years, online retail platforms have started competing through shipping programs. Product shipping or delivery is not a major concern for brick-and-mortar firms (except perhaps for large bulky items) and thus it has not been viewed as a significant element for differentiation by these firms. However, shipping is an indispensable part of online retailing for all (both large and small) physical products. In online retailing, shipping cost is the second highest cost component after the product purchase price (Fierce Retail, 2014; Information Age, 2015), and the shipping cost plays a pivotal role in consumers' purchasing decisions and satisfaction (Rosen and Howard, 2000; Sawhney, 1999; Ernst and Young, 1999; Trocchia and Janda, 2003; Janda et al., 2002; Pyke et al., 2001). Recognizing the importance of shipping in consumers' purchase process, online retail platforms have launched several innovations related to product shipping. One such innovation is membership-based free shipping (MFS), examples of which include *Amazon Prime*, *Google Express*, and Walmart.com's *ShippingPass*. Though the specific details such as product eligibility, minimum purchase amount, delivery mode and speed, and additional membership benefits vary across MFS programs, the core feature of these programs is that once a consumer becomes a member of the program by paying an upfront membership fee, products are shipped for free to the member whenever she makes a purchase during the membership period. While the first such program, Amazon Prime, was launched more than a decade ago in 2005, there has been little research on the role of these programs in a competitive setting.

In this research, we examine the impact of MFS-based competition between online retail platforms and seek to answer two important but related research questions:

(1) Does the adoption of MFS program mitigate or intensify online retail platform competition?

(2) Does competition encourage the adoption of the MFS program by online retail platforms?

To address the above questions, we develop a game-theoretic model in which two retail platforms sell (imperfectly) substitutable products from a manufacturer. We examine the equilibrium outcomes when only one or both platforms offer an MFS program. Using the scenario with no MFS program as the benchmark, we evaluate the MFS program's impact on competition between retailers and whether competition encourages or suppresses the adoption of MFS.

We show that the shipping cost plays a critical role in determining the impact of MFS under retail competition. When the shipping cost is high, neither retail platform has an incentive to adopt MFS. When the shipping cost is moderate, one of the platforms adopts MFS but the other one does not. In this asymmetric adoption equilibrium, the platform that does not adopt MFS is worse off and the platform that adopts the MFS is better off compared to the benchmark case where neither adopts the MFS program. When the shipping cost is low, both platforms adopt MFS in the equilibrium. However, the platforms are not necessarily better off when they implement MFS compared to the benchmark case. In particular, when the shipping cost is not too low, both platforms are hurt when they adopt MFS than when they do not, akin to the prisoners' dilemma situation. We identify *price increasing, purchase enhancing, and market expansion* effects of the MFS program for the implementing retailer as primary drivers for our findings.

Furthermore, we show that competing retailers indeed have a higher incentive to adopt MFS than a monopoly retailer. The result is particularly interesting because a monopolist retailer will never adopt MFS if it is not profitable to him, but competing retailers sometimes adopt MFS even if it hurts them. The findings suggest that shipping programs can indeed be a new vehicle for online retailer platforms to compete with each other.

4.2 Related Literature

This study is directly related to the recent but limited literature on free shipping programs. Tan et al. (2015) compare two variants of free shipping programs - (i) free shipping with a minimum order quantity, and (ii) free and expedited shipping with membership - for a monopolistic retailer. They show that expedited free shipping with membership benefits the retailer when the value of expedited shipping to consumers (e.g., savings in holding cost) is sufficiently high, but the program hurts the society. Sun et al. (2017) examine the impact of MFS on sellers, consumers, and the society by comparing the outcomes in the scenario where a monopolistic retail platform implements the MFS program to those in a scenario where the platform does not implement the MFS program. Related to our study, Wen and Lin (2017) study the impact of a MFS program in a competitive setting in which one of two competing retailers adopts the program. They show that the MFS program benefits both retailers by softening the price competition between them. This study considers a single-level channel structure—one without upstream sellers—in which online retailers set the retail prices. In contrast, we consider online retailers that rely on the platform model of selling and therefore allow third-party sellers to set their own retail prices. In that sense, we are interested in isolating MFS's role (by eliminating price competition between retailers) in shaping competition between retailers. Moreover, we allow the purchase frequency to be not only heterogeneous across consumers but also endogenous in our setup. Consequently, we show that free shipping could influence consumers' demand in various ways, which plays a key role in determining the impact of an MFS program on competition, and the impact that competition has on the decision to offer an MFS program.

Our work is also related to the vast literature that examines competition in a two-level channel structure. Some studies in this research stream approach the issue from a manufacturer's perspective and focus on the upstream competition. For instance, Choi (1991) analyzes a channel structure with two competing manufacturers and one intermediary that carries products from both manufactures and shows that the form of demand function is a critical driver of the results. Li et al. (2010) investigate the sourcing strategy of a retailer and the pricing strategies of two suppliers in a supply chain. In contrast, other studies have examined competition between downstream retailers, especially in the context of channel coordination. For example, Yao et al. (2008) investigate the role that revenue-sharing plays in coordinating a supply chain consisting of one manufacturer and two competing retailers and show that a contract of this type achieves a better performance than wholesale prices alone. Zhao et al. (2012) develop various pricing models based on different market structures of substitutable products in a supply chain with one manufacturer and two competitive retailers in the presence of uncertainties regarding consumer demand and manufacturing costs. Kong et al. (2013) examine how revenue-sharing can facilitate information sharing and mitigate the negative effects of information leakage in a channel structure where one upstream supplier serves two competing retailers. Although our paper appears to share similarities with these studies, especially in terms of channel structure with a single manufacturer and two downstream retailers, the research problem we address is fundamentally different from the ones addressed in prior research. In particular, the majority of previous studies consider either price competition or quantity competition between downstream retailers, while we posit the MFS program provides a new approach for retailers to compete with each other under the platform selling business model under which retailer functions are quite different from those in the traditional markets.

4.3 Model

We consider a dominant manufacturer M that sells two variants of a product, each through a different online retailer. The retailers adopt the platform model to sell the products, under which the manufacturer sells its products directly to consumers on the retailers' platforms, and the retailers charge a commission equal to α fraction of the sale price. There are n potential consumers in the market. We consider a time period that consists of N discrete shopping instances. For example, the time period could be a year and each day in the year could be a shopping instance such that the time period has 365 shopping instances. For any consumer, if a consumption need arises at a shopping instance, she visits the marketplace, essentially the retail platforms, to shop for a product that could possibly satisfy her need. A consumer may not face a consumption need, and hence may not shop, in every shopping instance. Furthermore, even when she faces a consumption need, the intensity of the need and her preference can be different in different shopping instances in the sense that she may not assign the same valuation or the same preference for the product offerings from the two retailers at different shopping instances. [1] When she visits the marketplace, a consumer either buys the product that offers the maximum positive surplus, or does not buy any product. The consumer will choose the second option if no product offers a positive surplus to her. In that case, a consumer does not make any purchase even if she shops. In addition, there is a cost associated with shipping the product to the consumer if she buys. A consumer buys a maximum of one unit of one product in a shopping instance. The fixed and marginal production costs are assumed to be zero for both products. In our setup, online platforms focus on value-added services such as those related to consumer convenience rather than traditional selling-related services such as pricing.

Consumer Utility and Consumer Segments. Consumers are heterogeneous in their *shopping frequency* in the sense that some consumers experience a need for shopping and therefore visit retailer platforms more frequently during the time period we consider. We assume σ fraction of consumers are *infrequent shoppers* and the probability that an infrequent shopper visits the retailers in any shopping instance is γ_l. The rest $(1-\sigma)$ fraction of the consumer population are *frequent shoppers* with the corresponding probability of visiting the retailers at any shopping instance being γ_h, where $\gamma_l < \gamma_h$.

The consumer utility for a product at a shopping instance depends on her base valuation, which represents the value she derives from an ideal product that meets her need perfectly, and the misfit cost if the offering does not meet her need perfectly at that instance. A consumer's base valuation and misfit cost can vary across shopping instances. We assume a

[1] There are many reasons that consumers' perceived valuation toward products from the same manufacturer sold through different outlets can be different. First, the manufacturer may create different model numbers for different distributing channels for various purposes such as tracking, production improvement, quality differentiation, and avoiding price-matching (TODAY, 2013; Quora, 2017). Second, the retailers may carry private label products that are manufactured by the third-party manufacturer and sold under each retailer's brand name (The PENNY HOARDER, 2015; Orderhive, 2017). Lastly, online platforms focus on value-added services rather than selling products alone, given that industry experts have argued the benefit of selling on value rather than price (Inc., 2011; CXL, 2017). Therefore, even very similar products sold on different platforms can be perceived dramatically different due to ways of offering.

consumer's base valuation at a shopping instance is low, v_l, with probability θ, or high, v_h, with probability $(1 - \theta)$, where $v_l < v_h$. [2] To model consumer's misfit cost, we assume that the two product offerings are imperfect substitutes. We denote the two product offerings as A and B. We use a typical horizontal product differentiation model for the misfit cost. In particular, we assume that products A and B are located at positions 0 and 1 of a unit line (i.e., at the two ends of the line), respectively. Since product offerings A and B can be different at each shopping instance, a consumer's location at any shopping instance is equally likely to be any point along the line. That is, the consumer location can vary across shopping instances. The distance between a consumer and a product offering measures the degree of misfit of the product offering to the consumer. Notice that when the degree of misfit between a consumer and product offering A is λ, $\lambda \in [0, 1]$, the degree of misfit between the consumer and product offering B is $(1 - \lambda)$. The misfit cost is the degree of misfit times a unit misfit cost t.

The cost to ship the product to the consumer at any shopping instance during the period is s, regardless of who pays for it. This is reasonable in a context where the shipping is done by an independent logistics provider. We examine this context in order to eliminate the impacts of other factors, such as differential shipping costs among platforms or strategic seller gaming behavior related to setting the shipping fee. We consider two scenarios that differ with respect to who bears the shipping cost. In the scenario in which none of the consumers joins the MFS program, they incur the shipping cost. In the scenario in which some consumers join the MFS program, the retailer bears the cost to ship products to members, but non-members bear the shipping cost themselves. Thus, for any shopping

[2] Consumers can potentially shop for different products at different shopping instances. For mathematical convenience and expositional clarity, we assume that base valuation distribution for each product is the same. However, the realized base valuation of a consumer can be different at each shopping instance. Moreover, the presence of correlation between the consumer type and base valuation, such as a frequent shopper having a higher probability of having valuation v_h compared to an infrequent shopper, does not change our results qualitatively.

instance, we can formulate the net utility derived by a consumer, when she has a base valuation v, is located at λ, and bears the shipping cost, from product offerings A and B as follows:

$$U_A = \quad v - \lambda t - s - p_A \ . \tag{4.1}$$

$$U_B = \quad v - (1-\lambda)t - s - p_B \ . \tag{4.2}$$

where p_A and p_B respectively denote the the prices of A and B in the shopping instance. Clearly, if the retailer bears the shipping cost for the consumer, then the shipping cost term will not be part of the net utility expressions given in 4.1 and 4.2.

We assume that a consumer knows her base valuation and her location on the Hotelling line before making the purchase decision if she visits the marketplace. The sellers do not know whether a specific consumer will visit the marketplace at a specific instance, her base valuation nor the consumer's location. However, they know the consumers' shopping frequency distribution, base valuation distribution, and location distribution.

Timing of the Game. The game sequence depends on whether a retailer offers the MFS program. If no retailer offers the MFS program, the manufacturer sets the retail prices p_A and p_B simultaneously at the beginning of each shopping instance (stage 1). Then, consumers that face a consumption need in the shopping instance visit the marketplace and make their purchase decisions, and all parties realize their payoffs (stage 2). The sequence of events when a retailer offers the MFS program has two additional stages that precede the stages present in the scenario without the free shipping program. In the first of these two preceding stages, the retailer announces a membership fee M at the beginning of the period and commits to bearing the member's shipping cost for all shopping instances during the period. In the following stage, consumers decide whether to participate in the MFS program by paying the membership fee at the beginning of the period.

4.4 Analysis of the MFS program

We first derive the sub game perfect equilibrium when there is no MFS program in place, followed by the sub game perfect equilibrium when one or both retailers implement the MFS program. We then compare the key quantities under the two equilibria to assess the impact of the MFS program.

4.4.1 No MFS (Benchmark Case)

When a consumer visits the marketplace, has a base valuation v_h and is located at λ, she will buy product offering A if $U_A > U_B$ and will buy product offering B otherwise. We use the superscript bc to indicate the the benchmark case. Thus, using Equation 4.1, we can verify that she will buy A if $\lambda < \frac{t-p_A^{bc}+p_B^{bc}}{2t}$ and B otherwise. On the other hand, if the same consumer has a base valuation v_l at that shopping instance, then she will buy A if $\lambda < \frac{v_l-p_A^{bc}-s}{t}$, buy B if $\lambda > \frac{v_l-p_B^{bc}-s}{t}$, and will not buy any product otherwise.

In stage 1 of the game, the manufacturer chooses retail prices to maximize its expected profit by solving the following model:

$$\begin{aligned}\arg\max_{p_A^{bc},p_B^{bc}} \ \pi_M^{bc} = \ & (\sigma\gamma_l+(1-\sigma)\gamma_h)(\theta\frac{v_l-p_A^{bc}-s}{t}+(1-\theta)\frac{t-p_A^{bc}+p_B^{bc}}{2t})p_A^{bc}(1-\alpha) \\ & +(\sigma\gamma_l+(1-\sigma)\gamma_h)(\theta\frac{v_l-p_B^{bc}-s}{t}+(1-\theta)\frac{t-p_B^{bc}+p_A^{bc}}{2t})p_B^{bc}(1-\alpha)\ .\end{aligned} \tag{4.3}$$

In Equation 4.3, $(\sigma\gamma_l+(1-\sigma)\gamma_h)$ denotes the expected number of consumers looking to buy a product at a shopping instance, and $(\theta\frac{v_l-p_A^{bc}-s}{t}+(1-\theta)\frac{t-p_A^{bc}+p_B^{bc}}{2t})$ denotes the expected demand for product offering A from a consumer that is looking to buy. The multiplication of these two expressions yields the expected demand for product offering A in any shopping instance. An analogous explanation holds for product offering B. By solving the manufacturer's maximization problem, we obtain the optimal retail prices.

The equilibrium profit for each of the retailers is α fraction of the total sale revenue generated on its platform. Therefore, we can formulate the retailers' expected profits as follows:

$$\pi_A^{bc} = \quad (\sigma\gamma_l + (1-\sigma)\gamma_h)(\theta\frac{v_l - p_A^{bc} - s}{t} + (1-\theta)\frac{t - p_A^{bc} + p_B^{bc}}{2t})p_A^{bc}\alpha \ .$$

$$\pi_B^{bc} = \quad (\sigma\gamma_l + (1-\sigma)\gamma_h)(\theta\frac{v_l - p_B^{bc} - s}{t} + (1-\theta)\frac{t - p_B^{bc} + p_A^{bc}}{2t})p_B^{bc}\alpha \ .$$

Substituting the equilibrium retail prices into the expected profit expressions, we obtain the equilibrium profits for the manufacturer and retailers. We present the equilibrium strategies and highlight the key equilibrium outcomes in the following lemma.

Lemma 8. *The equilibrium retail prices and demand for each retailer in the absence of the MFS program are as follows.*

(a)Retail Prices:

$$p_A^{bc*} = p_B^{bc*} = \quad \frac{t(1-\theta) + 2\theta(v_l - s)}{4\theta} \ . \tag{4.4}$$

(b)Demand for Retailers:

$$D_A^{bc*} = D_B^{bc*} = \quad \frac{(t(1-\theta) + 2\theta(v_l - s))((1-\sigma)\gamma_h + \sigma\gamma_l)}{4t} \ . \tag{4.5}$$

Using Lemma 8, we derive the equilibrium manufacturer profit (π_M^{bc*}) and retailer profits (π_A^{bc*}, π_B^{bc*}). We observe from Lemma 8 that an increase in shipping cost s reduces the retail prices because demand for each retailer decreases in s. Consequently, the manufacturer's and retailers' profits decrease in s.

Next, we characterize the equilibrium outcomes under the two configurations of platform competition: asymmetric implementation—only one of the retailers implements the MFS program and symmetric implementation—both retailers implement the MFS program.

4.4.2 MFS Program under Asymmetric Implementation

In this section, we analyze the case where only one of the platforms implements the MFS program (labeled with superscript ac). Without loss of generality, we assume retailer A offers the MFS program. In the last stage of the game, a consumer's purchase decision depends on her membership status. That is, the decision of a member of the MFS program can vary from that of a non-member because a member does not bear the shipping cost whereas a non-member does. A non-member's purchase decision rule remains the same as that under the benchmark scenario. Specifically, she will buy A if $\lambda < \frac{t-p_A^{ac}+p_B^{ac}}{2t}$ and B otherwise when her base valuation is v_h; and when the base valuation is v_l, she will buy A if $\lambda < \frac{v_l-p_A^{ac}-s}{t}$, buy B if $\lambda > \frac{v_l-p_B^{ac}-s}{t}$, and will not buy any product otherwise. On the other hand, if the consumer is a member, she will buy A if $\lambda < \frac{t+s-p_A^{ac}+p_B^{ac}}{2t}$ and B otherwise when the base valuation is v_h; and when the base valuation is v_l, she will buy A if $\lambda < \frac{v_l-p_A^{ac}}{t}$, buy B if $\lambda > \frac{v_l-p_B^{ac}-s}{t}$, and will not buy any product otherwise.

The expected manufacturer profit depends on the size and the composition of the membership base. There can be only two membership equilibria when at least some consumers join the MFS program: (i) only frequent shoppers sign up as members, or (ii) both frequent and infrequent shoppers sign up as members. Note that only infrequent shoppers joining the program is not possible because if an infrequent shopper finds it beneficial to join the MFS program, a frequent shopper will also find it beneficial. We focus on the first equilibrium as it provides the outcome consistent with our observation that not every consumer joins the MFS program. Therefore, we can formulate the expected manufacturer profit as:

$$\begin{aligned}
\pi_M^{ac} = \quad & (\sigma\gamma_l(\theta\frac{v_l-p_A^{ac}-s}{t}+(1-\theta)\frac{t-p_A^{ac}+p_B^{ac}}{2t}) \\
& +(1-\sigma)\gamma_h(\theta\frac{v_l-p_A^{ac}}{t}+(1-\theta)\frac{t+s-p_A^{ac}+p_B^{ac}}{2t}))p_A^{ac}(1-\alpha) \\
& +(\sigma\gamma_l(\theta\frac{v_l-p_B^{ac}-s}{t}+(1-\theta)\frac{t-p_B^{ac}+p_A^{ac}}{2t}) \\
& +(1-\sigma)\gamma_h(\theta\frac{v_l-p_B^{ac}-s}{t}+(1-\theta)\frac{t-s-p_B^{ac}+p_A^{ac}}{2t}))p_B^{ac}(1-\alpha)\ .
\end{aligned}$$

By solving the manufacturer's maximization problem, we obtain the optimal retail prices under the MFS program.

The retailers' expected profits are formulated as follows:

$$
\begin{aligned}
\pi_A^{ac} = \; & \sigma\gamma_l(\theta\frac{v_l - p_A^{ac} - s}{t} + (1-\theta)\frac{t - p_A^{ac} + p_B^{ac}}{2t})p_A^{ac}\alpha \\
& + (1-\sigma)\gamma_h(\theta\frac{v_l - p_A^{ac}}{t} + (1-\theta)\frac{t + s - p_A^{ac} + p_B^{ac}}{2t})(p_A^{ac}\alpha - s) + MF_A^{ac} \; . \\
\pi_B^{ac} = \; & (\sigma\gamma_l(\theta\frac{v_l - p_B^{ac} - s}{t} + (1-\theta)\frac{t - p_B^{ac} + p_A^{ac}}{2t}) \\
& + (1-\sigma)\gamma_h(\theta\frac{v_l - p_B^{ac} - s}{t} + (1-\theta)\frac{t - s - p_B^{ac} + p_A^{ac}}{2t}))p_B^{ac}\alpha \; .
\end{aligned}
$$

In the preceding stage, a consumer will join the membership program only if her expected (future) surplus gain by participating is not less than the membership fee, M_A^{ac}. Therefore, each consumer forms a rational expectation regarding the retail prices she is going to face when she participates in the MFS program and when she does not, and makes her participation decision based on the expected surplus gain from participation. Retailer A will set the membership fee that is just equal to the difference between a frequent shopper's expected surplus with the membership and without the membership; any fee less than this amount only reduces the retailer's profit without affecting consumers' participation decisions and any fee higher than this amount will result in no one joining the program. Note that an infrequent shopper will not find it valuable to join the program at this fee because her expected surplus gain is strictly less than that of a frequent shopper. For any frequent shopper, the expected surplus with the membership can be calculated as:

$$
\begin{aligned}
& \gamma_h(\int_0^{\frac{v_l - p_A^{ac}}{t}} (\theta(v_l - p_A^{ac} - \lambda t) + (1-\theta)(v_h - p_A^{ac} - \lambda t))d\lambda \\
& + \int_{\frac{v_l - p_A^{ac}}{t}}^{\frac{t + s - p_A^{ac} + p_B^{ac}}{2t}} (1-\theta)(v_h - p_A^{ac} - \lambda t)d\lambda \\
& + \int_0^{\frac{v_l - p_B^{ac} - s}{t}} (\theta(v_l - p_B^{ac} - \lambda t - s) + (1-\theta)(v_h - p_B^{ac} - \lambda t - s))d\lambda \\
& + \int_{\frac{v_l - p_B^{ac} - s}{t}}^{\frac{t - s + p_A^{ac} - p_B^{ac}}{2t}} (1-\theta)(v_h - p_B^{ac} - \lambda t - s)d\lambda) \; .
\end{aligned}
$$

The expected surplus for the same consumer without the membership can be calculated as:

$$\gamma_h(\int_0^{\frac{v_l - p_A^{ac} - s}{t}} (\theta(v_l - p_A^{ac} - \lambda t - s) + (1-\theta)(v_h - p_A^{ac} - \lambda t - s))d\lambda$$
$$+ \int_{\frac{v_l - p_A^{ac} - s}{t}}^{\frac{t - p_A^{ac} + p_B^{ac}}{2t}} (1-\theta)(v_h - p_A^{ac} - \lambda t - s)d\lambda$$
$$+ \int_0^{\frac{v_l - p_B^{ac} - s}{t}} (\theta(v_l - p_B^{ac} - \lambda t - s) + (1-\theta)(v_h - p_B^{ac} - \lambda t - s))d\lambda$$
$$+ \int_{\frac{v_l - p_B^{ac} - s}{t}}^{\frac{t + p_A^{ac} - p_B^{ac}}{2t}} (1-\theta)(v_h - p_B^{ac} - \lambda t - s)d\lambda) \ .$$

Taking the difference of the above two expressions, and substituting the equilibrium prices, we can get the expected surplus gain for a frequent shopper, as well as the equilibrium membership fee M_A^{ac*}.

Lemma 9. *If one of the retailers implements the MFS program, the equilibrium membership fee, retail prices and demand for each retailer are as follows:*

(a)Membership Fee:

$$M_A^{ac*} = \frac{s\gamma_h((1-\sigma)(t(1-\theta) + 2\theta(v_l - s))\gamma_h + \sigma((t+s)(1-\theta) + 2\theta v_l)\gamma_l)}{4t(1-\sigma)\gamma_h + 4t\sigma\gamma_l} \ .$$

(b)Retail Prices:

$$p_A^{ac*} = \frac{t(1-\theta) + 2\theta(v_l - s)}{4\theta} + \frac{s(1-\sigma)\gamma_h}{2(1-\sigma)\gamma_h + 2\sigma\gamma_l} \ . \tag{4.6}$$

$$p_B^{ac*} = \frac{t(1-\theta) + 2\theta(v_l - s)}{4\theta} \ . \tag{4.7}$$

(b)Demands

$$D_A^{ac*} = \frac{(1-\sigma)((t+s)(1-\theta) + 2\theta v_l)\gamma_h + \sigma(t(1-\theta) + 2\theta(v_l - s))\gamma_l}{4t} \ . \tag{4.8}$$

$$D_B^{ac*} = \frac{(1-\sigma)(t - s - \theta(t+s) + 2\theta v_l)\gamma_h + \sigma(t(1-\theta) + 2\theta(v_l - s))\gamma_l}{4t} \ . \tag{4.9}$$

Using Lemma 9, we also derive the equilibrium manufacturer profit (π_M^{ac*}) and retailer profits (π_A^{ac*}, π_B^{ac*}). By comparing Lemma 8 with Lemma 9, we identify some interesting similarities and differences between the equilibrium in which one of the retailers implements the MFS program and the one in which neither implements the program. Similar to Lemma 8, an increase in shipping cost s reduces retail prices in both equilibria because the manufacturer will expect a decrease in the overall demand. Note that although the demand for retailer B decreases with the shipping cost, the demand for retailer A does not necessarily follow the same pattern. This is because frequent shoppers, as they join the MFS program, do not pay the shipping cost. Higher shipping cost results in higher potential savings for the members, and therefore the demand from this consumer segment can increase with the shipping cost. Meanwhile, asymmetric implementation gives retailer A an advantage over retailer B in the competition for frequent shoppers as members, which eventually leads to potential increase of demand for retailer A. Finally, the membership fee is increasing in s as the surplus gain of join the MFS program clearly increases when shipping cost increases.

Proposition 18. *In the case of asymmetric implementation, retailer B's profit is lower with the MFS program than without, i.e.,* $\pi_B^{ac*} < \pi_B^{bc*}$*; however, retailer A's profit is higher with the MFS program than without, i.e.,* $\pi_A^{ac*} > \pi_A^{bc*}$*, if and only if* $s < \overline{s}^c$ *where*

$$\overline{s}^c = \frac{\alpha(1+3\theta)(t(1-\theta)+2\theta v_l)((1-\sigma)\gamma_h+\sigma\gamma_l)}{4\theta(1+\theta+\alpha\theta)(1-\sigma)\gamma_h+2\theta(2+\alpha+2\theta+3\alpha\theta)\sigma\gamma_l}\,. \tag{4.10}$$

Proposition 18 reveals that the MFS program in the case of asymmetric implementation can benefit the implementing retailer, but always hurts the other retailer. To understand why retailer B is worse off under such circumstance, we look at how the MFS program impacts the factors that are directly related to its profitability–price and demand. On one hand, we find that the implementation of MFS program by retailer A does not affect the price for retailer B, although it increases the price for retailer A. This finding is interesting because intuitively a price increase on one platform should motivate the manufacturer to increase price on the other platform as well. The intuition turns out to be incorrect. The price increase on platform A is to be expected because the MFS program reduces the overall shipping cost burden borne by members on this platform, and this increases the potential demand and thus allows the manufacturer to charge a higher price for consumers on the implementing platform, compared to the benchmark case. However, without the MFS program, the optimal price on the other platform remains the same as in the benchmark case because the costs to buy from this platform remain the same for consumers in the benchmark and asymmetric implementation cases. Yet, the overall demand for retailer B decreases when A implements the MFS program. This finding is also counter-intuitive, given the fact that the price in retailer B remains the same. To understand why it is the case, we look at the demand for retailer B from the two consumer segments separately. The non-members buy more frequently from retailer B because the price in retailer B is lower than that in retailer A, i.e., $p_A^{ac*} > p_B^{ac*}$. Therefore, retailer B's demand from infrequent shoppers as non-members increases compared to the benchmark case. In contrast, frequent shoppers, as members of retailer A's MFS program, buy more frequently from retailer A. This is because, although the product price in retailer B is lower, the frequent shoppers' overall purchase cost including the shipping cost they have to pay is lower when they purchase from retailer A than from B, i.e., $p_A^{ac*} < p_B^{ac*} + s$. Therefore, retailer B's demand from frequent shoppers as members decreases. Collectively, the negative effect from the frequent shopper segment dominates the positive effect from the infrequent shopper segment, leading to a decrease in the overall demand for retailer B. As a consequence, retailer B's profit goes down when retailer A implements the MFS program. In effect, a reduced demand with no change in price (or commission) results in a lower profit for retailer B when retailer A implements the MFS program, compared to when neither implements the program.

We decompose retailer A's profit in the case of asymmetric implementation of MFS program into three components: retailer A's commission revenue from sales (**CR**) which equals demand times profit margin, where profit margin is defined as retail price times commission rate; membership fee paid by subscribing consumers (**MF**); and absorbed shipping cost (**SC**). We note that in the absence of the MFS program, retailer A's profit comprises of CR only, which is equal to π_A^{bc*}.

By comparing Equations 4.6 with 4.4, we find that the price in retailer A is higher under the MFS program compared to the benchmark. Essentially, the MFS program allows a higher price to be charged on the platform of retailer A. We denote this impact of MFS on the retail price as the *price increasing* effect. The magnitude of the price increasing effect under the MFS program can be calculated as:

$$\Delta p_A^{abc*} = p_A^{ac*} - p_A^{bc*} = \frac{s(1-\sigma)\gamma_h}{2((1-\sigma)\gamma_h + \sigma\gamma_l)} \ .$$

By comparing Equations 4.8 with 4.5, we find that the overall demand for retailer A is higher under the MFS program compared to the benchmark. We quantify the two factors contributing to this effect under the two valuation scenarios separately. First, in the low valuation scenario (v_l), frequent shoppers as members tend to buy more with the MFS program, because the magnitude of price increase is only a fraction of their savings in shipping cost, resulting in a net reduction in their overall purchase cost from retailer A. In contrast, infrequent shoppers as non-members face a higher price to buy from retailer A and thus purchase less accordingly. Although the MFS program has opposite effects on the purchasing frequencies from members and non-members when their valuation is low, its impact on the overall purchase frequency is positive. Essentially, consumers as a whole buy more in the presence of the MFS program than in its absence. We denote this impact of MFS on the overall purchasing frequency as the *purchase enhancing* effect, which can be calculates as follows:

$$\begin{aligned}&[((1-\sigma)\gamma_h\frac{v_l - p_A^{ac*}}{t} + \sigma\gamma_l\frac{v_l - p_A^{ac*} - s}{t}) \\ &-((1-\sigma)\gamma_h\frac{v_l - p_A^{bc*} - s}{t} + \sigma\gamma_l\frac{v_l - p_A^{bc*} - s}{t})]\theta = \frac{s\theta(1-\sigma)\gamma_h}{2t} \ .\end{aligned}$$

Second, in the high valuation scenario (v_h), frequent shoppers as members buy more from retailer A than from retailer B, because their overall purchase cost is lower when they buy from retailer A, i.e., $p_A^{ac*} < p_B^{ac*} + s$. On the contrary, infrequent shoppers as non-members become more likely to buy from retailer B than from retailer A, as their purchase cost is lower from retailer B, i.e., $p_A^{ac*} > p_B^{ac*}$. Thus, because of the MFS program, retailer A gains some market share from the frequent shopper consumer segment, but loses some market share from the infrequent shopper consumer segment. However, the impact of the MFS program on retailer A's overall market share is actually positive. In other words, consumers shift their purchases toward retailer A in the high valuation market segment in the presence of the MFS program. We denote this impact of MFS program on the market shift as the *market expanding* effect, and its magnitude can be calculated as follows:

$$[((1-\sigma)\gamma_h \frac{t+s-p_A^{ac*}+p_B^{ac*}}{2t} + \sigma\gamma_l \frac{t-p_A^{ac*}+p_B^{ac*}}{2t}) \\ -((1-\sigma)\gamma_h \frac{t-p_A^{bc*}+p_B^{bc*}}{2t} + \sigma\gamma_l \frac{t-p_A^{bc*}+p_B^{bc*}}{2t})](1-\theta) = \frac{s(1-\theta)(1-\sigma)\gamma_h}{4t} \;.$$

Both the purchase enhancing effect and the market expanding effect contribute positively to the demand for retailer A. Together with the price increasing effect mentioned above, CR is higher under the MFS program compared to the benchmark.

In addition, retailer A also enjoys revenue in the form of membership fee, MF, when it implements the MFS program, but the gain from MF comes at the expense of shipping cost, SC. Further analysis on the relationship between MF and SC shows that under the MFS program, for retailer A, the revenue earned from membership fee is less than the shipping cost burden; that is, $MF_A^{a*} < SC_A^{a*}$. This interesting result reveals that retailer A ends up subsidizing the members' shipping cost by charging a membership fee that is less than the expected cost of shipping to each member.

Combining the effects of the MFS program on the various components that make up retailer A's profit, we find that the MFS program benefits retailer A only when the increase in commission revenue, $CR_A^{ac*} - \pi_A^{bc*}$, compensates the subsidy in shipping cost to members, $SC_A^{ac*} - MF_A^{ac*}$. Further analysis shows the following dynamics:

$$\begin{aligned}
\frac{\partial (CR_A^{ac*} - \pi_A^{bc*})}{\partial s} &= \frac{\alpha(1+3\theta)(1-\sigma)(t(1-\theta)+2\theta v_l)\gamma_h}{16t\theta} \\
&\quad - \frac{\alpha(1-\sigma)\gamma_h(2\theta(1-\sigma)\gamma_h + (1+3\theta)\sigma\gamma_l)}{4t((1-\sigma)\gamma_h + \sigma\gamma_l)} s \; . \\
\frac{\partial (SC_A^{ac*} - MF_A^{ac*})}{\partial s} &= \frac{(1+\theta)(1-\sigma)\gamma_h}{2t} s \; .
\end{aligned}$$

First we note that the MFS program has no effect if the shipping is free, i.e., $s = 0$. When shipping is not free, we can readily observe from the above equations that the shipping subsidy offered by retailer A is increasing in s in a convex fashion. On the other hand, the benefit from the program in the form of increased commission revenue is increasing in s in a concave fashion. Therefore, there exists a shipping cost at which retailer A's profit gain from the MFS program reaches its maximum and starts to decline thereafter. Eventually, when the shipping cost exceeds the threshold value specified in Proposition 18, the burden from shipping subsidy outweighs the increased commission revenue, and then makes it unprofitable for retailer A to implement such a program.

4.4.3 MFS Program under Symmetric Implementation

In this sub section, we analyze the case where both platforms implement the MFS program (labeled with superscript sc). Similar to the previous case, in the last stage of the game, a consumer's purchase decision depends on her membership status. A non-member's purchase decision rule remains the same as that under the benchmark scenario. Specifically, she will buy A if $\lambda < \frac{t - p_A^{sc} + p_B^{sc}}{2t}$ and B otherwise when her base valuation is v_h; and when the base valuation is v_l, she will buy A if $\lambda < \frac{v_l - p_A^{sc} - s}{t}$, buy B if $\lambda > \frac{v_l - p_B^{sc} - s}{t}$, and will not buy any product otherwise. On the other hand, if the consumer is a member, she will buy A if $\lambda < \frac{t - p_A^{sc} + p_B^{sc}}{2t}$ and B otherwise when the base valuation is v_h; and when the base valuation is v_l, she will buy A if $\lambda < \frac{v_l - p_A^{sc}}{t}$, buy B if $\lambda > \frac{v_l - p_B^{sc}}{t}$, and will not buy any product otherwise.

Analogous to the asymmetric implementation case, we can write the expected manufacturer profit under the symmetric implementation case as:

$$
\begin{aligned}
\pi_M^{sc} = \ & (\sigma\gamma_l(\theta\frac{v_l - p_A^{sc} - s}{t} + (1-\theta)\frac{t - p_A^{sc} + p_B^{sc}}{2t}) \\
& +(1-\sigma)\gamma_h(\theta\frac{v_l - p_A^{sc}}{t} + (1-\theta)\frac{t - p_A^{sc} + p_B^{sc}}{2t}))p_A^{sc}(1-\alpha) \\
& +(\sigma\gamma_l(\theta\frac{v_l - p_B^{sc} - s}{t} + (1-\theta)\frac{t - p_B^{sc} + p_A^{s}}{2t}) \\
& +(1-\sigma)\gamma_h(\theta\frac{v_l - p_B^{sc}}{t} + (1-\theta)\frac{t - p_B^{sc} + p_A^{sc}}{2t}))p_B^{sc}(1-\alpha)\ .
\end{aligned}
$$

By solving the manufacturer's maximization problem, we obtain the optimal retail prices under the MFS program.

The retailer's expected profits are formulated as follows:

$$
\begin{aligned}
\pi_A^{sc} = \ & \sigma\gamma_l(\theta\frac{v_l - p_A^{sc} - s}{t} + (1-\theta)\frac{t - p_A^{sc} + p_B^{sc}}{2t})p_A^{sc}\alpha \\
& +(1-\sigma)\gamma_h(\theta\frac{v_l - p_A^{sc}}{t} + (1-\theta)\frac{t - p_A^{sc} + p_B^{sc}}{2t})(p_A^{sc}\alpha - s) + MF_A^{sc}\ . \\
\pi_B^{sc} = \ & \sigma\gamma_l(\theta\frac{v_l - p_B^{sc} - s}{t} + (1-\theta)\frac{t - p_B^{sc} + p_A^{sc}}{2t})p_B^{sc}\alpha \\
& +(1-\sigma)\gamma_h(\theta\frac{v_l - p_B^{sc}}{t} + (1-\theta)\frac{t - p_B^{sc} + p_A^{sc}}{2t})(p_B^{sc}\alpha - s) + MF_B^{sc}\ .
\end{aligned}
$$

In the preceding stage, a consumer will join a membership program only if her expected (future) surplus gain by participating in it is not less than the membership fee, M_A^{sc} or M_B^{sc}. For any frequent shopper, the expected surplus with the membership can be calculated as:

$$
\begin{aligned}
& \gamma_h(\int_0^{\frac{v_l - p_A^{sc}}{t}} (\theta(v_l - p_A^{sc} - \lambda t) + (1-\theta)(v_h - p_A^{sc} - \lambda t))d\lambda \\
& + \int_{\frac{v_l - p_A^{sc}}{t}}^{\frac{t - p_A^{sc} + p_B^{sc}}{2t}} (1-\theta)(v_h - p_A^{sc} - \lambda t)d\lambda \\
& + \int_0^{\frac{v_l - p_B^{sc}}{t}} (\theta(v_l - p_B^{sc} - \lambda t) + (1-\theta)(v_h - p_B^{sc} - \lambda t))d\lambda \\
& + \int_{\frac{v_l - p_B^{sc}}{t}}^{\frac{t + p_A^{sc} - p_B^{sc}}{2t}} (1-\theta)(v_h - p_B^{sc} - \lambda t)d\lambda)\ .
\end{aligned}
$$

The expected surplus for the same consumer without the membership can be calculated as:

$$\gamma_h(\int_0^{\frac{v_l-p_A^{sc}-s}{t}}(\theta(v_l-p_A^{sc}-\lambda t-s)+(1-\theta)(v_h-p_A^{sc}-\lambda t-s))d\lambda$$
$$+\int_{\frac{v_l-p_A^{sc}-s}{t}}^{\frac{t-s-p_A^{sc}+p_B^{sc}}{2t}}(1-\theta)(v_h-p_A^{sc}-\lambda t-s)d\lambda$$
$$+\int_0^{\frac{v_l-p_B^{sc}}{t}}(\theta(v_l-p_B^{sc}-\lambda t)+(1-\theta)(v_h-p_B^{sc}-\lambda t))d\lambda$$
$$+\int_{\frac{v_l-p_B^{sc}}{t}}^{\frac{t+s+p_A^{sc}-p_B^{sc}}{2t}}(1-\theta)(v_h-p_B^{sc}-\lambda t)d\lambda)\ .$$

Taking the difference of the above two expressions, and substituting the equilibrium prices, we can get the expected surplus gain for a frequent shopper by joining retailer A's MFS program, as well as its equilibrium membership fee M_A^{sc*}, as in the asymmetric implementation case. The derivation of retailer B's equilibrium membership fee M_B^{sc*} follows a similar approach.

Lemma 10. *If both retailers implement the MFS program, the equilibrium membership fee, retail prices and demand for each retailer are as follows:*

(a)Membership Fee:

$$M_A^{sc*}=M_B^{sc*}=\frac{s\gamma_h((1-\sigma)(t-s-\theta(t+s)+2\theta v_l)\gamma_h+\sigma((t-s)(1-\theta)+2\theta v_l)\gamma_l)}{4t((1-\sigma)\gamma_h+\sigma\gamma_l)}\ .$$

(b)Retail Prices:

$$p_A^{sc*}=p_B^{sc*}=\frac{t(1-\theta)+2\theta(v_l-s)}{4\theta}+\frac{s(1-\sigma)\gamma_h}{2(1-\sigma)\gamma_h+2\sigma\gamma_l}\ . \tag{4.11}$$

(b)Demands for Retailers:

$$D_A^{sc*}=D_B^{sc*}=\frac{(1-\sigma)(t(1-\theta)+2\theta v_l)\gamma_h+\sigma(t(1-\theta)+2\theta(v_l-s))\gamma_l}{4t}\ . \tag{4.12}$$

Using Lemma 10, we derive the equilibrium manufacturer profit (π_M^{sc*}) and retailer profit (π_A^{sc*},π_B^{sc*}). It is intuitive that an increase in the shipping cost s reduces the equilibrium retail prices because the manufacturer will expect a smaller overall demand. Because of the symmetry between the retailers, demand for each retailer decreases with an increase in the shipping cost. Lastly, the membership fee increases in s as the loss in surplus a frequent shopper will have to incur if she does not join either program will increase with shipping cost.

Proposition 19. *In the case of symmetric implementation, retailer A and B's profits are higher with the MFS program than without, i.e.,* $\pi_A^{sc*} > \pi_A^{bc*}$ *and* $\pi_B^{sc*} > \pi_B^{bc*}$*, if and only if* $s < \widehat{s}^c$ *where*

$$\widehat{s}^c = \frac{\alpha(t(1-\theta)+2\theta v_l)((1-\sigma)\gamma_h+\sigma\gamma_l)}{(1+\theta+\alpha\theta)(1-\sigma)\gamma_h+(1+\theta+2\alpha\theta)\sigma\gamma_l} \ .$$

A comparison of Proposition 18 and Proposition 19 shows that the impact of the MFS program on the implementing retailer's profit is qualitatively similar in the case of asymmetric implementation and in the case of symmetric implementation. An examination of the impact of MFS model in the two cases reveals that while some of the underlying drivers of the MFS program's impact are same, there are also important differences between the two cases. First, we note that retailer B, when it also implements the MFS program, can benefit from it as well. Both the retail price and demand for retailer B are higher compared to the benchmark scenario, which results in a net increase in its commission revenue. By the logic of Proposition 1, we know that when the shipping cost is not too high so that the shipping subsidy burden can be offset by the increased commission revenue, each retailer can be better off in the presence of MFS than in its absence if they both choose to implement the program.

By comparing Equations 4.11 and 4.4, we find that the retail prices are higher under the MFS program compared to the benchmark. Therefore, the price increasing effect identified previously is still present in this case, and its magnitude can be calculated as follows:

$$\Delta p_i^{sbc*} = p_i^{sc*} - p_i^{bc*} = \frac{s(1-\sigma)\gamma_h}{2((1-\sigma)\gamma_h+\sigma\gamma_l)} \ .$$

As discussed above, retailer A's overall demand is also higher than the benchmark scenario; and the driving forces are the exactly the same as those in the case of asymmetric implementation. Thus, we can quantify the two contributing factors to the demand increase under both market scenarios. On one hand, in the low valuation scenario (v_l), frequent shoppers as members buy more with the MFS program, because the magnitude of price increase is only a fraction of their savings in shipping cost, resulting in a net reduction in their overall purchase cost from both retailers. In contrast, infrequent shoppers as non-members face a higher price to buy from each retailer and thus purchase less frequently. Nevertheless, the MFS program's impact on the overall purchase frequency in the low valuation scenario is positive, so the purchase enhancing effect remains to be effective. Its magnitude can be calculated as follows:

$$\begin{aligned}&[((1-\sigma)\gamma_h\frac{v_l-p_A^{sc*}}{t}+\sigma\gamma_l\frac{v_l-p_A^{sc*}-s}{t})\\&-((1-\sigma)\gamma_h\frac{v_l-p_A^{bc*}-s}{t}+\sigma\gamma_l\frac{v_l-p_A^{bc*}-s}{t})]\theta=\frac{s\theta(1-\sigma)\gamma_h}{2t}\ .\end{aligned}$$

On the other hand, in the high valuation scenario (v_h), because both retailers implement the MFS program and the manufacturer charges the same equilibrium retail price, no retailer has an advantage over the other in attracting consumers, regardless of their membership status. In that case, both frequent shoppers and infrequent shoppers are evenly split between the two retail platforms, as in the benchmark case. As a result, the market expanding effect is absent in the symmetric implementation case.

4.5 Competition via MFS program

In the previous sections, we analyzed the equilibrium outcomes under two cases–asymmetric implementation and symmetric implementation. To understand how retailing platforms compete with each other through the MFS program, in this section, we add a preceding stage to the game in which the two retailers decide whether or not to implement the MFS program simultaneously. Denote the strategy of implementing the MFS program as **M** and the strategy of not implementing the MFS program as **N**, there could be three possible combinations—NN, MN, and MM.[3] Figure 4.1 depicts these strategies. Based on these strategies, we derive which combination will be observed in the equilibrium given the values of parameters.

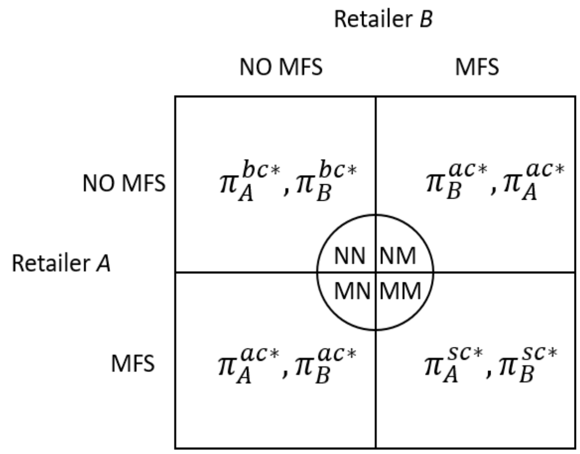

Figure 4.1: Strategy Matrix

Proposition 20. *If the two retailers choose whether or not to implement the MFS program at the beginning of the game simultaneously, the equilibrium is (1) NN if and only if $s > \overline{s}^c$; (2) MN if and only if $\underline{s}^c < s < \overline{s}^c$; (3) MM if and only if $s < \underline{s}^c$, where*

$$\underline{s}^c = \frac{\alpha(1+3\theta)(t(1-\theta)+2\theta v_l)((1-\sigma)\gamma_h+\sigma\gamma_l)}{2(2+\alpha)\theta(1+\theta)(1-\sigma)\gamma_h+2\theta(2+\alpha+2\theta+3\alpha\theta)\sigma\gamma_l}.$$

Proposition 20 characterizes the equilibria under different conditions. First, we find that when shipping cost s is high, neither retailer would implement the MFS program, because the shipping subsidy burden far more outweighs the increase in the commission revenue, consistent with Proposition 18. Second, when shipping cost is at intermediate levels, only one of the retailers implements the MFS program. This is because the market expansion

[3]Retailer A's strategy is on the left and retailer B's strategy is on the right; NM is the same as MN due to symmetry.

effect—a key factor contributing to the profitability of the MFS program—is present only in the asymmetric implementation case but is absent in the symmetric implementation case. Consequently, the MFS program tends to be less profitable to a retailer if its competitor chooses to implement such a program as well. Lastly, both retailers choose to implement the MFS program if shipping cost is low, as implementing the MFS program for each platform is a dominant strategy regardless of the other retailer's decision. Hence, a low shipping cost tends to encourage more retailers to compete in the realm of MFS.

Proposition 21. *Suppose MM is the equilibrium, the two retailers are both better off with the MFS program than without if an only if $s < \widehat{s}^c$; otherwise, if $\widehat{s}^c < s < \underline{s}^c$, i.e., although implementing the MFS program is a dominant strategy for both retailers, they may end up being worse off compared to the benchmark scenario.*

The result from Proposition 21 is particularly interesting given the possible equilibrium outcomes we have discussed above. Proposition 20 implies that when shipping cost is low, both retailers choose to implement the MFS program. Their profits, however, are not necessarily positively affected by the implementation of MFS. Specifically, only when shipping cost is low enough, the retailers are better off with MFS than without MFS; otherwise, both of them end up losing compared with the benchmark scenario. This is because though the retailer who implements the MFS in the asymmetric case can benefit from the market expanding effect, in addition to the price increasing effect and purchase enhancing effect, the market expanding effect itself is essentially a double-edged sword. In the scenario in which valuations are high (v_h), the shift of market share is a zero-sum game, that is, the gain of one retailer comes at the loss of the other retailer. In that case, while retailer A is gaining some market share leveraging on the price advantage afforded by MFS, retailer B is losing its market share. This forces retailer B to take back its lost territory by also implementing the MFS so as to compete with retailer A. Under such a circumstance, retailer B is already worse off compared to the benchmark scenario, and the only decision retailer B has to make regarding offering the MFS program is determined by whether MFS is able to give itself an edge on competition and improve its current level profitability. As shown by Proposition 3, retailer B will choose to fight back when the shipping cost is low; however, this practice may make both retailers end up losing compared with the benchmark scenario if shipping cost is not low enough. In other words, when shipping cost is low but not too low, the profitability of the MFS program in the case of symmetric implementation is not high enough to support the shipping cost burden. Then, although implementing such program is at the best interest of both retailers due to competition, none of them can actually be better off, thereby resulting in a prisoner's dilemma situation.

4.6 MFS in a Monopolist Retailer Market

The previous section explores how the MFS program affects retailers' profitability and thus their adoption decisions in a competitive market. To sharpen our understanding of the role competition plays in the effectiveness of the MFS program, we consider a monopolistic market where a single retailer dominates instead of two retailers competing with each other. The comparison between this scenario and the previous one provides us additional insights into the interaction between MFS and competition.

We consider a single online retailer R that carries products from the manufacturer M. Retailer R operates two platforms A and B, which are equivalent to platforms from the two retailers in the competition scenario, everything else remains the same as the base model. Since the manufacturer sets the retail prices, the pricing decisions will be the same as before. The only distinction is that retailer R's profit now equals the summation of profits of retailers A and B in the previous scenario. We summarize the key equilibrium outcomes in the following proposition.

Proposition 22. *The monopolist retailer's decision regarding the implementation of the MFS program is: (i) No MFS if and only if $s > \overline{s}^m$; (ii) asymmetric implementation if and only if $\underline{s}^m < s < \overline{s}^m$; (iii) symmetric implementation if and only if $s < \underline{s}^m$, where*

$$\overline{s}^m = \frac{2\alpha(t(1-\theta) + 2\theta v_l)((1-\sigma)\gamma_h + \sigma\gamma_l)}{(2-\alpha+2\theta+3\alpha\theta)(1-\sigma)\gamma_h + 2(1+\theta+2\alpha\theta)\sigma\gamma_l}.$$

$$\underline{s}^m = \frac{2\alpha(t(1-\theta) + 2\theta v_l)((1-\sigma)\gamma_h + \sigma\gamma_l)}{(2+\alpha)(1+\theta)(1-\sigma)\gamma_h + 2(1+\theta+2\alpha\theta)\sigma\gamma_l}.$$

The same logic that explains Proposition 20 follows through here. In principle, the MFS program is profitable only when the shipping cost is not too high. The monopolistic retailer would choose to implement the MFS program on only one of two platforms if shipping cost is at the intermediate levels, because a symmetric implementation in such case would be too costly for the program to be profitable. If shipping cost is low enough, the retailer would implement the MFS program on both platforms to reap the full benefit of MFS at affordable expenses in terms of shipping subsidy.

Proposition 23. *If $\overline{s}^m < s < \overline{s}^c$, competing retailers adopt MFS but a monopolist retailer does not.*

Proposition 23 reveals a very interesting phenomenon, that is, the MFS program is feasible in a larger region of the parameter space in the competition scenario than in the monopoly scenario. This is because the MFS program is profitable when the shipping cost is not too high and asymmetric implementation is chosen in both the competition and monopoly scenarios. In addition to the price increasing effect and purchase enhancing effect of the MFS program, retailer A also benefits from the market expanding effect in such case, though, at the expense of retailer B's loss in market share. Essentially, this market expanding effect offers further motivation for retailer A to implement the MFS program. On the contrary, in the monopoly scenario, retailer R could not benefit from the market expanding effect even if it adopts the asymmetric implementation. This is because the gain of market share on one platform comes at the cost of reduction in the market share on the other platform. Hence, a monopolistic retailer's incentive to implement the MFS program is lower compared to the competing retailers. In addition, we know from Proposition 21 that both retailers are worse off with the MFS program if $\widehat{s}^c < s < \underline{s}^c$, when the symmetric implementation is chosen and fierce competition between the retailers makes both retailers worse off. In contrast, in the monopoly scenario, the retailer will choose the symmetric implementation only if it achieves higher profit than both the benchmark and the asymmetric implementation, which guarantees an increase in its profit. As a result, the MFS program, when implemented symmetrically, is always profitable in the monopoly scenario but may not be profitable in the competitive scenario.

4.7 Conclusion and Implications

In this chapter, we examine the potential role of membership-based free shipping (MFS) programs in facilitating competitive advantage in online retailing. We show that the MFS benefits the retailers that implement the program as long as shipping cost is not very high. This is because the MFS program allows the implementing platform not only to increase demand among existing consumers but also to expand its consumer base. Plus, the retailer price on the implementing platform paid by consumers increases after adopting the MFS program. All three effects contribute to a higher commission revenue for the implementing platform. However, our results reveal that the implementing platform effectively subsidizes its members as their membership fee does not cover the cost of shipping burden. As a result, the implementing platform may not benefit from the MFS program unless shipping cost is low enough. Furthermore, we show that the retailer platform that does not implement the program is always hurt when its competitor offers the MFS program. This is because the non-implementing platform loses some of its consumers as they sign up for membership in MFS offered by the competing platform. This issue gets more problematic as the third party seller does not change the retail price on the non-implementing platform in response to an increase in the retail price on the implementing platform. Hence, the commission revenue of the non-implementing platform, which is the only source of revenue, drops after the competing platform offers the MFS program. When both retail platforms offer their own MFS programs, our results reveal that both platforms can gain from their implementations. This is because the demand enhancement and the price increase effects can be significant enough to compensate the shipping subsidy burden even if there is no market expansion effect, unlike the asymmetric implementation scenario. When the retailer platforms choose to decide whether to offer the MFS program simultaneously, we show that both platforms adopt the program if shipping cost is sufficiently low; no platform adopts the program if shipping cost is sufficiently high; and only one platform adopts the program if shipping cost is neither too low nor too high. Although adopting the MFS program can be a dominant strategy for both platforms when shipping cost is low, surprisingly, both platform can be worse of with the MFS program compared to the scenario in which neither platform adopts the program.

Our findings regarding the strategic impacts of the MFS program in a competitive market contribute to a deeper understanding of the role of the program and provide important managerial insights. First, gaining competitive advantage in online retailing via MFS may not be possible. Retail platforms may offer an MFS program even if this decision can hurt their bottom line. Hence, competitive pressures can force them to adopt the program. Second, adopting the MFS program does not necessarily intensify the price competition. In fact, retail price of each adopting platform goes up after the implementation of the program. However, increased commission revenue through higher retail prices may not be sufficient for the platform to benefit from the program. Third, even though the implementing platform benefits from the MFS program, the platform effectively subsidizes the shipping costs of its members even after accounting for the membership dues. Therefore, assessing the success of the MFS program to each platform solely based on the shipping cost and the membership fee can be misleading; an assessment that ignores the demand enhancement and price increasing effects and compares only the shipping cost and membership fee may likely show that the program is a failure even though the program is profitable overall.

CHAPTER 5

CONCLUSION

This dissertation strives to study the trending phenomenon of membership-based free shipping programs (MFS), which have been commonly adopted by online retailers to couple with the shipping problem in such context. In spite of the popularity of such programs and the exemplary success of Amazon Prime, there has been a lack of clarity about MFS among academics and practitioners. By using game-theoretical modelling, we contribute to a better understanding of the economics of membership-based free shipping programs from various aspects and provide a foundation to better leverage such programs in the online retailing industry.

In the first chapter, we examine the strategic implications of MFS. We find that assessing the success of the MFS program to the platform solely based on the shipping cost and the membership fee can be misleading. Interestingly, a low shipping cost is neither a prerequisite nor a guarantee for the platform to benefit from the MFS program. Moreover, concluding that members of the MFS program gain from it just because they realize more savings in shipping cost than the membership fee they pay is also incorrect. Meanwhile, when individual consumers make participation decisions based on their own self interests, the platform can exploit the prisoners' dilemma faced by consumers when the MFS program is implemented. Despite the stimulation of consumer demand by the MFS program, more demand could hurt the society because consumer surplus from the additional demand could be offset by excessive shipping cost required to satisfy the extra demand. That is, the MFS program may not be social welfare enhancing. Taken together, the implications suggest that the the MFS program is generally a vehicle for the platform to benefit at consumers' and possibly the society's expense.

In the second chapter, we identify the strategic relationship between online retailer's consumer-side MFS adoption and its supplier-side business model shift. Our results show that the retailer's profit gain from the MFS program is higher under the agency model than the wholesale model and the retailer finds it profitable to implement the MFS program in a larger region of the parameter space under the agency model than under the wholesale model. Moreover, consumers as a whole are worse off with the MFS program under the wholesale model but they can be better off under agency model. While the society is always worse off with the MFS program under the wholesale model, it is better off with the agency model if the societal cost is not too high. The results demonstrate that viewing the MFS program as a simple shipping cost transfer mechanism would fail to uncover the intricate strategic impacts of the program and could lead to incorrect conclusions about the program's impacts on various stakeholders. The primary implication of these findings is that they posit a potential strategic relationship between the adoption of the consumer-side MFS program and the shift in the supplier-side pricing model to agency.

In the last chapter, we focus on MFS in the context of platform competition. Our findings suggest that adopting the MFS program does not necessarily intensify the price competition. In fact, retail price of each adopting platform goes up after the implementation of the program. However, increased commission revenue through higher retail prices may not be sufficient for the platform to benefit from the MFS program. As a result, gaining competitive advantage in online retailing via MFS may not be possible. Retail platforms may offer an MFS program even if this decision can hurt their bottom line. Hence, competitive pressures can force them to adopt the program, resulting in a prisoner's dilemma situation. Our analysis also shows that MFS is more likely to appear in the presence of competition, which provides a reasonable explanation to firms' growing interest toward and the striking popularity of MFS.

APPENDIX A

SUPPLEMENTAL MATERIAL FOR CHAPTER 2

Proof of Lemma 1 The first-order conditions for sellers' optimization problems in stage 4 are given by the following:

$$\frac{\partial \pi_A^b}{\partial p_A^b} = \frac{(\sigma\gamma_l + (1-\sigma)\gamma_h)[t + \theta(2v_l - 2s - t) - 2(1+\theta)p_A^b + (1-\theta)p_B^b]p_A^b(1-\alpha_A^b)}{2t} = 0 \ ,$$
$$\frac{\partial \pi_B^b}{\partial p_B^b} = \frac{(\sigma\gamma_l + (1-\sigma)\gamma_h)[t + \theta(2v_l - 2s - t) - 2(1+\theta)p_B^b + (1-\theta)p_A^b]p_B^b(1-\alpha_B^b)}{2t} = 0 \ .$$

Solving the above two equations simultaneously, we obtain the equilibrium retail prices. We further verify the second-order conditions are satisfied as shown below:

$$\frac{\partial^2 \pi_i^b}{\partial {p_i^b}^2} = -\frac{(1-\alpha_i^b)(1+\theta)(\sigma\gamma_l + (1-\sigma)\gamma_h)}{t} < 0 \ .$$

The demand functions for the two consumer segments are given by:

$$D_h^b = (1-\sigma)\gamma_h[\theta\frac{v_l - p_A^b - s}{t} + (1-\theta)\frac{t - p_A^b + p_B^b}{2t} + \theta\frac{v_l - p_B^b - s}{t} + (1-\theta)\frac{t - p_B^b + p_A^b}{2t}] \ ,$$
$$D_l^b = \sigma\gamma_l[\theta\frac{v_l - p_A^b - s}{t} + (1-\theta)\frac{t - p_A^b + p_B^b}{2t} + \theta\frac{v_l - p_B^b - s}{t} + (1-\theta)\frac{t - p_B^b + p_A^b}{2t}] \ .$$

In stage 3, plugging in the equilibrium retail prices and solving for the platform's optimization problem with binding constraints, $\pi_A^{b*} = \pi_B^{b*} = \mu$, we can get the equilibrium commission rate α^{b*}. It is easily verified that $0 < \alpha^{b*} < 1$ as long as the the sellers' reservation profit is less than the channel profit, i.e., $\mu < \frac{(1+\theta)[t(1-\theta)+2\theta(v_l-s)]^2(\sigma\gamma_l+(1-\sigma)\gamma_h)}{2t(1+3\theta)^2}$. Then we can obtain the equilibrium platform profit as:

$$\pi_R^{b*} = \frac{(1+\theta)[]t(1-\theta) + 2\theta(v_l - s)]^2(\sigma\gamma_l + (1-\sigma)\gamma_h)}{t(1+3\theta)^2} - 2\mu \ .$$

The total consumer surplus can be calculated as:

$$\begin{aligned} CS^b = \ & (\sigma\gamma_l + (1-\sigma)\gamma_h)[\int_0^{\frac{v_l - p_A^b - s}{t}} \theta(v_l - \lambda t - p_A^b - s)d\lambda \\ & + \int_0^{\frac{t - p_A^b + p_B^b}{2t}} (1-\theta)(v_h - \lambda t - p_A^b - s)d\lambda + \int_0^{\frac{v_l - p_B^b - s}{t}} \theta(v_l - \lambda t - p_B^b - s)d\lambda \\ & + \int_0^{\frac{t - p_B^b + p_A^b}{2t}} (1-\theta)(v_h - \lambda t - p_B^b - s)d\lambda] \ , \end{aligned}$$

$$
\begin{aligned}
CS^{b*} = \ & (\sigma\gamma_l + (1-\sigma)\gamma_h)[\frac{(1-\theta)(t(\theta-5) - 4s(1+\theta) + 4(1+3\theta)v_h - 8\theta v_l)}{4+12\theta} \\
& + \frac{\theta(t+s-\theta(t-s)-(1+\theta)v_l)^2}{t(1+3\theta)^2}] \ .
\end{aligned}
$$

Social welfare can be calculated as:

$$
\begin{aligned}
SW^b = \ & (\sigma\gamma_l + (1-\sigma)\gamma_h)[\int_0^{\frac{v_l-p_A^b-s}{t}} \theta(v_l - \lambda t - s)d\lambda + \int_0^{\frac{t-p_A^b+p_B^b}{2t}} (1-\theta)(v_h - \lambda t - s)d\lambda \\
& + \int_0^{\frac{v_l-p_B^b-s}{t}} \theta(v_l - \lambda t - s)d\lambda + \int_0^{\frac{t-p_B^b+p_A^b}{2t}} (1-\theta)(v_h - \lambda t - s)d\lambda] \ ,
\end{aligned}
$$

$$
\begin{aligned}
SW^{b*} = \ & (\sigma\gamma_l + (1-\sigma)\gamma_h)[\frac{(1-\theta)(4v_h - t - 4s)}{4} \\
& + \frac{\theta(t(1-\theta) + s(1+\theta) + (1+\theta)v_l)(s + t(\theta-1) + 5s\theta - (1+5\theta)v_l)}{t(1+3\theta)^2}] \ .
\end{aligned}
$$

Proof of Lemma 2

The first-order conditions for sellers' optimization problems in stage 4 are given by the following:

$$
\begin{aligned}
\frac{\partial \pi_A^m}{\partial p_A^m} = \ & \frac{(1-\alpha_A^m)}{2t}[(1-\sigma)\gamma_h(2v_l\theta + t(1-\theta) - 2(1+\theta)p_A^m + (1-\theta)p_B^m) \\
& + \sigma\gamma_l(t(1-\theta) + 2\theta(v_l - s) - 2(1+\theta)p_A^m + (1-\theta)p_B^m)] = 0 \ , \\
\frac{\partial \pi_B^m}{\partial p_B^m} = \ & \frac{(1-\alpha_B^m)}{2t}[(1-\sigma)\gamma_h(2v_l\theta + t(1-\theta) - 2(1+\theta)p_B^m + (1-\theta)p_A^m) \\
& + \sigma\gamma_l(t(1-\theta) + 2\theta(v_l - s) - 2(1+\theta)p_B^m + (1-\theta)p_A^m)] = 0 \ .
\end{aligned}
$$

Solving the above two equations simultaneously, we obtain the equilibrium retail prices. We further verify the second-order conditions are satisfied as shown below:

$$
\frac{\partial^2 \pi_i^m}{\partial p_i^{m2}} = \ -\frac{(1-\alpha_i^m)(1+\theta)(\sigma\gamma_l + (1-\sigma)\gamma_h)}{t} < 0 \ .
$$

The demand functions from each consumer segment are given as follows:

$$
\begin{aligned}
D_h^m = \ & (1-\sigma)\gamma_h[\theta\frac{v_l - p_A^m}{t} + (1-\theta)\frac{t - p_A^m + p_B^m}{2t} + \theta\frac{v_l - p_B^m}{t} + (1-\theta)\frac{t - p_B^m + p_A^m}{2t}] \ , \\
D_l^m = \ & \sigma\gamma_l[\theta\frac{v_l - p_A^m - s}{t} + (1-\theta)\frac{t - p_A^m + p_B^m}{2t} + \theta\frac{v_l - p_B^m - s}{t} + (1-\theta)\frac{t - p_B^m + p_A^m}{2t}] \ .
\end{aligned}
$$

In stage 3, plugging in the equilibrium retail prices and solving for the platform's optimization problem with binding constraints, $\pi_A^{m*} = \pi_B^{m*} = \mu$, we can get the equilibrium commission rates α_A^{m*} and α_B^{m*}. It is easily verified that $0 < \alpha_i^{m*} < 1$ as long as the sellers' reservation profit is less than the total channel profit, i.e., $\mu < \frac{(1+\theta)(t(1-\theta)+2\theta(v_l-s))^2(\sigma\gamma_l+(1-\sigma)\gamma_h)}{2t(1+3\theta)^2}$.

The profit of the platform consists of three parts: commission revenue collected from the sellers (**CR**), membership fee paid by subscribing consumers (**MF**), and absorbed shipping cost (**SC**). These three parts are calculated as follows:

$$\begin{aligned} CR^m = \;& p_A^m\alpha_A^m[\sigma\gamma_l(\theta\frac{v_l-p_A^m-s}{t}+(1-\theta)\frac{t-p_A^m+p_B^m}{2t}) \\ & +(1-\sigma)\gamma_h(\theta\frac{v_l-p_A^m}{t}+(1-\theta)\frac{t-p_A^m+p_B^m}{2t})] \\ & +p_B^m\alpha_B^m[\sigma\gamma_l(\theta\frac{v_l-p_B^m-s}{t}+(1-\theta)\frac{t-p_B^m+p_A^m}{2t}) \\ & +(1-\sigma)\gamma_h(\theta\frac{v_l-p_B^m}{t}+(1-\theta)\frac{t-p_B^m+p_A^m}{2t})] \;, \end{aligned}$$

$$\begin{aligned} SC^m = \;& s(1-\sigma)\gamma_h[\theta\frac{v_l-p_A^m}{t}+(1-\theta)\frac{t-p_A^m+p_B^m}{2t} \\ & +\theta\frac{v_l-p_B^m}{t}+(1-\theta)\frac{t-p_B^m+p_A^m}{2t}] \;, \end{aligned} \tag{A.1}$$

$$MF^m = \; (1-\sigma)M^m \;. \tag{A.2}$$

Substituting the equilibrium retail prices and commission rate in the above equations, and calculating the platform profit using the formula $\pi_R^{m*} = CR^{m*} + MF^{m*} - SC^{m*}$.

$$\begin{aligned} \pi_R^{m*} = \;& [t(1+3\theta)^2(\sigma\gamma_l+(1-\sigma)\gamma_h)]^{-1}[(1+\theta)(t(1-\theta)+2\theta(v_l-s))^2\sigma^2\gamma_l^2 \\ & -(2t^2(1-\theta)^2(1+\theta)-\theta(s+3s\theta)^2-4ts\theta(1-\theta^2)+8\theta(1+\theta)v_l(t(1-\theta) \\ & +\theta(v_l-s)))\sigma(1-\sigma)\gamma_l\gamma_h+(t^2(1-\theta)^2(1+\theta)-\theta(s+3s\theta)^2 \\ & +4\theta(1+\theta)v_l(t-t\theta+\theta v_l))(1-\sigma)^2\gamma_h^2]-2\mu \;. \end{aligned}$$

The total consumer surplus can be calculated as:

$$
\begin{aligned}
CS^m = \ & \sigma\gamma_l[\int_0^{\frac{v_l-p_A^m-s}{t}} \theta(v_l-\lambda t-p_A^m-s)d\lambda \\
& + \int_0^{\frac{t-p_A^m+p_B^m}{2t}} (1-\theta)(v_h-\lambda t-p_A^m-s)d\lambda + \int_0^{\frac{v_l-p_B^m-s}{t}} \theta(v_l-\lambda t-p_B^m-s)d\lambda \\
& + \int_0^{\frac{t-p_B^m+p_A^m}{2t}} (1-\theta)(v_h-\lambda t-p_B^m-s)d\lambda] + (1-\sigma)\gamma_h[\int_0^{\frac{v_l-p_A^m}{t}} \theta(v_l-\lambda t-p_A^m)d\lambda \\
& + \int_0^{\frac{t-p_A^m+p_B^m}{2t}} (1-\theta)(v_h-\lambda t-p_A^m)d\lambda + \int_0^{\frac{v_l-p_B^m}{t}} \theta(v_l-\lambda t-p_B^m)d\lambda \\
& + \int_0^{\frac{t-p_B^m+p_A^m}{2t}} (1-\theta)(v_h-\lambda t-p_B^m)d\lambda] - MF^m \ ,
\end{aligned}
$$

$$
\begin{aligned}
CS^{m*} = \ & [s(1-\sigma)\gamma_h((s\theta-t+(t+3s)\theta^2-2\theta(1+\theta))(1-\sigma)\gamma_h \\
& +((\theta-1)(t+t\theta-s\theta)-2\theta(1+\theta)v_l)\sigma\gamma_l)][t(1+3\theta)(\sigma\gamma_l+(1-\sigma)\gamma_h)]^{-1} \\
& +\frac{(1-\sigma)\gamma_h}{4(1+3\theta)^2}\Big[[4\theta((t(1-\theta)-(1+\theta)v_l)(1-\sigma)\gamma_h \\
& -(2s\theta+(1+\theta)v_l-t(1-\theta))\sigma\gamma_l)^2][t(\sigma\gamma_l+(1-\sigma)\gamma_h)^2]^{-1} \\
& +(1-\theta)(1+3\theta)(t(\theta-5)+8s\theta+4(1+3\theta)v_h-8\theta v_l+\frac{8s\theta(1-\sigma)\gamma_h}{\sigma\gamma_l+(1-\sigma)\gamma_h})\Big] \\
& +\sigma\gamma_l[[\theta((t(1-\theta)+s(1+3\theta)-(1+\theta)v_l)(1-\sigma)\gamma_h \\
& +(t+s-t\theta+s\theta-(1+\theta)v_l)\sigma\gamma_l)^2][t(1+3\theta)^2(\sigma\gamma_l+(1-\sigma)\gamma_h)^2]^{-1} \\
& +\frac{1}{4}(1-\theta)(4v_h+\frac{t(\theta-5)-4s(1+\theta)-8\theta v_l+\frac{8s\theta(1-\sigma)\gamma_h}{\sigma\gamma_l+(1-\sigma)\gamma_h}}{1+3\theta})] \ .
\end{aligned}
$$

Social welfare can be calculated as:

$$
\begin{aligned}
SW^m = \ & \sigma\gamma_l[\int_0^{\frac{v_l-p_A^m-s}{t}} \theta(v_l-\lambda t-s)d\lambda + \int_0^{\frac{t-p_A^m+p_B^m}{2t}} (1-\theta)(v_h-\lambda t-s)d\lambda \\
& + \int_0^{\frac{v_l-p_B^m-s}{t}} \theta(v_l-\lambda t-s)d\lambda + \int_0^{\frac{t-p_B^m+p_A^m}{2t}} (1-\theta)(v_h-\lambda t-s)d\lambda] \\
& +(1-\sigma)\gamma_h[\int_0^{\frac{v_l-p_A^m}{t}} \theta(v_l-\lambda t-s)d\lambda + \int_0^{\frac{t-p_A^m+p_B^m}{2t}} (1-\theta)(v_h-\lambda t-s)d\lambda \\
& + \int_0^{\frac{v_l-p_B^m}{t}} \theta(v_l-\lambda t-s)d\lambda \\
& + \int_0^{\frac{t-p_B^m+p_A^m}{2t}} (1-\theta)(v_h-\lambda t-s)d\lambda] \ ,
\end{aligned}
$$

$$
\begin{aligned}
SW^{m*} = \ & \sigma\gamma_l[\frac{1}{4}(1-\theta)(4v_h-t-4s) - \frac{\theta}{t(1+3\theta)^2(\sigma\gamma_l+(1-\sigma)\gamma_h)^2}((t(1-\theta)+s(1+3\theta) \\
& -(1+\theta)v_l)(1-\sigma)\gamma_h + (t+s-t\theta+s\theta-(1+\theta)v_l)\sigma\gamma_l)((t(1-\theta)-s-3s\theta \\
& +(1+5\theta)v_l)(1-\sigma)\gamma_h + (t-s-(t+5s)\theta+(1+5\theta)v_l)\sigma\gamma_l)] \\
& +(1-\sigma)\gamma_h[\frac{1}{4}(1-\theta)(4v_h-t-4s) - \frac{\theta}{t(1+3\theta)^2(\sigma\gamma_l+(1-\sigma)\gamma_h)^2} \\
& ((t(1-\theta)-(1+\theta)v_l)(1-\sigma)\gamma_h + (t(1-\theta)-2s\theta-(1+\theta)v_l)\sigma\gamma_l) \\
& ((t(1-\theta)-2s-6s\theta+(1+5\theta)v_l)(1-\sigma)\gamma_h \\
& +(t-2s-(t+8s)\theta+(1+5\theta)v_l)\sigma\gamma_l)] \ .
\end{aligned}
$$

Proof of Proposition 1 The difference between the membership fee paid by subscribing consumers (**MF**) and absorbed shipping cost (**SC**) is equal to the difference (A.2) - (A.1). Substituting the equilibrium retail prices, we get $MF^{m*} - SC^{m*} = -\frac{s^2\theta(1-\sigma)\gamma_h}{t} < 0$.

Proof of Proposition 2 Platform profit gain from the MFS program can be calculated as $\Delta\pi_R^* = \pi_R^{m*} - \pi_R^{b*}$. Plugging in the equilibrium platform profits, we have:

$$\begin{aligned}\Delta\pi_R^* = &\ \frac{s\theta(1-\sigma)\gamma_h[4t - s - 14s\theta - 4t\theta^2 - 17s\theta^2 + 8\theta v_l + 8\theta^2 v_l + \frac{4s\theta(1+\theta)(1-\sigma)\gamma_h}{\sigma\gamma_l + (1-\sigma)\gamma_h}]}{t(1+3\theta)^2} \\ = &\ -\frac{\theta(1-\sigma)\gamma_h[1 + 14\theta + 17\theta^2 - \frac{4\theta(1+\theta)(1-\sigma)\gamma_h}{\sigma\gamma_l + (1-\sigma)\gamma_h}]}{t(1+3\theta)^2} \times s^2 \\ &+ \frac{4\theta(1+\theta)(t(1-\theta) + 2\theta v_l)(1-\sigma)\gamma_h}{t(1+3\theta)^2} \times s\ .\end{aligned}$$

Clearly, $1 + 14\theta + 17\theta^2 - \frac{4\theta(1+\theta)(1-\sigma)\gamma_h}{\sigma\gamma_l + (1-\sigma)\gamma_h} > 1 + 14\theta + 17\theta^2 - 4\theta(1+\theta) > 0$ for any $\theta \in [0, 1]$ so that $\Delta\pi_R^*$ is a quadratic function of s with inverted-U shape. Meanwhile, the two solutions to $\Delta\pi_R^{m*} = 0$ are $s_1 = 0$ and $s_2 = s^{m*} > 0$. Therefore, $\Delta\pi_R^{m*} > 0$ if and only if $0 < s < s^{m*}$.

Proof of Proposition 3 This is a direct result from Proposition 2.

Proof of Proposition 4 The difference in consumer surplus can be calculated as $\Delta CS^* = CS^{m*} - CS^{b*}$. Plugging in the equilibrium consumer surplus, we have:

$$\begin{aligned}\Delta CS^* = &\ [2s\theta(1-\sigma)\gamma_h[(2s\theta - t + (t+4s)\theta^2 - 2\theta(1+\theta)v_l)(1-\sigma)\gamma_h - (1+\theta) \\ &(t(1-\theta) + 2\theta(v_l - s))\sigma\gamma_l]][t(1+3\theta)^2(\sigma\gamma_l + (1-\sigma)\gamma_h)]^{-1} \\ = &\ \frac{4\theta^2(1-\sigma)\gamma_h((1+2\theta)(1-\sigma)\gamma_h + (1+\theta)\sigma\gamma_l)}{t(1+3\theta)^2(\sigma\gamma_l + (1-\sigma)\gamma_h)} \times s^2 \\ &+ \frac{2\theta(1+\theta)(1-\sigma)(t(1-\theta) + 2\theta v_l)\gamma_h}{t(1+3\theta)^2} \times s\ .\end{aligned}$$

It is easily verified that ΔCS^* is a quadratic function of s with U shape and the two solutions to $\Delta CS^* = 0$ are $s_1 = 0$ and $s_2 = \frac{(1+\theta)(t(1-\theta)+2\theta v_l)(\sigma\gamma_l+(1-\sigma)\gamma_h)}{2\theta(1+2\theta)(1-\sigma)\gamma_h+2\theta(1+\theta)\sigma\gamma_l} > 0$. As long as the demand of low base valuation v_l is positive, i.e. $v_l > \frac{t(1-\theta)+s(1+\theta)+\frac{2s\theta(1-\sigma)\gamma_h}{\sigma\gamma_l+(1-\sigma)\gamma_h}}{1+\theta}$, we have $s < \frac{((1+\theta)v_l-t(1-\theta))(\sigma\gamma_l+(1-\sigma)\gamma_h)}{(1+3\theta)(1-\sigma)\gamma_h+(1+\theta)\sigma\gamma_l} < \frac{((1+\theta)v_l+\frac{t(1-\theta)}{2\theta})(\sigma\gamma_l+(1-\sigma)\gamma_h)}{(1+2\theta)(1-\sigma)\gamma_h+(1+\theta)\sigma\gamma_l} = s_2$. Therefore, $\Delta CS^* < 0$ holds for any positive s in our parameter space.

Proof of Proposition 5 The difference in social welfare can be calculated as $\Delta SW^* = SW^{m*} - SW^{b*}$. Plugging in the equilibrium social welfare, we have:

$$\begin{aligned}
\Delta SW^* = \;& [s\theta(1-\sigma)\gamma_h[(1+\theta)(2t(1-\theta)-s-5s\theta+4\theta v_l)(1-\sigma)\gamma_h-(s+s\theta(10+13\theta)\\
& -2t(1-\theta^2)-4\theta(1+\theta)v_l)\sigma\gamma_l]][t(1+3\theta)^2(\sigma\gamma_l+(1-\sigma)\gamma_h)]\\
= \;& -\frac{\theta(1-\sigma)\gamma_h((1+6\theta+5\theta^2)(1-\sigma)\gamma_h+(1+10\theta+13\theta^2)\sigma\gamma_l)}{t(1+3\theta)^2(\sigma\gamma_l+(1-\sigma)\gamma_h)}\times s^2\\
& +\frac{2\theta(1+\theta)(1-\sigma)\gamma_h(t(1-\theta)+2\theta v_l)}{t(1+3\theta)^2}\times s\ .
\end{aligned}$$

It is easy to see that ΔSW^* is a quadratic function of s with inverted-U shape and the two solutions to $\Delta SW^* = 0$ are $s_1 = 0$ and $s_2 = \overline{s}^m > 0$. Therefore, $\Delta SW^* > 0$ if and only if $0 < s < \overline{s}^m$.

Proof of Table 1 To show that $s^{m*} > \overline{s}^m$, we know that

$$\begin{aligned}
s^{m*} - \overline{s}^m = \;& [2(1+\theta)(1+3\theta)(t(1-\theta)+2\theta v_l)(\sigma\gamma_l+(1-\sigma)\gamma_h)((1-\theta)(1-\sigma)\gamma_h\\
& +(1+3\theta)\sigma\gamma_l)][[(1+\theta)(1+5\theta)(1-\sigma)\gamma_h+(1+\theta(10+13\theta))\sigma\gamma_l]\\
& [(1+\theta(10+13\theta))(1-\sigma)\gamma_h+(1+\theta(14+17\theta))\sigma\gamma_l]]^{-1}\ .
\end{aligned}$$

Clearly, this terms is positive, so $s^{m*} > \overline{s}^m$.

Analysis of MFS in Conjunction with Contingent Free Shipping (CFS) When there is no MFS, the sellers' optimization problems in stage 4 are formulated as the following:

$$\begin{aligned}
\arg\max_{p_A^b}\ \pi_A^b = \;& (\sigma\gamma_l+(1-\sigma)\gamma_h)[\theta\frac{v_l-p_A^b-s}{t}\\
& +(1-\theta)(\frac{t-p_A^b+p_B^b}{2t}+\epsilon\frac{\rho v_h+s-p_A^b}{t})]p_A^b(1-\alpha_A^b)\ ,\\
\arg\max_{p_B^b}\ \pi_B^b = \;& (\sigma\gamma_l+(1-\sigma)\gamma_h)[\theta\frac{v_l-p_B^b-s}{t}\\
& +(1-\theta)(\frac{t-p_B^b+p_A^b}{2t}+\epsilon\frac{\rho v_h+s-p_B^b}{t})]p_B^b(1-\alpha_B^b)\ .
\end{aligned}$$

Solving the first-order conditions, we obtain the equilibrium retail prices as follows:

$$p_A^{b*} = p_B^{b*} = \frac{t(1-\theta)-2s(\theta-\epsilon(1-\theta))+2\epsilon(1-\theta)\rho v_h+2\theta v_l}{1+3\theta+4\epsilon(1-\theta)}\ .$$

We further verify the second-order conditions are satisfied as shown below:

$$\frac{\partial^2 \pi_i^b}{\partial {p_i^b}^2} = -\frac{(1-\alpha_i^b)(1+\theta+2\epsilon(1-\theta))(\sigma\gamma_l+(1-\sigma)\gamma_h)}{t} < 0 \ .$$

In stage 3, plugging in the equilibrium retail prices and solving for the platform's optimization problem with binding constraints, $\pi_A^{b*} = \pi_B^{b*} = \mu$, we can get the equilibrium commission rate:

$$\begin{aligned} \alpha_i^{b*} = \ & 1 - [2t(1+3\theta+4\epsilon(1-\theta))^2\mu][(1+\theta+2\epsilon(1-\theta))(t(1-\theta) \\ & -2s(\theta-\epsilon(1-\theta)) + 2\epsilon(1-\theta)\rho v_h + 2\theta v_l)^2(\sigma\gamma_l+(1-\sigma)\gamma_h)]^{-1} \ . \end{aligned}$$

The platform profit can be calculated as:

$$\begin{aligned} \pi_R^b = \ & (\sigma\gamma_l+(1-\sigma)\gamma_h)[\theta\frac{v_l-p_A^b-s}{t}p_A^b\alpha_A^b + (1-\theta)(\frac{t-p_A^b+p_B^b}{2t}p_A^b\alpha_A^b \\ & +\epsilon\frac{\rho v_h+s-p_A^b}{t}(p_A^b\alpha_A^b-2s)) + \theta\frac{v_l-p_B^b-s}{t}p_B^b\alpha_B^b \\ & +(1-\theta)(\frac{t-p_B^b+p_A^b}{2t}p_B^b\alpha_B^b + \epsilon\frac{\rho v_h+s-p_B^b}{t}(p_B^b\alpha_B^b-2s))] \ . \end{aligned}$$

Plugging in the equilibrium retail prices and commission rate, we have the equilibrium platform profit:

$$\begin{aligned} \pi_R^{b*} = \ & [(1+\theta+2\epsilon(1-\theta))(t(1-\theta)-2s(\theta-\epsilon(1-\theta))+2\epsilon(1-\theta)\rho v_h+2\theta v_l)^2 \\ & (\sigma\gamma_l+(1-\sigma)\gamma_h)][t(1+3\theta+4\epsilon(1-\theta))^2]^{-1} - [4s\epsilon(1-\theta)(t(1-\theta)-s-2s\epsilon \\ & -s(5-2\epsilon)\theta-(1+2\epsilon(1-\theta)+3\theta)\rho v_h+2\theta v_l)(\sigma\gamma_l+(1-\sigma)\gamma_h)] \\ & [t(1+3\theta+4\epsilon(1-\theta))]^{-1} - 2\mu \ . \end{aligned}$$

When the retail platform implements the MFS program, the sellers' optimization problems in stage 4 are formulated as the following:

$$\begin{aligned} \arg\max_{p_A^m} \ \pi_A^m = \ & [\sigma\gamma_l(\theta\frac{v_l-p_A^m-s}{t} + (1-\theta)(\frac{t-p_A^m+p_B^m}{2t} + \epsilon\frac{\rho v_h+s-p_A^m}{t})) \\ & +(1-\sigma)\gamma_h(\theta\frac{v_l-p_A^m}{t} + (1-\theta)(\frac{t-p_A^m+p_B^m}{2t} + \epsilon\frac{\rho v_h-p_A^m}{t}))]p_A^m(1-\alpha_A^m) \ , \\ \arg\max_{p_B^m} \ \pi_B^m = \ & [\sigma\gamma_l(\theta\frac{v_l-p_B^m-s}{t} + (1-\theta)(\frac{t-p_B^m+p_A^m}{2t} + \epsilon\frac{\rho v_h+s-p_B^m}{t})) \\ & +(1-\sigma)\gamma_h(\theta\frac{v_l-p_B^m}{t} + (1-\theta)(\frac{t-p_B^m+p_A^m}{2t} + \epsilon\frac{\rho v_h-p_B^m}{t}))]p_B^m(1-\alpha_B^m) \ . \end{aligned}$$

Solving the first-order conditions, we obtain the equilibrium retail prices as follows:

$$\begin{aligned} p_A^{m*} = p_B^{m*} = \; & [(1-\sigma)((1-\theta)(t+2\epsilon\rho v_h)+2\theta v_l)\gamma_h+\sigma(t+2s\epsilon-\theta(t+2s(1+\epsilon)) \\ & +2\epsilon(1-\theta)\rho v_h+2\theta v_l)\gamma_l][2t(1+3\theta+4\epsilon(1-\theta))^2(\sigma\gamma_l+(1-\sigma)\gamma_h)]^{-1} \; . \end{aligned}$$

We further verify the second-order conditions are satisfied as shown below:

$$\frac{\partial^2 \pi_i^m}{\partial p_i^{m2}} = \; -\frac{(1-\alpha_i^m)(1+\theta+2\epsilon(1-\theta))(\sigma\gamma_l+(1-\sigma)\gamma_h)}{t} < 0 \; .$$

In stage 3, plugging in the equilibrium retail prices and solving for the platform's optimization problem with binding constraints, $\pi_A^{b*} = \pi_B^{b*} = \mu$, we can get the equilibrium commission rates:

$$\begin{aligned} \alpha_i^{m*} = \; & 1-[2t(1+3\theta+4\epsilon(1-\theta))^2(\sigma\gamma_l+(1-\sigma)\gamma_h)\mu][(1+\theta+2\epsilon(1-\theta)) \\ & ((1-\sigma)((1-\theta)(t+2\epsilon\rho v_h)+2\theta v_l)\gamma_h+\sigma(t+2s\epsilon-\theta(t+2s(1+\epsilon)) \\ & +2\epsilon(1-\theta)\rho v_h+2\theta v_l)\gamma_l)^2]^{-1} \; . \end{aligned}$$

The three components of platform profit, namely CR, SC and MF, can be calculated as follows:

$$\begin{aligned} CR^m = \; & [\sigma\gamma_l(\theta\frac{v_l-p_A^m-s}{t}+(1-\theta)(\frac{t-p_A^m+p_B^m}{2t}+\epsilon\frac{\rho v_h+s-p_A^m}{t})) \\ & +(1-\sigma)\gamma_h(\theta\frac{v_l-p_A^m}{t}+(1-\theta)(\frac{t-p_A^m+p_B^m}{2t}+\epsilon\frac{\rho v_h-p_A^m}{t}))]p_A^m\alpha_A^m \\ & +[\sigma\gamma_l(\theta\frac{v_l-p_B^m-s}{t}+(1-\theta)(\frac{t-p_B^m+p_A^m}{2t}+\epsilon\frac{\rho v_h+s-p_B^m}{t})) \\ & +(1-\sigma)\gamma_h(\theta\frac{v_l-p_B^m}{t}+(1-\theta)(\frac{t-p_B^m+p_A^m}{2t}+\epsilon\frac{\rho v_h-p_B^m}{t}))]p_B^m\alpha_B^m \; , \end{aligned}$$

$$\begin{aligned} SC^m = \; & (1-\sigma)\gamma_h(\theta\frac{v_l-p_A^m}{t}+\theta\frac{v_l-p_B^m}{t})s+\epsilon[\sigma\gamma_l(1-\theta)(\frac{\rho v_h+s-p_A^m}{t} \\ & +\frac{\rho v_h+s-p_B^m}{t})2s+(1-\sigma)\gamma_h((1-\theta)\frac{\rho v_h-p_A^m}{t}+(1-\theta)\frac{\rho v_h-p_B^m}{t})2s \\ & +(1-\sigma)\gamma_h((1-\theta)(\frac{t-p_A^m+p_B^m}{2t}-\frac{\rho v_h-p_A^m}{t})+(1-\theta)(\frac{t-p_B^m+p_A^m}{2t} \\ & -\frac{\rho v_h-p_B^m}{t}))s]+(1-\epsilon)(1-\sigma)\gamma_h((1-\theta)\frac{t-p_A^m+p_B^m}{2t}+(1-\theta)\frac{t-p_B^m+p_A^m}{2t})s \; , \end{aligned}$$

$$MF^m = \; (1-\sigma)M^m \; .$$

The equilibrium membership fee M^m equals the expected surplus gain from the MFS program. For any frequent shopper, the expected surplus with the membership can be calculated as:

$$\begin{aligned}
\gamma_h[& \int_0^{\frac{v_l-p_A^m}{t}} \theta(v_l - p_A^m - \lambda t)d\lambda + \int_0^{\frac{v_l-p_B^m}{t}} \theta(v_l - p_B^m - \lambda t)d\lambda \\
+ & \int_0^{\frac{\rho v_h-p_A^m}{t}} \epsilon(1-\theta)(v_h(1+\rho) - 2p_A^m - 2\lambda t)d\lambda + \int_0^{\frac{\rho v_h-p_A^m}{t}} (1-\epsilon)(1-\theta)(v_h - p_A^m - \lambda t)d\lambda \\
+ & \int_{\frac{\rho v_h-p_A^m}{t}}^{\frac{t-p_A^m+p_B^m}{2t}} (1-\theta)(v_h - p_A^m - \lambda t)d\lambda + \int_0^{\frac{\rho v_h-p_B^m}{t}} \epsilon(1-\theta)(v_h(1+\rho) - 2p_B^m - 2\lambda t)d\lambda \\
+ & \int_0^{\frac{\rho v_h-p_B^m}{t}} (1-\epsilon)(1-\theta)(v_h - p_B^m - \lambda t)d\lambda + \int_{\frac{\rho v_h-p_B^m}{t}}^{\frac{t-p_B^m+p_A^m}{2t}} (1-\theta)(v_h - p_B^m - \lambda t)d\lambda] \; .
\end{aligned}$$

The expected surplus for the same consumer without the membership can be calculated as:

$$\begin{aligned}
\gamma_h[& \int_0^{\frac{v_l-p_A^m-s}{t}} \theta(v_l - p_A^m - \lambda t - s)d\lambda + \int_0^{\frac{v_l-p_B^m-s}{t}} \theta(v_l - p_B^m - \lambda t - s)d\lambda \\
+ & \int_0^{\frac{\rho v_h-p_A^m-s}{t}} \epsilon(1-\theta)(v_h(1+\rho) - 2p_A^m - 2\lambda t)d\lambda \\
+ & \int_0^{\frac{\rho v_h-p_A^m-s}{t}} (1-\epsilon)(1-\theta)(v_h - p_A^m - \lambda t - s)d\lambda \\
+ & \int_{\frac{\rho v_h-p_A^m-s}{t}}^{\frac{t-p_A^m+p_B^m}{2t}} (1-\theta)(v_h - p_A^m - \lambda t - s)d\lambda + \int_0^{\frac{\rho v_h-p_B^m-s}{t}} \epsilon(1-\theta)(v_h(1+\rho) - 2p_B^m - 2\lambda t)d\lambda \\
+ & \int_0^{\frac{\rho v_h-p_B^m-s}{t}} (1-\epsilon)(1-\theta)(v_h - p_B^m - \lambda t - s)d\lambda + \int_{\frac{\rho v_h-p_B^m-s}{t}}^{\frac{t-p_B^m+p_A^m}{2t}} (1-\theta)(v_h - p_B^m - \lambda t - s)d\lambda] \; .
\end{aligned}$$

Taking the difference of the two terms, we have the equilibrium membership fee. Substituting the equilibrium retail prices and commission rate, we can calculate the platform profit using the formula $\pi_R^{m*} = CR^{m*} + MF^{m*} - SC^{m*}$ so that

$$\begin{aligned}
\pi_R^{m*} = \; & [(1+2\epsilon(1-\theta)+\theta)((1-\sigma)((1-\theta)(t+2\epsilon\rho v_h) \\
& +2\theta v_l)\gamma_h + \sigma(t+2s\epsilon-(t+2s(1+\epsilon))\theta + 2\epsilon(1-\theta)\rho v_h + 2\theta v_l)\gamma_l)^2 \\
& -s(1+4\epsilon(1-\theta)+3\theta)(1-\sigma)\gamma_h((1-\sigma)(t(1+6\epsilon(1-\theta)+\theta)(1-\theta) \\
& -s(1+4\epsilon(1-\theta)+3\theta)(\theta-\epsilon(1-\theta)) - 2\epsilon(1+2\epsilon(1-\theta)+5\theta)(1-\theta)\rho v_h \\
& +2\theta(1+6\epsilon(1-\theta)+\theta)v_l)\gamma_h + \sigma((1-\theta)(t(1+6\epsilon(1-\theta)+\theta) - s(\epsilon+\theta+15\epsilon\theta) \\
& -2\epsilon(1+2\epsilon(1-\theta)+5\theta)\rho v_h) + 2(1+6\epsilon(1-\theta)+\theta)\theta v_l)\gamma_l) + s(1+4\epsilon(1-\theta)+3\theta) \\
& ((1-\sigma)^2(2\epsilon(1-\theta)((2\epsilon-1)\theta-(1+3\epsilon))\rho v_h + (1+2\epsilon(1-\theta)+\theta) \\
& (t(1-\theta)+2\theta v_l))\gamma_h^2 + (1-\sigma)\sigma(8s\epsilon(3\epsilon-1)\theta - 2s\epsilon(4\epsilon+4) - 2s(2+\epsilon(4\epsilon-4))\theta^2 \\
& -t(1-\theta)(1-2\epsilon(1-\theta)+\theta) + 2\epsilon(1-\theta)(1+2\epsilon-2(2+4\epsilon(1-\theta)+6\theta) \\
& +5\theta-2\epsilon\theta)\rho v_h + 2\theta\epsilon(1-\theta)+\theta))\gamma_h\gamma_l \\
& -4\epsilon(1-\theta)\sigma^2(s+2s\epsilon-t(1-\theta)+s(5-2\epsilon)\theta+(1+2\epsilon(1-\theta)+3\theta)\rho v_h - 2\theta v_l)\gamma_l^2)] \\
& [t(1+3\theta+4\epsilon(1-\theta))^2(\sigma\gamma_l+(1-\sigma)\gamma_h)]^{-1} - 2\mu \; .
\end{aligned}$$

Proof of Proposition 6 Platform profit gain from the MFS program can be calculated as $\Delta\pi_R^* = \pi_R^{m*} - \pi_R^{b*}$. Plugging in the equilibrium platform profits, we have:

$$\begin{aligned}
\Delta\pi_R^* = \; & \frac{s(1-\sigma)\gamma_h}{t(1+4\epsilon(1-\theta)+3\theta)^2(\sigma\gamma_l+(1-\sigma)\gamma_h)}[(1-\sigma)(4t(1+2\epsilon(1-\theta)+\theta)(1-\theta) \\
& (\theta-\epsilon(1-\theta)) + s(8\epsilon^3(1-\theta)^3 - \theta - \theta^2(10+13\theta) + \epsilon(1-\theta)(4(1+3\theta)(1+5\theta) \\
& -1-3\theta(2+11\theta)) + 4\epsilon^2(1-\theta)^2(3+19\theta)) + 8(1+3\epsilon(1-\theta)+\theta)(\theta-\epsilon(1-\theta)) \\
& (\epsilon(1-\theta)\rho v_h + \theta v_l))\gamma_h + \sigma(4t(1+2\epsilon(1-\theta)+\theta)(1-\theta)(\theta-\epsilon(1-\theta)) \\
& +s(\epsilon(1-\theta)(4(1+3\theta)(1+5\theta) - 1 + \theta(2-33\theta)) + 4\epsilon^2(1-\theta)^2(2+22\theta)) \\
& -\theta(1+\theta(14+17\theta))) + 8(1+2\epsilon(1-\theta)+\theta)(\theta-\epsilon(1-\theta))(\epsilon(1-\theta)\rho v_h + \theta v_l))\gamma_l] \\
= \; & -\frac{(1-\sigma)\gamma_h(\eta_1(1-\sigma)\gamma_h + \eta_2\sigma\gamma_l)}{t(1+4\epsilon(1-\theta)+3\theta)^2(\sigma\gamma_l+(1-\sigma)\gamma_h)} \times s^2 \\
& +[4(\theta(1-\theta) - \epsilon(1-\theta)^2 - 2\epsilon^2(1-\theta)^2)(1-\sigma)(t(1-\theta)+2\epsilon(1-\theta)\rho v_h + 2\theta v_l)\gamma_h] \\
& [t(1+4\epsilon(1-\theta)+3\theta)^2]^{-1} \times s \; .
\end{aligned}$$

If $\epsilon < \dfrac{\theta}{3}$, then $\eta_1(1-\sigma)\gamma_h + \eta_2\sigma\gamma_l > 0$. It is easily verified that $\Delta\pi_R^*$ is a quadratic function of s with inverted-U Shape and the two solutions to $\Delta\pi_R^* = 0$ are $s_1 = 0$ and $s_2 = \dot{s}$. Meanwhile, it can be shown that $\dot{s} > 0$ given that $\epsilon < \dfrac{\theta}{3} < \dfrac{\theta}{1-\theta}$. Hence, we have $\Delta\pi_R^* > 0$ if $s < \dot{s}$.

Analysis of Shipping Fee vs. Shipping Cost When there is no MFS, the sellers' optimization problems in stage 4 are formulated as the following:

$$\begin{aligned}
\arg\max_{p_A^b, f_A^b}\ \pi_A^b = \ & (\sigma\gamma_l + (1-\sigma)\gamma_h)[\theta\frac{v_l - p_A^b - f_A^b}{t} \\
& + (1-\theta)\frac{t - p_A^b - f_A^b + p_B^b + f_B^b}{2t}](p_A^b + f_A^b - s)(1-\alpha_A^b)\ , \\
\arg\max_{p_B^b, f_B^b}\ \pi_B^b = \ & (\sigma\gamma_l + (1-\sigma)\gamma_h)[\theta\frac{v_l - p_B^b - f_B^b}{t} \\
& + (1-\theta)\frac{t - p_B^b - f_B^b + p_A^b + f_A^b}{2t}](p_B^b + f_B^b - s)(1-\alpha_B^b)\ .
\end{aligned}$$

As p_i^b and f_i^b always appear in pairs, we denote $tp_i^b = p_i^b + f_i^b$ as the total price and then the optimization problems transform into the following:

$$\begin{aligned}
\arg\max_{tp_A^b}\ \pi_A^b = \ & (\sigma\gamma_l + (1-\sigma)\gamma_h)[\theta\frac{v_l - tp_A^b}{t} + (1-\theta)\frac{t - tp_A^b + tp_B^b}{2t}](tp_A^b - s)(1-\alpha_A^b)\ , \\
\arg\max_{tp_B^b}\ \pi_B^b = \ & (\sigma\gamma_l + (1-\sigma)\gamma_h)[\theta\frac{v_l - tp_B^b}{t} + (1-\theta)\frac{t - tp_B^b + tp_A^b}{2t}](tp_B^b - s)(1-\alpha_B^b)\ .
\end{aligned}$$

Solving the first-order conditions, we obtain the equilibrium total prices as follows:

$$tp_A^{b*} = tp_B^{b*} = \frac{t(1-\theta) + s(1+\theta) + 2\theta v_l}{1+3\theta}\ .$$

We further verify the second-order conditions are satisfied as shown below:

$$\frac{\partial^2 \pi_i^b}{\partial {tp_i^b}^2} = -\frac{(1-\alpha_i^b)(1+\theta)(\sigma\gamma_l + (1-\sigma)\gamma_h)}{t} < 0\ .$$

As the sellers can choose any partition between the product price and shipping fee here, we assume they will set the shipping fee equal to shipping cost and charge the rest of the total price as product price in the equilibrium, which is most likely, so that:

$$\begin{aligned}
f_A^{b*} = f_B^{b*} = \ & s\ , \\
p_A^{b*} = p_B^{b*} = \ & \frac{t(1-\theta) + 2\theta(v_l - s)}{1+3\theta}\ .
\end{aligned}$$

In stage 3, plugging in the equilibrium total prices and solving for the platform's optimization problem with binding constraints, $\pi_A^{b*} = \pi_B^{b*} = \mu$, we can get the equilibrium commission rates:

$$\alpha_i^{b*} = 1 - \frac{2t(1+3\theta)^2\mu}{(1+\theta)(t(1-\theta)+2\theta(v_l - s))^2(\sigma\gamma_l + (1-\sigma)\gamma_h)} .$$

The platform profit can be calculated as:

$$\begin{aligned}\pi_R^b = \; & \alpha_i^b(\sigma\gamma_l + (1-\sigma)\gamma_h)[(\theta\frac{v_l - tp_A^b}{t} + (1-\theta)\frac{t - tp_A^b + tp_B^b}{2t})(tp_A^b - s) \\ & +(\theta\frac{v_l - tp_B^b}{t} + (1-\theta)\frac{t - tp_B^b + tp_A^b}{2t})(tp_B^b - s)] .\end{aligned}$$

Plugging in the equilibrium total prices and commission rate, we have the equilibrium platform profit:

$$\pi_R^{b*} = \frac{(1+\theta)(t(1-\theta)+2\theta(v_l - s))^2(\sigma\gamma_l + (1-\sigma)\gamma_h)}{t(1+3\theta)^2} - 2\mu .$$

When the retail platform implements the MFS program, the sellers' optimization problems in stage 4 are formulated as the following:

$$\begin{aligned}\arg\max_{p_A^m, f_A^m} \pi_A^m = \; & [\sigma\gamma_l(\theta\frac{v_l - p_A^m - f_A^m}{t} \\ & +(1-\theta)\frac{t - p_A^m - f_A^m + p_B^m + f_B^m}{2t})](p_A^m + f_A^m - s)(1-\alpha_A^m) \\ & +[(1-\sigma)\gamma_h(\theta\frac{v_l - p_A^m}{t} + (1-\theta)\frac{t - p_A^m + p_B^m}{2t})]p_A^m(1-\alpha_A^m) , \\ \arg\max_{p_B^m, f_B^m} \pi_B^m = \; & [\sigma\gamma_l(\theta\frac{v_l - p_B^m - f_B^m}{t} \\ & +(1-\theta)\frac{t - p_B^m - f_B^m + p_A^m + f_A^m}{2t})](p_B^m + f_B^m - s)(1-\alpha_B^m) \\ & +[(1-\sigma)\gamma_h(\theta\frac{v_l - p_B^m}{t} + (1-\theta)\frac{t - p_B^m + p_A^m}{2t})]p_B^m(1-\alpha_B^m) .\end{aligned}$$

Solving the first-order conditions, we obtain the equilibrium retail prices and shipping fees as follows:

$$\begin{aligned}p_A^{m*} = p_B^{m*} = \; & \frac{t(1-\theta)+2\theta v_l}{1+3\theta} , \\ f_A^{m*} = f_B^{m*} = \; & \frac{s(1+\theta)}{1+3\theta} .\end{aligned}$$

It is easily verified that the Hessian Matrix at this point is negative semi-definite.

In stage 3, plugging in the equilibrium total prices and solving for the platform's optimization problem with binding constraints, $\pi_A^{m*} = \pi_B^{m*} = \mu$, we can get the equilibrium commission rates:

$$\alpha_i^{m*} = 1 - \frac{2t(1+3\theta)^2\mu}{(1+\theta)((1-\sigma)(t(1-\theta)+2\theta v_l)^2\gamma_h + \sigma(t(1-\theta)+2\theta(v_l-s))^2\gamma_l)} \ .$$

The three components of platform profit, namely CR, SC and MF, can be calculated as follows:

$$\begin{aligned} CR^m = \ & \alpha_i^m[\sigma\gamma_l(\theta\frac{v_l-p_A^m-f_A^m}{t} + (1-\theta)\frac{t-p_A^m-f_A^m+p_B^m+f_B^m}{2t})(p_A^m+f_A^m-s) \\ & +(1-\sigma)\gamma_h(\theta\frac{v_l-p_A^m}{t} + (1-\theta)\frac{t-p_A^m+p_B^m}{2t})p_A^m \\ & +\sigma\gamma_l(\theta\frac{v_l-p_B^m-f_B^m}{t} + (1-\theta)\frac{t-p_B^m-f_B^m+p_A^m+f_A^m}{2t})(p_B^m+f_B^m-s) \\ & +(1-\sigma)\gamma_h(\theta\frac{v_l-p_B^m}{t} + (1-\theta)\frac{t-p_B^m+p_A^m}{2t})p_B^m] \ , \end{aligned}$$

$$SC^m = (1-\sigma)\gamma_h[\theta\frac{v_l-p_A^m}{t} + \theta\frac{v_l-p_B^m}{t} + (1-\theta)\frac{t-p_A^m+p_B^m}{2t} + +(1-\theta)\frac{t-p_B^m+p_A^m}{2t}]s \ ,$$

$$MF^m = (1-\sigma)M^m \ .$$

The equilibrium membership fee M^m equals the expected surplus gain from the MFS program. For any frequent shopper, the expected surplus with the membership can be calculated as:

$$\begin{aligned} & \gamma_h[\int_0^{\frac{v_l-p_A^m}{t}} \theta(v_l-p_A^m-\lambda t)d\lambda + \int_0^{\frac{t-p_A^m+p_B^m}{2t}} (1-\theta)(v_h-p_A^m-\lambda t)d\lambda \\ & + \int_0^{\frac{v_l-p_B^m}{t}} \theta(v_l-p_B^m-\lambda t)d\lambda + \int_0^{\frac{t-p_B^m+p_A^m}{2t}} (1-\theta)(v_h-p_B^m-\lambda t)d\lambda] \ . \end{aligned}$$

The expected surplus for the same consumer without the membership can be calculated as:

$$\begin{aligned} & \gamma_h[\int_0^{\frac{v_l-p_A^m-f_A^m}{t}} \theta(v_l-p_A^m-f_A^m-\lambda t)d\lambda + \int_0^{\frac{t-p_A^m-f_A^m+p_B^m+f_B^m}{2t}} (1-\theta)(v_h-p_A^m-f_A^m-\lambda t)d\lambda \\ & + \int_0^{\frac{v_l-p_B^m-f_B^m}{t}} \theta(v_l-p_B^m-f_B^m-\lambda t)d\lambda + \int_0^{\frac{t-p_B^m-f_B^m+p_A^m+f_A^m}{2t}} (1-\theta)(v_h-p_B^m-f_B^m-\lambda t)d\lambda] \ . \end{aligned}$$

Taking the difference of the two terms, we have the equilibrium membership fee. Substituting the equilibrium retail prices and commission rate, we can calculate the platform profit using the formula $\pi_R^{m*} = CR^{m*} + MF^{m*} - SC^{m*}$ so that

$$\begin{aligned}\pi_R^{m*} = \ & \frac{(1+\theta)}{t(1+3\theta)^2}[(1-\sigma)(t^2(1-\theta)^2 - 2ts(1-\theta)\theta - s^2\theta(1+\theta) \\ & +4\theta v_l(t-(t+s)\theta+\theta v_l))\gamma_h + \sigma(t-(t+2s)\theta+2\theta v_l)^2\gamma_l] - 2\mu \ .\end{aligned}$$

Proof of Proposition 7

Platform profit gain from the MFS program can be calculated as $\Delta\pi_R^* = \pi_R^{m*} - \pi_R^{b*}$. Plugging in the equilibrium platform profits, we have:

$$\begin{aligned}\Delta\pi_R^* = \ & \frac{s\theta(1-\sigma)(2t(1-\theta)-s-5s\theta+4\theta v_l)\gamma_h}{t(1+3\theta)^2} \\ = \ & -\frac{\theta(1+\theta)(1+5\theta)(1-\sigma)\gamma_h}{t(1+3\theta)^2} \times s^2 + \frac{\theta(1+\theta)(1-\sigma)(2t(1-\theta)+4\theta v_l)}{t(1+3\theta)^2} \times s \ .\end{aligned}$$

Clearly, $\Delta\pi_R^*$ is a quadratic function of s with inverted-U shape and the two solutions to $\Delta\pi_R^* = 0$ are $s_1 = 0$ and $s_2 = \ddot{s} > 0$. Therefore, $\Delta\pi_R^* > 0$ if and only if $0 < s < \ddot{s}$.

APPENDIX B

SUPPLEMENTAL MATERIAL FOR CHAPTER 3

Proof of Lemma 3

The first-order condition for retail platform's optimization problem in stage 2 is given by the following:

$$\frac{\partial \pi_R^{wb}}{\partial p^{wb}} = \frac{v_h + v_l + 2w^{wb} - 4p^{wb} - 2s}{t} = 0 \ .$$

Solving the above equation, we obtain the equilibrium retail price in terms of the wholesale price given as follows:

$$p^{wb*} = \frac{v_h + v_l + 2w^{wb} - 2s}{4} \ .$$

We further verify the second-order condition is satisfied as shown below:

$$\frac{\partial^2 \pi_R^{wb}}{\partial {p^{wb}}^2} = -\frac{4}{t} < 0 \ .$$

The first-order condition for the manufacturer's optimization problem in stage 1 is given by the following:

$$\frac{\partial \pi_M^{wb}}{\partial w^{wb}} = \frac{v_h + v_l - 2s - 2w^{wb}}{2t} = 0 \ .$$

Solving the above equations, we can get the equilibrium wholesale price and retail price. We also verify the second-order condition is satisfied for the manufacturer's optimization problem:

$$\frac{\partial^2 \pi_M^{wb}}{\partial {w^{wb}}^2} = -\frac{2}{t} < 0 \ .$$

The demand from a consumer of type θ and the overall demand are given by:

$$D_\theta^{wb} = \int\limits_{-\frac{v_h - p^{wb} - s}{t}}^{\frac{v_h - p^{wb} - s}{t}} \theta d\lambda + \int\limits_{-\frac{v_l - p^{wb} - s}{t}}^{\frac{v_l - p^{wb} - s}{t}} (1-\theta) d\lambda \ ,$$

$$D^{wb} = \int\limits_0^1 \int\limits_{-\frac{v_h - p^{wb} - s}{t}}^{\frac{v_h - p^{wb} - s}{t}} \theta d\lambda d\theta + \int\limits_0^1 \int\limits_{-\frac{v_l - p^{wb} - s}{t}}^{\frac{v_l - p^{wb} - s}{t}} (1-\theta) d\lambda d\theta \ .$$

Plugging in the equilibrium prices, we get equilibrium retail platform profit as follows:

$$\pi_R^{wb*} = \frac{(v_h + v_l - 2s)^2}{32t} \ . \tag{B.1}$$

In stage 1, plugging in the equilibrium wholesale price, we can get the equilibrium manufacturer profit:

$$\pi_M^{wb*} = \frac{(v_h + v_l - 2s)^2}{16t} \ .$$

The total consumer surplus can be calculated as:

$$\begin{aligned} CS^{wb} = & \int\limits_0^1 \int\limits_{-\frac{v_h - p^{wb} - s}{t}}^{\frac{v_h - p^{wb} - s}{t}} \theta(v_h - p^{wb} - s - t \mid \lambda \mid) d\lambda d\theta \\ & + \int\limits_0^1 \int\limits_{-\frac{v_l - p^{wb} - s}{t}}^{\frac{v_l - p^{wb} - s}{t}} (1-\theta)(v_l - p^{wb} - s - t \mid \lambda \mid) d\lambda d\theta \ . \end{aligned}$$

$$CS^{wb*} = \frac{17{v_h}^2 - 30 v_h v_l + 17{v_l}^2 - 4s(v_h + v_l) + 4s^2}{64t} \ . \tag{B.2}$$

Analogous to CS, social welfare can be calculated as:

$$SW^{wb} = \int_{0}^{1} \int_{-\frac{v_h - p^{wb} - s}{t}}^{\frac{v_h - p^{wb} - s}{t}} \theta(v_h - s - t \mid \lambda \mid) d\lambda d\theta$$

$$+ \int_{0}^{1} \int_{-\frac{v_l - p^{wb} - s}{t}}^{\frac{v_l - p^{wb} - s}{t}} (1-\theta)(v_l - s - t \mid \lambda \mid) d\lambda d\theta \ .$$

$$SW^{wb*} = \frac{23{v_h}^2 - 18 v_h v_l + 23{v_l}^2 - 28s(v_h + v_l) + 28s^2}{64t} \ . \tag{B.3}$$

Proof of Lemma 4

The first-order condition for the retail platform's optimization problem in stage 4 is given by the following:

$$\frac{\partial \pi_R^{wm}}{\partial p^{wm}} = \frac{v_h + v_l + 2s + 2w^{wm} - 4p^{wm} - 4s\hat{\theta}^{wm}}{t} = 0 \ .$$

Solving the above equation, we obtain the equilibrium retail price in terms of the wholesale price and the membership base given as follows:

$$p^{wm*} = \frac{v_h + v_l + 2s + 2w^{wm} - 4s\hat{\theta}^{wm}}{4} \ .$$

We further verify the second-order condition:

$$\frac{\partial^2 \pi_R^{wm}}{\partial p^{wm2}} = -\frac{4}{t} < 0 \ .$$

The first-order condition for the manufacturer's optimization problem in stage 3 is given by the following:

$$\frac{\partial \pi_M^{wm}}{\partial w^{wm}} = \frac{v_h + v_l - 2s - 4w^{wm}}{2t} = 0 \ .$$

Solving the above equation, we can get the equilibrium wholesale price as follows:

$$w^{wm*} = \frac{v_h + v_l - 2s}{4} \ .$$

We also verify the second-order condition on the manufacturer's sides:

$$\frac{\partial^2 \pi_M^{wm}}{\partial w^{wm2}} = \frac{2}{t} < 0 \ .$$

Besides the program administration cost f, the profit of the retail platform consists of three parts: retail platform's net revenue collected from the manufacturers (**NR**), membership fee paid by subscribing consumers (**MF**), and absorbed shipping cost (**SC**). These three parts are calculated as follows:

$$\begin{aligned} NR^{wm} = & \Big(\int_0^{\hat{\theta}^{wm}} \int_{-\frac{v_h - p^{wm} - s}{t}}^{\frac{v_h - p^{wm} - s}{t}} \theta d\lambda d\theta + \int_0^{\hat{\theta}^{wm}} \int_{-\frac{v_l - p^{wm} - s}{t}}^{\frac{v_l - p^{wm} - s}{t}} (1-\theta) d\lambda d\theta \\ & + \int_{\hat{\theta}^{wm}}^{1} \int_{-\frac{v_h - p^{wm}}{t}}^{\frac{v_h - p^{wm}}{t}} \theta d\lambda d\theta + \int_{\hat{\theta}^{wm}}^{1} \int_{-\frac{v_l - p^{wm}}{t}}^{\frac{v_l - p^{wm}}{t}} (1-\theta) d\lambda d\theta \Big) (p^{wm} - w^{wm}) \ , \\ SC^{wm} = & \Big(\int_{\hat{\theta}^{wm}}^{1} \int_{-\frac{v_h - p^{wm}}{t}}^{\frac{v_h - p^{wm}}{t}} \theta d\lambda d\theta + \int_{\hat{\theta}^{wm}}^{1} \int_{-\frac{v_l - p^{wm}}{t}}^{\frac{v_l - p^{wm}}{t}} (1-\theta) d\lambda d\theta \Big) s \ , \\ MF^{wm} = & (1 - \hat{\theta}^{wm}) M^{wm} \ . \end{aligned}$$

Calculating the retail platform profit using the formula $\pi_R^{wm} = NR^{wm} + MF^{wm} - SC^{wm} - f(1-\hat{\theta}^{wm})^2$, we obtain:

$$\begin{aligned} \pi_R^{wm} = & [(v_h + v_l)^2 - 32tf - 44s^2 + 4s(9v_l - 7v_h) + 8\hat{\theta}^{wm}(8tf + s(6s + 7v_h - 9v_l) \\ & -4(tf + s(v_h - v_l))\hat{\theta}^{wm})][32t]^{-1} \ . \end{aligned}$$

Thus, the retail platform's problem of choosing the membership fee in stage 1 becomes equivalent to choosing the membership base in the stage 1.

The first-order condition for the retail platform's optimization problem in stage 1 is given by the following:

$$\frac{\partial \pi_R^{wm}}{\partial \hat{\theta}^{wm}} = \frac{8tf + s(6s + 7v_h - 9v_l) - 8(tf + s(v_h - v_l))\hat{\theta}^{wm}}{4t} = 0 \ .$$

Solving the above equation, we obtain the optimal membership base given as follows:

$$\hat{\theta}^{wm*} = \frac{8tf + 6s^2 + 7sv_h - 9sv_l}{8tf + 8sv_h - 8sv_l} \ .$$

We verify the second-order condition:

$$\frac{\partial^2 \pi_R^{wm}}{\partial \hat{\theta}^{wm2}} = -\frac{2s(v_h - v_l)}{t} < 0 \ .$$

It is easily verified that $\hat{\theta}^{wm*} < 1$ if and only if $s < \frac{v_h+v_l}{6}$; and $\hat{\theta}^{wm*} > 0$ if and only if $f > \frac{s(9v_l-7v_h-6s)}{8t}$, which is true given by the assumption $f > \frac{s(5v_l-3v_h-2s)}{4t}$. The equilibrium retail platform profit is then given as follows:

$$\begin{aligned} \pi_R^{wm*} = \ & [2tf(v_h + v_l - 2s)^2 + s(36s^3 - s(7v_h - 9v_l)(v_h + v_l) + 2(v_h - v_l)(v_h + v_l)^2 \\ & -4s^2(v_h + 5v_l))][64t(tf + s(v_h - v_l))]^{-1} \ . \end{aligned} \tag{B.4}$$

The demand from a consumer of type θ without and with the membership, and the overall demand are given by:

$$D^{wm*}_{\theta<\hat{\theta}^{wm}} = \int\limits_{-\frac{v_h - p^{wm} - s}{t}}^{\frac{v_h - p^{wm} - s}{t}} \theta d\lambda + \int\limits_{-\frac{v_l - p^{wm} - s}{t}}^{\frac{v_l - p^{wm} - s}{t}} (1-\theta) d\lambda \ ,$$

$$D^{wm*}_{\theta>\hat{\theta}^{wm}} = \int\limits_{-\frac{v_h - p^{wm}}{t}}^{\frac{v_h - p^{wm}}{t}} \theta d\lambda + \int\limits_{-\frac{v_l - p^{wm}}{t}}^{\frac{v_l - p^{wm}}{t}} (1-\theta) d\lambda \ ,$$

$$D^{wm} = \int\limits_{0}^{\hat{\theta}^{wm}} \int\limits_{-\frac{v_h - p^{wm} - s}{t}}^{\frac{v_h - p^{wm} - s}{t}} \theta d\lambda d\theta + \int\limits_{0}^{\hat{\theta}^{wm}} \int\limits_{-\frac{v_l - p^{wm} - s}{t}}^{\frac{v_l - p^{wm} - s}{t}} (1-\theta) d\lambda d\theta$$

$$+ \int\limits_{\hat{\theta}^{wm}}^{1} \int\limits_{-\frac{v_h - p^{wm}}{t}}^{\frac{v_h - p^{wm}}{t}} \theta d\lambda d\theta + \int\limits_{\hat{\theta}^{wm}}^{1} \int\limits_{-\frac{v_l - p^{wm}}{t}}^{\frac{v_l - p^{wm}}{t}} (1-\theta) d\lambda d\theta \ .$$

Substituting the equilibrium wholesale price, retail price, and membership base in the above equations, we get the equilibrium demands. Similarly, we get equilibrium manufacturer profit as follows:

$$\pi^{wm*}_{M} = \frac{(v_h + v_l - 2s)^2}{16t} \ .$$

The total consumer surplus can be calculated as:

$$CS^{wm} = \int_{0}^{\hat{\theta}^{wm}} \int_{-\frac{v_h - p^{wm} - s}{t}}^{\frac{v_h - p^{wm} - s}{t}} \theta(v_h - p^{wm} - s - t \mid \lambda \mid) d\lambda d\theta$$
$$+ \int_{0}^{\hat{\theta}^{wm}} \int_{-\frac{v_l - p^{wm} - s}{t}}^{\frac{v_l - p^{wm} - s}{t}} (1-\theta)(v_l - p^{wm} - s - t \mid \lambda \mid) d\lambda d\theta$$
$$+ \int_{\hat{\theta}^{wm}}^{1} \int_{-\frac{v_h - p^{wm}}{t}}^{\frac{v_h - p^{wm}}{t}} \theta(v_h - p^{wm} - t \mid \lambda \mid) d\lambda d\theta$$
$$+ \int_{\hat{\theta}^{wm}}^{1} \int_{-\frac{v_l - p^{wm}}{t}}^{\frac{v_l - p^{wm}}{t}} (1-\theta)(v_l - p^{wm} - t \mid \lambda \mid) d\lambda d\theta - MF^{wm} \ ,$$

$$\begin{aligned} CS^{wm*} = \ & [t^2 f^2 (4s^2 + 17v_h^2 - 30 v_h v_l + 17 v_l^2 - 4s(v_h + v_l)) + 2tfs(4s^2(3v_h + v_l) - 12s^3 \\ & - s(5v_h - 3v_l)(v_h + v_l) + (v_h - v_l)(17v_h^2 - 30v_h v_l + 17v_l^2)) \\ & + s^2(36s^4 - 24s^3 v_l + s^2(v_l - 3v_h)^2 - s(5v_h - 3v_l)(v_h - v_l)(v_h + v_l) \\ & + (v_h - v_l)^2(17v_h^2 - 30v_h v_l + 17v_l^2))][64t(tf + s(v_h - v_l))^2]^{-1} \ . \end{aligned} \tag{B.5}$$

Similarly, social welfare can be calculated as:

$$SW^{wm} = \int_{0}^{\hat{\theta}^{wm}} \int_{-\frac{v_h - p^{wm} - s}{t}}^{\frac{v_h - p^{wm} - s}{t}} \theta(v_h - s - t \mid \lambda \mid) d\lambda d\theta + \int_{0}^{\hat{\theta}^{wm}} \int_{-\frac{v_l - p^{wm} - s}{t}}^{\frac{v_l - p^{wm} - s}{t}} (1-\theta)(v_l - s - t \mid \lambda \mid) d\lambda d\theta$$
$$+ \int_{\hat{\theta}^{wm}}^{1} \int_{-\frac{v_h - p^{wm}}{t}}^{\frac{v_h - p^{wm}}{t}} \theta(v_h - s - t \mid \lambda \mid) d\lambda d\theta + \int_{\hat{\theta}^{wm}}^{1} \int_{-\frac{v_l - p^{wm}}{t}}^{\frac{v_l - p^{wm}}{t}} (1-\theta)(v_l - s - t \mid \lambda \mid) d\lambda d\theta$$
$$- f(1 - \hat{\theta}^{wm})^2 \ .$$

$$
\begin{aligned}
SW^{wm*} = \quad & [t^2 f^2(28s^2 + 23v_h^2 - 18v_h v_l + 23v_l^2 - 28s(v_h + v_l)) + tfs(12s^3 + s^2(60v_h - 52v_l) \\
& -s(57v_h - 55v_l)(v_h + v_l) + 2(v_h - v_l)(23v_h^2 - 18v_h v_l + 23v_l^2)) \\
& +s^2(36s^4 + 12s^3(3v_h - 5v_l) - 28s(v_h - v_l)^2(v_h + v_l) \\
& +(v_h - v_l)^2(23v_h^2 - 18v_h v_l + 23v_l^2) + s^2(21v_h^2 - 54v_h v_l + 37v_l^2))] \\
& [64t(tf + s(v_h - v_l))^2]^{-1} \ .
\end{aligned}
\tag{B.6}
$$

Proof of Proposition 8

From Proof of Lemma 4, we know that $\hat{\theta}^{wm*} \in (0,1)$ if and only if $s < \frac{v_h+v_l}{6}$, in which case we have an interior solution of π_R^{wm*}. Then the retail platform profit gain $\Delta\pi_R^{w*}$ equals $\pi_R^{wm*} - \pi_R^{wb*}$. Substituting Equations B.4 and B.1, we get the equilibrium retail platform profit gain as follows:

$$
\Delta\pi_R^{w*} = \frac{s^2(v_h + v_l - 6s)^2}{64t(tf + s(v_h - v_l))} > 0 \ . \tag{B.7}
$$

Next, we examine the corner solutions. If $s \geq \frac{v_h+v_l}{6}$, then $\hat{\theta}^{wm*} = 1$. Essentially, no consumer would join the MFS program and the equilibrium reduces to that of the benchmark case.

Proof of Corollary 1

From Proof of Lemma 4, we get that $SC^{wm*} - MF^{wm*} = \frac{s(1-\hat{\theta}^{wm})(s+(v_h-v_l)(1-\hat{\theta}^{wm}))}{t} > 0$. Thus, we have $MF^{wm*} < SC^{wm*}$.

Proof of Lemma 5

The first-order condition for manufacturer's optimization problem in stage 2 is given by the following:

$$
\frac{\partial \pi_M^{ab}}{\partial p^{ab}} = \frac{(v_h + v_l - 4p^{ab} - 2s)(1 - \alpha^{ab})}{t} = 0 \ .
$$

Solving the above equation, we obtain the equilibrium retail price. We further verify the second-order condition:

$$
\frac{\partial^2 \pi_M^{ab}}{\partial p^{ab2}} = -\frac{1 - \alpha^{ab}}{t} < 0 \ .
$$

The demand from a consumer of type θ and the overall demand are given by:

$$D_{\theta}^{ab} = \int_{-\frac{v_h - p^{ab} - s}{t}}^{\frac{v_h - p^{ab} - s}{t}} \theta d\lambda + \int_{-\frac{v_l - p^{ab} - s}{t}}^{\frac{v_l - p^{ab} - s}{t}} (1-\theta) d\lambda \ ,$$

$$D^{ab} = \int_0^1 \int_{-\frac{v_h - p^{ab} - s}{t}}^{\frac{v_h - p^{ab} - s}{t}} \theta d\lambda d\theta + \int_0^1 \int_{-\frac{v_l - p^{ab} - s}{t}}^{\frac{v_l - p^{ab} - s}{t}} (1-\theta) d\lambda d\theta \ .$$

Substituting the equilibrium retail price, we get equilibrium manufacturer profit as follows:

$$\pi_M^{ab*} = \frac{(v_h + v_l - 2s)^2 (1 - \alpha^{ab})}{8t} \ .$$

In stage 1, plugging in the equilibrium retail price and solving for the retail platform's optimization problem with binding constraints, $\pi_M^{pb*} = \mu$, we can get the equilibrium commission rate α^{ab*} and it is easily verified that $0 < \alpha^{ab*} < 1$ given that $\mu < \frac{(v_h + v_l - 2s)^2}{8t}$.

The equilibrium retail platform profit is:

$$\pi_R^{ab*} = \frac{(v_h + v_l - 2s)^2}{8t} - \mu \ . \tag{B.8}$$

The total consumer surplus can be calculated as:

$$CS^{ab} = \int_0^1 \int_{-\frac{v_h - p^{ab} - s}{t}}^{\frac{v_h - p^{ab} - s}{t}} \theta (v_h - p^{ab} - s - t \mid \lambda \mid) d\lambda d\theta$$
$$+ \int_0^1 \int_{-\frac{v_l - p^{ab} - s}{t}}^{\frac{v_l - p^{ab} - s}{t}} (1-\theta)(v_l - p^{ab} - s - t \mid \lambda \mid) d\lambda d\theta \ .$$

$$CS^{ab*} = \frac{4s^2 + 5v_h^2 - 6v_h v_l + 5v_l^2 - 4s(v_h + v_l)}{16t} \ . \tag{B.9}$$

Analogous to CS, social welfare can be calculated as:

$$SW^{ab} = \int_{0}^{1} \int_{-\frac{v_h - p^{ab} - s}{t}}^{\frac{v_h - p^{ab} - s}{t}} \theta(v_h - s - t \mid \lambda \mid) d\lambda d\theta + \int_{0}^{1} \int_{\frac{v_l - p^{ab} - s}{t}}^{\frac{v_l - p^{ab} - s}{t}} (1-\theta)(v_l - s - t \mid \lambda \mid) d\lambda d\theta \ .$$

$$SW^{ab*} = \frac{12s^2 + 7v_h^2 - 12v_h v_l + 7v_l^2 - 12s(v_h + v_l)}{16t} \ . \tag{B.10}$$

Proof of Lemma 6

The first-order condition for manufacturer's optimization problem in stage 4 is given by the following:

$$\frac{\partial \pi_M^{am}}{\partial p^{am}} = \frac{(v_h + v_l - 2p^{am} - 2s\hat{\theta}^{am})(1 - \alpha^{am})}{t} = 0 \ .$$

Solving the above equation, we obtain the equilibrium retail price given as follows:

$$p^{am*} = \frac{v_h + v_l - 2s\hat{\theta}^{am}}{4} \ .$$

We further verify the second-order condition:

$$\frac{\partial^2 \pi_M^{am}}{\partial p^{am2}} = -\frac{4(1 - \alpha^{am})}{t} < 0 \ .$$

In stage 3, the retail platform will extract the manufacturer's gain from the MFS program by choosing a commission rate α^{am} that leaves the reservation profit as the surplus for the manufacturer.

In stage 1, besides the program administration cost f, the profit of the retail platform consists of three parts: retail platform's net revenue collected from the manufacturers (**NR**), membership fee paid by subscribing consumers (**MF**), and absorbed shipping cost (**SC**).

These three parts are calculated as follows:

$$
\begin{aligned}
NR^{am} = \;& \Big(\int\limits_{0}^{\hat{\theta}^{am}} \int\limits_{-\frac{v_h - p^{am} - s}{t}}^{\frac{v_h - p^{am} - s}{t}} \theta d\lambda d\theta + \int\limits_{0}^{\hat{\theta}^{am}} \int\limits_{-\frac{v_l - p^{am} - s}{t}}^{\frac{v_l - p^{am} - s}{t}} (1-\theta) d\lambda d\theta \\
& + \int\limits_{\hat{\theta}^{am}}^{1} \int\limits_{-\frac{v_h - p^{am}}{t}}^{\frac{v_h - p^{am}}{t}} \theta d\lambda d\theta + \int\limits_{\hat{\theta}^{am}}^{1} \int\limits_{-\frac{v_l - p^{am}}{t}}^{\frac{v_l - p^{am}}{t}} (1-\theta) d\lambda d\theta \Big) p^{am} - \mu \ , \\
SC^{am} = \;& \Big(\int\limits_{\hat{\theta}^{am}}^{1} \theta d\theta \int\limits_{-\frac{v_h - p^{am}}{t}}^{\frac{v_h - p^{am}}{t}} 1 d\lambda + \int\limits_{\hat{\theta}^{am}}^{1} (1-\theta) d\theta \int\limits_{-\frac{v_l - p^{am}}{t}}^{\frac{v_l - p^{am}}{t}} 1 d\lambda \Big) s \ , \\
MF^{am} = \;& (1 - \hat{\theta}^{am}) M^{am} \ .
\end{aligned}
$$

Calculating the retail platform profit using the formula $\pi_R^{am} = NR^{am} + MF^{am} - SC^{am} - f(1-\hat{\theta}^{am})^2$, we obtain:

$$
\begin{aligned}
\pi_R^{am} = \;& [(v_h + v_l)^2 - 8s^2 - 8s(v_h - v_l) - 8tf + 4\hat{\theta}^{am}(4tf + s(2s + 3v_h - 5v_l) \\
& + (s(s - 2v_h + 2v_l) - 2tf)\hat{\theta}^{am})][8t]^{-1} - \mu \ .
\end{aligned}
$$

Thus, the retail platform's problem of choosing the membership fee in stage 1 becomes equivalent to choosing the membership base in the stage 1.

The first-order condition for the retail platform's optimization problem in stage 1 is given by the following:

$$
\frac{\partial \pi_R^{am}}{\partial \hat{\theta}^{am}} = \frac{4tf + s(2s + 3v_h - 5v_h) + 2(s(s - 2v_h + 2v_h) - 2tf)\hat{\theta}^{am}}{2t} = 0 \ .
$$

Solving the above equation, we obtain the optimal membership base given as follows:

$$
\hat{\theta}^{am*} = \frac{4tf + s(2s + 3v_h - 5v_l)}{4tf - 2s(s - 2v_h + 2v_l)} \ .
$$

We verify the second-order condition:

$$\frac{\partial^2 \pi_R^{am}}{\partial \hat{\theta}^{am2}} = \frac{s(s-2v_h+2v_l)}{t} - 2f \ .$$

For the solution to be a local maximum, we need to have $f > \frac{s(s-2v_h+2v_l)}{2t}$. It is easily verified that $\hat{\theta}^{am*} < 1$ if and only if $s < \frac{v_h+v_l}{4}$; and $\hat{\theta}^{am*} > 0$ if and only if $f > \frac{s(5v_l-3v_h-2s)}{4t}$, which is true by the upfront assumption. Given any $s < \frac{v_h+v_l}{4}$, we have $f > \frac{s(5v_l-3v_h-2s)}{4t} > \frac{s(s-2v_h+2v_l)}{2t}$. The equilibrium retail platform profit is then given as follows:

$$\pi_R^{am*} = \frac{tf(v_h+v_l-2s)^2 + s(6s^3+2s^2(v_h-3v_l)+(v_h-v_l)(v_h+v_l)^2-4s(v_h^2-v_l^2))}{4t(2tf-s(s-2v_h+2v_l))} - \mu \ . \tag{B.11}$$

The demand from a consumer of type θ without and with the membership, and the overall demand are given by:

$$D_{\theta<\hat{\theta}^{am}}^{am} = \int_{-\frac{v_h-p^{am}-s}{t}}^{\frac{v_h-p^{am}-s}{t}} \theta d\lambda + \int_{-\frac{v_l-p^{am}-s}{t}}^{\frac{v_l-p^{am}-s}{t}} (1-\theta)d\lambda \ ,$$

$$D_{\theta\geq\hat{\theta}^{am}}^{am} = \int_{-\frac{v_h-p^{am}}{t}}^{\frac{v_h-p^{am}}{t}} \theta d\lambda + \int_{-\frac{v_l-p^{am}}{t}}^{\frac{v_l-p^{am}}{t}} (1-\theta)d\lambda \ ,$$

$$D^{am} = \int_0^{\hat{\theta}^{am}} \int_{\frac{v_h-p^{am}-s}{t}}^{\frac{v_h-p^{am}-s}{t}} \theta d\lambda d\theta + \int_0^{\hat{\theta}^{am}} \int_{-\frac{v_l-p^{am}-s}{t}}^{\frac{v_l-p^{am}-s}{t}} (1-\theta)d\lambda d\theta$$
$$+ \int_{\hat{\theta}^{am}}^{1} \int_{-\frac{v_h-p^{am}}{t}}^{\frac{v_h-p^{am}}{t}} \theta d\lambda d\theta + \int_{\hat{\theta}^{am}}^{1} \int_{-\frac{v_l-p^{am}}{t}}^{\frac{v_l-p^{am}}{t}} (1-\theta)d\lambda d\theta \ .$$

Similarly, the commission rate α^{am*} can be calculated by plugging the equilibrium retail price and membership base. It is easily verified that $0 < \alpha^{am*} < 1$ given that $\mu < \frac{(v_h+v_l-2s)^2}{8t}$.

The total consumer surplus can be calculated as:

$$
\begin{aligned}
CS^{am} = & \int_{0}^{\hat{\theta}^{am}} \int_{-\frac{v_h - p^{am} - s}{t}}^{\frac{v_h - p^{am} - s}{t}} \theta(v_h - p^{am} - s - t \mid \lambda \mid) d\lambda d\theta \\
& + \int_{0}^{\hat{\theta}^{am}} \int_{-\frac{v_l - p^{am} - s}{t}}^{\frac{v_l - p^{am} - s}{t}} (1-\theta)(v_l - p^{am} - s - t \mid \lambda \mid) d\lambda d\theta \\
& + \int_{\hat{\theta}^{am}}^{1} \int_{-\frac{v_h - p^{am}}{t}}^{\frac{v_h - p^{am}}{t}} \theta(v_h - p^{am} - t \mid \lambda \mid) d\lambda d\theta \\
& + \int_{\hat{\theta}^{am}}^{1} \int_{-\frac{v_l - p^{am}}{t}}^{\frac{v_l - p^{am}}{t}} (1-\theta)(v_l - p^{am} - t \mid \lambda \mid) d\lambda d\theta - MF^{am} \ .
\end{aligned}
$$

$$
\begin{aligned}
CS^{am*} = \ & [t^2 f^2 (4s^2 + 5v_h^2 - 6v_h v_l + 5v_l^2 - 4s(v_h + v_l)) + 2tfs(s^2(9v_h + v_l) \\
& -6s^3 + s(2v_h v_l - 7v_h^2 + v_l^2) + (v_h - v_l)(5v_h^2 - 6v_h v_l + 5v_l^2)) \\
& +s^2(9s^4 - s(v_h - v_l)(v_l - 3v_h)^2 - 2s^3(v_h + 5v_l) + 4s^2(2v_h^2 + 2v_h v_h + v_l^2) \\
& +(v_h - v_l)^2(5v_h^2 - 6v_h v_l + 5v_l^2)))][4t(s(s - 2v_h + 2v_l) - 2tf)^2]^{-1} \ .
\end{aligned}
\tag{B.12}
$$

Similarly, social welfare can be calculated as:

$$SW^{am} = \int_{0}^{\hat{\theta}^{am}} \int_{-\frac{v_h - p^{am} - s}{t}}^{\frac{v_h - p^{am} - s}{t}} \theta(v_h - s - t \mid \lambda \mid) d\lambda d\theta$$
$$+ \int_{0}^{\hat{\theta}^{am}} \int_{-\frac{v_l - p^{am} - s}{t}}^{\frac{v_l - p^{am} - s}{t}} (1-\theta)(v_l - s - t \mid \lambda \mid) d\lambda d\theta$$
$$+ \int_{\hat{\theta}^{am}}^{1} \int_{-\frac{v_h - p^{am}}{t}}^{\frac{v_h - p^{am}}{t}} \theta(v_h - s - t \mid \lambda \mid) d\lambda d\theta$$
$$+ \int_{\hat{\theta}^{am}}^{1} \int_{-\frac{v_l - p^{am}}{t}}^{\frac{v_l - p^{am}}{t}} (1-\theta)(v_l - s - t \mid \lambda \mid) d\lambda d\theta - f(1-\hat{\theta}^{am})^2 \ .$$

$$\begin{aligned} SW^{am*} = \ & [t^2 f^2 (12s^2 + 7v_h^2 - 2v_h v_l + 7v_l^2 - 12s(v_h + v_l)) + tfs(2s^2(17v_h - 7v_l) - 4s^3 \\ & +2(v_h - v_l)(7v_h^2 - 2v_h v_l + 7v_l^2) + s(2v_h v_l - 31v_h^2 + 17v_l^2)) \\ & +s^2(3s^4 + 8s^3(v_h - 2v_l) + 4s^2(4v_h^2 - 6v_h v_l + 3v_l^2) \\ & +(v_h - v_l)^2(7v_h^2 - 2v_h v_l + 7v_l^2) \\ & +2s(11v_h^2 v_l - 9v_h^3 + v_h v_l^2 - 3v_l^3))][4t(s(s - 2v_h + 2v_l) - 2tf)^2]^{-1} \ . \end{aligned} \tag{B.13}$$

Proof of Proposition 9

From Proof of Lemma 6, we know that $\hat{\theta}^{am*} \in (0,1)$ if and only if $s < \frac{v_h + v_l}{4}$, in which case we have an interior solution of π_R^{am*}. Then the retail platform profit gain $\Delta\pi_R^{a*} = \pi_R^{am*} - \pi_R^{ab*}$. Substituting Equations B.11 and B.8, we get the equilibrium retail platform profit gain as follows:

$$\Delta\pi_R^{a*} = \frac{s^2(v_h + v_l - 4s)^2}{8t(2tf - s(s - 2v_h + 2v_l))} > 0 \ . \tag{B.14}$$

Next, we examine the corner solution. If $s \geq \frac{v_h+v_l}{4}$, then $\hat{\theta}^{am*} = 1$. Essentially, no consumer would join the MFS program and the equilibrium reduces to that of the benchmark case.

Proof of Corollary 2

From Proof of Lemma 6, we get that $SC^{am*} - MF^{am*} = \frac{s(1-\hat{\theta}^{am})(s+(v_h-v_l)(1-\hat{\theta}^{am}))}{t} > 0$. Thus, we have $MF^{am*} < SC^{am*}$.

Proof of Proposition 10

If $s \geq \frac{v_h+v_l}{4}$, the retail platform will not implement the MFS program under either the agency model or the wholesale model, and then $\Delta\pi_R^{a*} = \Delta\pi_R^{w*} = 0$. If $\frac{v_h+v_l}{6} \leq s < \frac{v_h+v_l}{4}$, the retail platform will only implement the MFS program under the agency model but not the wholesale model, and thus $\Delta\pi_R^{a*} > \Delta\pi_R^{w*} = 0$. If $s < \frac{v_h+v_l}{6}$, the retail platform will implement the MFS program under both the agency model and the wholesale model, and the difference between the retail platform profit gains can be calculated by taking the difference of Equations B.14 and B.7 as follows:

$$\Delta\pi_R^{a*} - \Delta\pi_R^{w*} = \frac{s^2\left(\frac{8(v_h+v_l-4s)^2}{2tf-s(s-2v_h+2v_l)} - \frac{(v_h+v_l-6s)^2}{tf+s(v_h-v_l)}\right)}{64t}.$$

We know from the Proof of Lemma 4 that $f > \frac{s(5v_l-3v_h-2s)}{4t}$, so $2tf - s(s-2v_h+2v_l) > \frac{s(v_h+v_l-4s)}{2} > 0$. Then it can be shown that $\frac{8(v_h+v_l-4s)^2}{2tf-s(s-2v_h+2v_l)} - \frac{(v_h+v_l-6s)^2}{tf+s(v_h-v_l)} > \frac{8(v_h+v_l-6s)^2}{2tf-s(-2v_h+2v_l)} - \frac{(v_h+v_l-6s)^2}{tf+s(v_h-v_l)} = \frac{3(v_h+v_l-6s)^2}{tf+s(v_h-v_l)}$. Therefore $\Delta\pi_R^{a*} - \Delta\pi_R^{w*} > 0$ is true.

Proof of Corollary 3

Since we are only comparing the interior solutions, we assume $s < \frac{v_h+v_l}{6}$ for the following analysis:

(i):

$$1-\hat{\theta}^{am*} > 1-\hat{\theta}^{wm*} = \frac{s(v_h+v_l-4s)}{4tf+2s(2v_h-2v_l-s)} - \frac{s(v_h+v_l-6s)}{8(tf+s(v_h-v_l))}$$

$$> \frac{s(v_h+v_l-6s)}{4tf+2s(2v_h-2v_l)} - \frac{s(v_h+v_l-6s)}{8(tf+s(v_h-v_l))}$$

$$= \frac{s(v_h+v_l-6s)}{8(tf+s(v_h-v_l))} > 0 \ .$$

(ii): From Proof of Lemma 5, we get $SC^{wm*} - MF^{wm*} = \frac{s(1-\hat{\theta}^{wm})(s+(v_h-v_l)(1-\hat{\theta}^{wm}))}{t}$. Similarly, from Proof of Lemma 6, we get $SC^{am*} - MF^{am*} = \frac{s(1-\hat{\theta}^{am})(s+(v_h-v_l)(1-\hat{\theta}^{am}))}{t}$. The two equations are in the same form that is a decreasing function of $\hat{\theta}^{wm}$ or $\hat{\theta}^{am}$. By Proof of Proposition 4 below, we know that $\hat{\theta}^{am*} < \hat{\theta}^{wm*}$, so we have $SC^{am*} - MF^{am*} > SC^{wm*} - MF^{wm*}$.

(iii): From Equations 3.26 and 3.15, we get $\Delta PM^{a*} - \Delta PM^{w*} = [s^3(s(6s-5v_h+3v_l)-4tf)][8(tf+s(v_h-v_l))(s(s-2v_h+2v_l)-2tf)]^{-1}$. Similarly, given that $f > \frac{s(5v_l-3v_h-2s)}{4t}$ by Proof of Lemma 4, we have $s(6s-5v_h+3v_l)-4tf < 2s(4s-v_h-v_l) < 0$ and $s(s-2v_h+2v_l)-2tf < \frac{s(4s-v_h-v_l)}{2} < 0$.Therefore, it is true that $\Delta PM^{a*} > \Delta PM^{w*}$.

(iv): It is straightforward to get the result by comparing Equations 3.27 and 3.16.

Proof of Proposition 11

This result follows by combining the results from Proposition 8 and Proposition 9.

Analysis of Consignment Model

When there is no MFS, in stage 2 of the game, the manufacturer's optimization problem is given as the following:

$$\arg\max_{p^{cb}} \ \pi_M^{cb} = \Big(\int_0^1 \int_{-\frac{v_h-p^{cb}-s}{t}}^{\frac{v_h-p^{cb}-s}{t}} \theta d\lambda d\theta + \int_0^1 \int_{-\frac{v_l-p^{cb}-s}{t}}^{\frac{v_l-p^{cb}-s}{t}} (1-\theta) d\lambda d\theta\Big)(p^{cb}-w^{cb}) \ .$$

Solving the first-order condition, we obtain the equilibrium retail price:

$$p^{cb*} = \frac{v_h + v_l - 2s + 2w^{cb}}{4} .$$

In stage 1, the retailer maximizes its profit by solving the following model:

$$\arg\max_{w^{cb}} \ \pi_R^{cb} = \Big(\int_0^1 \int_{-\frac{v_h - p^{cb} - s}{t}}^{\frac{v_h - p^{cb} - s}{t}} \theta d\lambda d\theta + \int_0^1 \int_{-\frac{v_l - p^{cb} - s}{t}}^{\frac{v_l - p^{cb} - s}{t}} (1-\theta) d\lambda d\theta\Big) w^{cb} .$$

Plugging in the equilibrium retail price and solving the first-order condition, we obtain the equilibrium wholesale price:

$$w^{cb*} = \frac{v_h + v_l - 2s}{4} ,$$

Given the equilibrium prices, the retailer and manufacturer equilibrium profits equal:

$$\pi_R^{cb*} = \frac{(v_h + v_l - 2s)^2}{16t} . \tag{B.15}$$

$$\pi_M^{cb*} = \frac{(v_h + v_l - 2s)^2}{32t} .$$

When the retail platform implements the MFS program, the manufacturer's optimization problem in stage 4 is formulated as following:

$$\begin{aligned} \arg\max_{p^{cm}} \ \pi_M^{cm} = & \Big(\int_0^{\hat{\theta}^{cm}} \int_{-\frac{v_h - p^{cm} - s}{t}}^{\frac{v_h - p^{cm} - s}{t}} \theta d\lambda d\theta + \int_0^{\hat{\theta}^{cm}} \int_{-\frac{v_l - p^{cm} - s}{t}}^{\frac{v_l - p^{cm} - s}{t}} (1-\theta) d\lambda d\theta \\ & + \int_{\hat{\theta}^{cm}}^1 \int_{-\frac{v_h - p^{cm}}{t}}^{\frac{v_h - p^{cm}}{t}} \theta d\lambda d\theta + \int_{\hat{\theta}^{cm}}^1 \int_{-\frac{v_l - p^{cm}}{t}}^{\frac{v_l - p^{cm}}{t}} (1-\theta) d\lambda d\theta\Big) (p^{cm} - w^{cm}) . \end{aligned}$$

Solving the first-order condition, we obtain the equilibrium retail price:

$$p^{cm*} = \frac{v_h + v_l + 2w^{cm} + 2s\hat{\theta}^{cm}}{4} .$$

In stage 3, the retailer maximize its profit by solving the following model:

$$
\begin{aligned}
\arg\max_{w^{cm}} \ \pi_R^{cm} = \ & \Big(\int_0^{\hat{\theta}^{cm}} \int_{-\frac{v_h - p^{cm} - s}{t}}^{\frac{v_h - p^{cm} - s}{t}} \theta d\lambda d\theta + \int_0^{\hat{\theta}^{cm}} \int_{-\frac{v_l - p^{cm} - s}{t}}^{\frac{v_l - p^{cm} - s}{t}} (1-\theta) d\lambda d\theta \Big) w^{cm} \\
& + \Big(\int_{\hat{\theta}^{cm}}^{1} \int_{-\frac{v_h - p^{cm}}{t}}^{\frac{v_h - p^{cm}}{t}} \theta d\lambda d\theta + \int_{\hat{\theta}^{cm}}^{1} \int_{-\frac{v_l - p^{cm}}{t}}^{\frac{v_l - p^{cm}}{t}} (1-\theta) d\lambda d\theta \Big) (w^{cm} - s) \\
& + MF^{cm} - f(1 - \hat{\theta}^{cm})^2 \ .
\end{aligned}
$$

Plugging in the equilibrium retail price and solving the first-order condition, we obtain the equilibrium wholesale price:

$$
w^{cm*} = \frac{v_h + v_l + 2s - 4s\hat{\theta}^{cm}}{4} \ ,
$$

Following the similar procedure of the main model, we can write down the retail platform profit as:

$$
\begin{aligned}
\pi_R^{cm} = \ & [(v_h + v_l)^2 - 16tf - 20s^2 - 16s(v_h - v_l) + 4\hat{\theta}^{cm}(8tf + s(6s + 7v_h - 9v_l) \\
& -4(tf + s(v_h - v_l))\hat{\theta}^{cm})][16t]^{-1} \ .
\end{aligned}
$$

Solving the first-order condition with respect to $\hat{\theta}^{cm}$ yields:

$$
\hat{\theta}^{cm*} = \frac{8tf + 6s^2 + 7sv_h - 9sv_l}{8tf + 8s(v_h - v_l)} \ .
$$

Given that, the retailer and manufacturer equilibrium profits equal:

$$
\begin{aligned}
\pi_R^{cm*} = \ & [4tf(v_h + v_l - 2s)^2 + s(36s^3 + 4s^2(v_h - 7v_l) - s(15v_h - 17v_l)(v_h + v_l) \\
& +4(v_h - v_l)(v_h + v_l)^2)][64t(tf + s(v_h - v_l))]^{-1} \ .
\end{aligned}
\tag{B.16}
$$

$$
\pi_M^{cm*} = \frac{(v_h + v_l - 2s)^2}{32t} \ .
$$

Proof of Corollary 4

Under the consignment model, the retailer's profit gain from implementing the MFS program can be calculated as the following:

$$\Delta\pi_R^{c*} = \pi_R^{cm*} - \pi_R^{cb*} = \frac{s^2(v_h + v_l - 6s)^2}{64t(tf + s(v_h - v_l))} .$$

It can be seen that $\Delta\pi_R^{c*} = \Delta\pi_R^{w*}$, where $\Delta\pi_R^{w*}$ is the retailer's profit gain from the MFS program under the wholesale model in the main model. Meanwhile, we can show from the above analysis that $\pi_M^{cm*} = \pi_M^{cb*}$, so the manufacturer profit remains the same regardless of the presence of the MFS program.

Analysis of Franchise Model

When there is no MFS, the equilibrium outcomes are identical to those under the agency model of the main model. When the retail platform implements the MFS program, its price optimization problem is formulated as the following:

$$\begin{aligned} \arg\max_{p^{fm}} \pi_R^{fm} = & \Big(\int_0^{\hat{\theta}^{fm}} \int_{-\frac{v_h - p^{fm} - s}{t}}^{\frac{v_h - p^{fm} - s}{t}} \theta d\lambda d\theta + \int_0^{\hat{\theta}^{fm}} \int_{-\frac{v_l - p^{fm} - s}{t}}^{\frac{v_l - p^{fm} - s}{t}} (1-\theta) d\lambda d\theta\Big) p^{fm} \\ & + \Big(\int_{\hat{\theta}^{fm}}^{1} \int_{-\frac{v_h - p^{fm}}{t}}^{\frac{v_h - p^{fm}}{t}} \theta d\lambda d\theta + \int_{\hat{\theta}^{fm}}^{1} \int_{-\frac{v_l - p^{fm}}{t}}^{\frac{v_l - p^{fm}}{t}} (1-\theta) d\lambda d\theta\Big)(p^{fm} - s) \\ & + MF^{fm} - f(1-\hat{\theta}^{fm})^2 - \mu . \end{aligned}$$

Solving the first-order condition, we obtain the equilibrium retail price as:

$$p^{fm*} = \frac{(v_h + v_l + 2s - 4s\hat{\theta}^{fm})}{4} .$$

Similarly, we can solve or the optimal membership base as:

$$\hat{\theta}^{fm*} = \frac{4tf + 4s^2 + 3sv_h + 5sv_l}{4tf + 4sv_h - 4sv_l} .$$

Substituting the equilibrium retail price and membership base, we can then calculate the retailer's profit gain from MFS as:

$$\Delta\pi_R^{f*} = \frac{s^2(v_h + v_l - 4s)^2}{16t(tf + s(v_h - v_l))} \ . \tag{B.17}$$

Proof of Corollary 5

First, we compare the retailer's profit gain with MFS under the agency model and the franchise model (i.e., $\Delta\pi_R^{a*}$ and $\Delta\pi_R^{f*}$)

$$\Delta\pi_R^{a*} - \Delta\pi_R^{f*} = \frac{s^4(v_h + v_l - 4s)^2}{16t(tf + s(v_h - v_l))(2tf - s(s - 2v_h + 2v_l))} \ .$$

This term is non-negative from Proof of Proposition 9. Therefore, $\Delta\pi_R^{a*} \geq \Delta\pi_R^{f*}$.

Next, we compare the retailer's profit gain with MFS under the wholesale model and the franchise model (i.e., $\Delta\pi_R^{w*}$ and $\Delta\pi_R^{a*}$)

$$\Delta\pi_R^{w*} - \Delta\pi_R^{f*} = -\frac{s^2(28s^2 - 20s(v_h + v_l) + 3(v_h + v_l)^2)}{64t(tf + s(v_h - v_l))} \ .$$

Clearly, $\Delta\pi_R^{w*} > \Delta\pi_R^{f*}$ if $28s^2 - 20s(v_h + v_l) + 3(v_h + v_l)^2 < 0$ and vice versa.

Proof of Proposition 12

(a) Under the wholesale model, the difference between consumer surplus with and without the MFS program can be calculated as $CS^{wm*} - CS^{wb*}$. Substituting Equations B.5 and B.2, we get:

$$CS^{wm*} - CS^{wb*} = -\frac{s^2(v_h + v_l - 6s)(2tf(v_h + v_l - 2s) + s(6s^2 + sv_h + v_h^2 - 3sv_l - v_l^2))}{64t(tf + s(v_h - v_l))^2} \ .$$

Clearly, the sign of the term depends on $2tf(v_h+v_l-2s)+s(6s^2+sv_h+v_h^2-3sv_l-v_l^2)$. Given that $f > \frac{s(9v_l-7v_h-6s)}{8t}$, $2tf(v_h+v_l-2s)+s(6s^2+sv_h+v_h^2-3sv_l-v_l^2) > \frac{s(6s+3v_h-5v_l)(6s-v_h-v_l)}{4}$, which is strictly positive if $s < \frac{v_h+v_l}{6}$. Therefore, $CS^{wm*} < CS^{wb*}$ whenever the retail platform implements the MFS program under the wholesale model.

(b) Under the agency model, the difference between consumer surplus with and without the MFS program can be calculated as $CS^{am*} - CS^{ab*}$. Substituting Equations B.12 and B.9, we get:

$$CS^{am*} - CS^{ab*} = -\frac{s^2(v_h + v_l - 4s)(s^2(8s + 5v_h - 11v_l) + 4tf(v_h + v_l - 2s))}{16t(s(s - 2v_h + 2v_l) - 2tf)^2} .$$

Clearly, $CS^{am*} > CS^{ab*}$ if and only if on $s^2(8s + 5v_h - 11v_l) + 4tf(v_h + v_l - 2s) < 0$.

(c) The surplus of any non-member consumer can be calculated as:

$$CS_\theta = \int_{-\frac{v_h - p - s}{t}}^{\frac{v_h - p - s}{t}} \theta(v_h - p - s - t \mid \lambda \mid) d\lambda + \int_{-\frac{v_l - p - s}{t}}^{\frac{v_l - p - s}{t}} (1-\theta)(v_l - p - s - t \mid \lambda \mid) d\lambda$$

$$= \frac{(v_l - s - p)^2(1-\theta) + (v_h - s - p)^2\theta}{t} .$$

Clearly, CS_θ is decreasing in p. We also know that the retail prices are higher with the MFS program under both the wholesale model and the agency model. Thus, non-members are worse off with the MFS program.

(d) Under the wholesale model, the surplus of any consumer without the MFS program can be calculated as:

$$CS_\theta^{wb*} = \int_{-\frac{v_h - p^{wb} - s}{t}}^{\frac{v_h - p^{wb} - s}{t}} \theta(v_h - p^{wb} - s - t \mid \lambda \mid) d\lambda + \int_{-\frac{v_l - p^{wb} - s}{t}}^{\frac{v_l - p^{wb} - s}{t}} (1-\theta)(v_l - p^{wb} - s - t \mid \lambda \mid) d\lambda$$

$$= \frac{(2s + 3v_h - 5v_l)^2(1-\theta) + (2s - 5v_h + 3v_l)^2\theta}{64t} .$$

The surplus of any member with the MFS program can be calculated as:

$$
\begin{aligned}
CS^{wm*}_{\theta \geq \hat{\theta}^{wm}} = & \int_{-\frac{v_h - p^{wm}}{t}}^{\frac{v_h - p^{wm}}{t}} \theta(v_h - p^{wm} - t \mid \lambda \mid) d\lambda + \int_{-\frac{v_l - p^{wm}}{t}}^{\frac{v_l - p^{wm}}{t}} (1-\theta)(v_l - p^{wm} - t \mid \lambda \mid) d\lambda - M^{wm} \\
= & [16s(6s + 3v_h - \frac{(8tf + s(6s + 7v_h - 9v_l))(s + v_h - v_l)}{tf + s(v_h - v_l)} - 5v_l) \\
& +(\frac{s(6tf + s(6s + 5v_h - 7v_l))}{tf + s(v_h - v_l)} + 5v_l - 3v_h)^2(1-\theta) \\
& +(5v_h - 3v_l + \frac{s(6tf + s(6s + 5v_h - 7v_l))}{tf + s(v_h - v_l)})\theta][64t]^{-1} \\
& -[(2s + 3v_h - 5v_l)^2(1-\theta) + (2s - 5v_h + 3v_l)^2\theta][64t]^{-1} \ .
\end{aligned}
$$

It is easily verified that the surplus is higher if and only if $\theta > \theta^{wm*}$, where

$$
\begin{aligned}
\theta^{wm*} = & [128t^2f^2(v_h - v_l) + 2tfs(12s^2 + 64sv_h + 117v_h^2 - 80sv_l + 141v_l^2) \\
& +s^2(12s^2(3v_h - v_l) - 36s^3 + 2(v_h - v_l)(53v_h^2 - 126v_hv_l + 77v_l^2) \\
& +s(127v_h^2 - 290v_hv_l + 159v_l^2))] \\
& [16(8tf + s(6s + 7v_h - 9v_l))(tf + s(v_h - v_l))(v_h - v_l)]^{-1} \ .
\end{aligned}
$$

Similarly, under the agency model, the surplus of any consumer without the MFS program can be calculated as:

$$
\begin{aligned}
CS^{ab*}_{\theta} = & \int_{-\frac{v_h - p^{ab} - s}{t}}^{\frac{v_h - p^{ab} - s}{t}} \theta(v_h - p^{ab} - s - t \mid \lambda \mid) d\lambda \\
& + \int_{-\frac{v_l - p^{ab} - s}{t}}^{\frac{v_l - p^{ab} - s}{t}} (1-\theta)(v_l - p^{ab} - s - t \mid \lambda \mid) d\lambda \\
= & \frac{(2s + v_h - 3v_l)^2 + 8(v_h + v + l - 2s)(v_h - v_l)\theta}{16t} \ .
\end{aligned}
$$

The surplus of any member with the MFS program can be calculated as:

$$
\begin{aligned}
CS^{am*}_{\theta\geq\hat{\theta}^{am}} &= \int\limits_{-\frac{v_h-p^{am}}{t}}^{\frac{v_h-p^{am}}{t}} \theta(v_h-p^{am}-t\mid\lambda\mid)d\lambda + \int\limits_{-\frac{v_l-p^{am}}{t}}^{\frac{v_l-p^{am}}{t}} (1-\theta)(v_l-p^{am}-t\mid\lambda\mid)d\lambda - M^{am} \\
&= [2s^2+s(v_h-3v_l)+\frac{s(4tf+s(2s+3v_h-5v_l))(s+2v_h-2v_l)}{s(s-2v_h+2v_l)-2tf} \\
&+\frac{1}{8}(v_h-3v_l+\frac{s(4tf+s(2s+3v_h-5v_l))}{s(s-2v_h+2v_l)-2tf})^2(1-\theta) \\
&+\frac{1}{8}(v_l-3v_h+\frac{s(4tf+s(2s+3v_h-5v_l))}{s(s-2v_h+2v_l)-2tf})^2\theta][2t]^{-1}\ .
\end{aligned}
$$

It is easily verified that the surplus is higher if and only if $\theta > \theta^{am*}$, where

$$
\begin{aligned}
\theta^{am*} = \ & [128t^2f^2(v_h-v_l)+4tfs(8s^2+2sv_h+55v_h^2-14(s+9v_h)v_l+75v_l^2) \\
& +s^2(-32s^3+s(5v_h-11v_l)(5v_h-3v_l)+4s^2(v_h+9v_l) \\
& +4(v_h-v_l)(23v_h^2-62v_hv_l+43v_l^2))] \\
& [8(v_h-v_l)(8tf+7sv_h-9sv_l)(2tf-s(s-2v_h+2v_l))]^{-1}\ .
\end{aligned}
$$

Proof of Proposition 13

Under the wholesale model, the difference between social welfare with and without the MFS program can be calculated as $SW^{wm*}-SW^{wb*}$. Substituting Equations B.6 and B.3, we get:

$$
SW^{wm*}-SW^{wb*} = -\frac{s^2(v_h+v_l-6s)(tf(2s+v_h+v_l)+s^2(6s+7v_h-9v_l))}{64t(tf+s(v_h-v_l))^2}\ .
$$

Clearly, the sign of the term depends on $tf(2s+v_h+v_l)+s^2(6s+7v_h-9v_l)$. Given that $3v_h > 5v_l-2s$, $tf(2s+v_h+v_l)+s^2(6s+7v_h-9v_l)$ is strictly positive. Therefore, $SW^{wm*} < SW^{wb*}$ for any $s < \frac{v_h+v_l}{6}$.

Under the agency model, the difference between social welfare with and without the MFS program can be calculated as $SW^{am*}-SW^{ab*}$. Substituting Equations B.13 and B.10, we get:

$$
SW^{am*}-SW^{ab*} = \frac{s^3(v_h+v_l-4s)(4v_h^2-23sv_h+25sv_l-4v_l^2-8tf)}{16t(s(s-2v_h+2v_l)-2tf)^2}\ . \tag{B.18}
$$

Clearly, this term is strictly positive if and only if $4v_h^2 - 23sv_h + 25sv_l - 4v_l^2 - 8tf > 0$ for any $s < \frac{v_h+v_l}{4}$.

Analysis of K Manufacturers in the Marketplace

Under the wholesale model, when there is no MFS, the retail platform's optimization problem in stage 2 is formulated as the following:

$$\arg\max_{p_i^{wb}} \ \pi_R^{wb} = \sum_{i=1}^{K}\Big[\Big(\int_0^1 \int_{-\frac{t-Kp_i^{wb}+Kp_{i-1}^{wb}}{2tK}}^{\frac{t-Kp_i^{wb}+Kp_{i+1}^{wb}}{2tK}} \theta d\lambda d\theta + \int_0^1 \int_{-\frac{v_l-p_i^{wb}-s}{t}}^{\frac{v_l-p_i^{wb}-s}{t}} (1-\theta) d\lambda d\theta\Big)(p_i^{wb} - w_i^{wb})\Big] .$$

Solving the first-order conditions, we obtain the equilibrium retail prices in terms of the wholesale prices:

$$p_i^{wb*} = \frac{t - 2Ks + 2Kv_l + 2Kw_i^{wb}}{4K} .$$

In stage 1 of the game, manufacturer i maximizes his profit by solving for the optimal wholesale price using the following model:

$$\arg\max_{w_i^{wb}} \ \pi_i^{wb} = \Big(\int_0^1 \int_{-\frac{t-Kp_i^{wb}+Kp_{i-1}^{wb}}{2tK}}^{\frac{t-Kp_i^{wb}+Kp_{i+1}^{wb}}{2tK}} \theta d\lambda d\theta + \int_0^1 \int_{-\frac{v_l-p_i^{wb}-s}{t}}^{\frac{v_l-p_i^{wb}-s}{t}} (1-\theta) d\lambda d\theta\Big) w_i^{wb} .$$

Solving the first-order conditions, we obtain the wholesale prices in the symmetric equilibrium:

$$w_i^{wb*} = \frac{t - 2Ks + 2Kv_l}{5K} .$$

Then we get the equilibrium retail profit as follows:

$$\pi_R^{wb*} = \frac{9(t + 2K(v_l - s))^2}{400tK} . \tag{B.19}$$

Under the wholesale model, when the retail platform implements the MFS program, its optimization problem in stage 4 is formulated as the following:

$$\begin{aligned}\arg\max_{p_i^{wm}} \ \pi_R^{wm} = \ & \textstyle\sum_{i=1}^{K}\Big[\Big(\int\limits_{0}^{\hat{\theta}^{wm}}\int\limits_{-\frac{t-Kp_i^{wm}+Kp_{i-1}^{wm}}{2tK}}^{\frac{t-Kp_i^{wm}+Kp_{i+1}^{wm}}{2tK}} \theta d\lambda d\theta \\ & + \int\limits_{0}^{\hat{\theta}^{wm}}\int\limits_{-\frac{v_l-p_i^{wm}-s}{t}}^{\frac{v_l-p_i^{wm}-s}{t}} (1-\theta)d\lambda d\theta\Big)(p_i^{wm}-w_i^{wm}) \\ & +\Big(\int\limits_{\hat{\theta}^{wm}}^{1}\int\limits_{-\frac{t-Kp_i^{wm}+Kp_{i-1}^{wm}}{2tK}}^{\frac{t-Kp_i^{wm}+Kp_{i+1}^{wm}}{2tK}} \theta d\lambda d\theta + \int\limits_{\hat{\theta}^{wm}}^{1}\int\limits_{-\frac{v_l-p_i^{wm}}{t}}^{\frac{v_l-p_i^{wm}}{t}} (1-\theta)d\lambda d\theta\Big)(p_i^{wm}-w_i^{wm}-s)\Big] \\ & +MF^{wm} - f(1-\hat{\theta}^{wm})^2 \ .\end{aligned}$$

Solving the first-order conditions, we obtain the equilibrium retail prices in terms of the wholesale prices and the membership base given as follows:

$$p_i^{wm*} = \frac{t+2K(s+v_l)+4Ks(\hat{\theta}^{wm}-2)\hat{\theta}^{wm}+2Kw_i^{wm}}{4K} \ .$$

In stage 3 of the game, manufacturer i maximizes its profit by solving for the optimal wholesale price in the following model:

$$\begin{aligned}\arg\max_{w_i^{wm}} \ \pi_i^{wm} = \ & \Big(\int\limits_{0}^{\hat{\theta}^{wm}}\int\limits_{-\frac{t-Kp_i^{wm}+Kp_{i-1}^{wm}}{2tK}}^{\frac{t-Kp_i^{wm}+Kp_{i+1}^{wm}}{2tK}} \theta d\lambda d\theta + \int\limits_{0}^{\hat{\theta}^{wm}}\int\limits_{-\frac{v_l-p_i^{wm}-s}{t}}^{\frac{v_l-p_i^{wm}-s}{t}} (1-\theta)d\lambda d\theta \\ & + \int\limits_{\hat{\theta}^{wm}}^{1}\int\limits_{-\frac{t-Kp_i^{wm}+Kp_{i-1}^{wm}}{2tK}}^{\frac{t-Kp_i^{wm}+Kp_{i+1}^{wm}}{2tK}} \theta d\lambda d\theta + \int\limits_{\hat{\theta}^{wm}}^{1}\int\limits_{-\frac{v_l-p_i^{wm}}{t}}^{\frac{v_l-p_i^{wm}}{t}} (1-\theta)d\lambda d\theta\Big) w_i^{wm} \ .\end{aligned}$$

Solving the above equation, we can get the wholesale prices in the symmetric equilibrium as follows:

$$w_i^{wm*} = \frac{t-2Ks+2Kv_l}{5K} \ .$$

For the marginal member, the expected surplus with the membership can be calculated as:

$$\sum_{i=1}^{K}\Bigg[\int_{-\frac{t-Kp_i^{wm}+Kp_{i-1}^{wm}}{2tK}}^{\frac{t-Kp_i^{wm}+Kp_{i+1}^{wm}}{2tK}} \hat{\theta}^{wm}(v_h - p_i^{wm} - t\mid\lambda\mid)d\lambda + \int_{-\frac{v_l-p_i^{wm}}{t}}^{\frac{v_l-p_i^{wm}}{t}} (1-\hat{\theta}^{wm})(v_l - p_i^{wm} - t\mid\lambda\mid)d\lambda\Bigg].$$

The expected surplus for the same consumer without the membership can be calculated as:

$$\sum_{i=1}^{K}\Bigg[\int_{-\frac{t-Kp_i^{wm}+Kp_{i-1}^{wm}}{2tK}}^{\frac{t-Kp_i^{wm}+Kp_{i+1}^{wm}}{2tK}} \hat{\theta}^{wm}(v_h - p_i^{wm} - s - t\mid\lambda\mid)d\lambda$$
$$+ \int_{-\frac{v_l-p_i^{wm}-s}{t}}^{\frac{v_l-p_i^{wm}-s}{t}} (1-\hat{\theta}^{wm})(v_l - p_i^{wm} - s - t\mid\lambda\mid)d\lambda\Bigg].$$

The membership fee M^{wm} equals the surplus gain which is the difference of the above two equations. Besides the program administration cost f, the profit of the retail platform consists of three parts: retail platform's net revenue collected from the manufacturers (**NR**), membership fee paid by subscribing consumers (**MF**), and absorbed shipping cost (**SC**). These three parts are calculated as follows:

$$NR^{wm} = \sum_{i=1}^{K}\Bigg[\Bigg(\int_{0}^{\hat{\theta}^{wm}}\int_{-\frac{t-Kp_i^{wm}+Kp_{i-1}^{wm}}{2tK}}^{\frac{t-Kp_i^{wm}+Kp_{i+1}^{wm}}{2tK}} \theta d\lambda d\theta + \int_{0}^{\hat{\theta}^{wm}}\int_{-\frac{v_l-p_i^{wm}-s}{t}}^{\frac{v_l-p_i^{wm}-s}{t}} (1-\theta)d\lambda d\theta$$
$$+ \int_{\hat{\theta}^{wm}}^{1}\int_{-\frac{t-Kp_i^{wm}+Kp_{i-1}^{wm}}{2tK}}^{\frac{t-Kp_i^{wm}+Kp_{i+1}^{wm}}{2tK}} \theta d\lambda d\theta + \int_{\hat{\theta}^{wm}}^{1}\int_{-\frac{v_l-p_i^{wm}}{t}}^{\frac{v_l-p_i^{wm}}{t}} (1-\theta)d\lambda d\theta\Bigg)(p_i^{wm} - w_i^{wm})\Bigg],$$

$$SC^{wm} = \sum_{i=1}^{K}\Bigg[\Bigg(\int_{\hat{\theta}^{wm}}^{1}\int_{-\frac{t-Kp_i^{wm}+Kp_{i-1}^{wm}}{2tK}}^{\frac{t-Kp_i^{wm}+Kp_{i+1}^{wm}}{2tK}} \theta d\lambda d\theta + \int_{\hat{\theta}^{wm}}^{1}\int_{-\frac{v_l-p_i^{wm}}{t}}^{\frac{v_l-p_i^{wm}}{t}} (1-\theta)d\lambda d\theta\Bigg)s\Bigg],$$

$$MF^{wm} = \quad (1-\hat{\theta}^{wm})M^{wm} \ .$$

We can calculate the retail platform profit using the formula $\pi_R^{wm} = NR^{wm} + MF^{wm} - SC^{wm} - f(1-\hat{\theta}^{wm})^2$, and then solve for the optimal membership base given as follows:

$$\hat{\theta}^{wm*} = \quad 1 - \frac{\sqrt{-K^2 s(t(10f+7s)+6Ks(s-v_l))}}{2\sqrt{5}Ks^2} \ .$$

It is easily verified that $\hat{\theta}^{wm*} < 1$ if and only if $t(10f+7s)+6Ks(s-v_l) < 0$ and then the equilibrium retail platform profit equals:

$$\pi_R^{wm*} = \quad \frac{1}{200}\left(\frac{t(50f^2+70fs+29s^2)}{Ks^2} + \frac{12(5f+2s)(s-v_l)}{s} + \frac{36K(s-v_l)^2}{t}\right) \ . \tag{B.20}$$

The retail platform profit gain equals:

$$\Delta\pi_R^{w*} = \quad \frac{(t(10f+7s)+6Ks(s-v_l))^2}{400tKs^2} \ . \tag{B.21}$$

Under the agency model, when there is no MFS, manufacturer i's optimization problem in stage 2 is formulated as the following:

$$\arg\max_{p_i^{ab}} \ \pi_i^{ab} = \quad \Bigg(\int_0^1 \int_{-\frac{t-Kp_i^{ab}+Kp_{i-1}^{ab}}{2tK}}^{\frac{t-Kp_i^{ab}+Kp_{i+1}^{ab}}{2tK}} \theta d\lambda d\theta + \int_0^1 \int_{-\frac{v_l-p_i^{ab}-s}{t}}^{\frac{v_l-p_i^{ab}-s}{t}} (1-\theta) d\lambda d\theta\Bigg) p_i^{ab}(1-\alpha^{ab}) \ .$$

Solving the first-order conditions, we obtain the retail prices in the symmetric equilibrium:

$$p_i^{ab*} = \quad \frac{t-2Ks+2Kv_l}{5K} \ .$$

In stage 1, the retail platform maximizes its profit by choosing the optimal commission rate subject to each manufacturer's individual rationality (IR) constraint; that is, the retail platform solves the following model to choose the commission rate:

$$\arg\max_{\alpha} \ \pi_R^{ab} = \quad \textstyle\sum_{i=1}^{K} \Bigg[\Bigg(\displaystyle\int_0^1 \int_{-\frac{t-Kp_i^{ab}+Kp_{i-1}^{ab}}{2tK}}^{\frac{t-Kp_i^{ab}+Kp_{i+1}^{ab}}{2tK}} \theta d\lambda d\theta + \int_0^1 \int_{-\frac{v_l-p_i^{ab}-s}{t}}^{\frac{v_l-p_i^{ab}-s}{t}} (1-\theta) d\lambda d\theta\Bigg) p_i^{ab}\alpha^{ab}\Bigg] \ ,$$

$$\text{subject to} \qquad \pi_i^{ab} \geq \mu \ .$$

Then we can get the equilibrium commission rate as follows:

$$\alpha^{ab*} = \ 1 - \frac{50tK^2\mu}{3(t + 2K(v_l - s))^2} \ .$$

The equilibrium retail platform profit is calculated as follows:

$$\pi_R^{ab*} = \ \frac{3(t + 2K(v_l - s))^2}{50tK} - K\mu \ . \tag{B.22}$$

Under the agency model, when the retail platform implements the MFS program, manufacturer i's optimization problem in stage 4 is formulated as the following:

$$\begin{aligned}\arg\max_{p_i^{am}} \ \pi_i^{am} = \ & \Big(\int_0^{\hat{\theta}^{am}} \int_{-\frac{t-Kp_i^{am}+Kp_{i-1}^{am}}{2tK}}^{\frac{t-Kp_i^{am}+Kp_{i+1}^{m}}{2tK}} \theta d\lambda d\theta + \int_0^{\hat{\theta}^{am}} \int_{-\frac{v_l-p_i^{am}-s}{t}}^{\frac{v_l-p_i^{am}-s}{t}} (1-\theta) d\lambda d\theta \\ & + \int_{\hat{\theta}^{am}}^{1} \int_{-\frac{t-Kp_i^{am}+Kp_{i-1}^{am}}{2tK}}^{\frac{t-Kp_i^{am}+Kp_{i+1}^{am}}{2tK}} \theta d\lambda d\theta + \int_{\hat{\theta}^{am}}^{1} \int_{-\frac{v_l-p_i^{am}}{t}}^{\frac{v_l-p_i^{am}}{t}} (1-\theta) d\lambda d\theta \Big) p_i^{am} (1 - \alpha^{am}) \ .\end{aligned}$$

Solving the first-order conditions, we obtain the retail prices in the symmetric equilibrium:

$$p_i^{am*} = \ \frac{t + 2Kv_l + 2Ks(\hat{\theta}^{am})\hat{\theta}^{am}}{5K} \ .$$

For the marginal member, the expected surplus with the membership can be calculated as:

$$\textstyle\sum_{i=1}^{K} \Big[\displaystyle\int_{-\frac{t-Kp_i^{am}+Kp_{i-1}^{am}}{2tK}}^{\frac{t-Kp_i^{am}+Kp_{i+1}^{am}}{2tK}} \hat{\theta}^{am}(v_h - p_i^{am} - t \mid \lambda \mid) d\lambda + \int_{-\frac{v_l-p_i^{am}}{t}}^{\frac{v_l-p_i^{am}}{t}} (1 - \hat{\theta}^{am})(v_l - p_i^{am} - t \mid \lambda \mid) d\lambda \Big] \ .$$

The expected surplus for the same consumer without the membership can be calculated as:

$$\sum_{i=1}^{K}\Big[\int_{-\frac{t-Kp_i^{am}+Kp_{i-1}^{am}}{2tK}}^{\frac{t-Kp_i^{am}+Kp_{i+1}^{am}}{2tK}} \hat{\theta}^{am}(v_h - p_i^{am} - s - t \mid \lambda \mid)d\lambda$$
$$+ \int_{-\frac{v_l-p_i^{am}-s}{t}}^{\frac{v_l-p_i^{am}-s}{t}} (1-\hat{\theta}^{am})(v_l - p_i^{am} - s - t \mid \lambda \mid)d\lambda\Big] .$$

The membership fee M^{am} equals the surplus gain which is the difference of the above two equations. Besides the program administration cost f, the profit of the retail platform consists of three parts: retail platform's net revenue collected from the manufacturers (**NR**), membership fee paid by subscribing consumers (**MF**), and absorbed shipping cost (**SC**). These three parts are calculated as follows:

$$NR^{am} = \sum_{i=1}^{K}\Big[\Big(\int_0^{\hat{\theta}^{am}}\int_{-\frac{t-Kp_i^{am}+Kp_{i-1}^{am}}{2tK}}^{\frac{t-Kp_i^{am}+Kp_{i+1}^{am}}{2tK}} \theta d\lambda d\theta + \int_0^{\hat{\theta}^{am}}\int_{-\frac{v_l-p_i^{am}-s}{t}}^{\frac{v_l-p_i^{am}-s}{t}} (1-\theta)d\lambda d\theta$$
$$+ \int_{\hat{\theta}^{am}}^{1}\int_{-\frac{t-Kp_i^{am}+Kp_{i-1}^{am}}{2tK}}^{\frac{t-Kp_i^{am}+Kp_{i+1}^{am}}{2tK}} \theta d\lambda d\theta + \int_{\hat{\theta}^{am}}^{1}\int_{-\frac{v_l-p_i^{am}}{t}}^{\frac{v_l-p_i^{am}}{t}} (1-\theta)d\lambda d\theta\Big)p_i^{am} - \mu\Big] ,$$

$$SC^{am} = \sum_{i=1}^{K}\Big[\Big(\int_{\hat{\theta}^{am}}^{1}\int_{-\frac{t-Kp_i^{am}+Kp_{i-1}^{am}}{2tK}}^{\frac{t-Kp_i^{am}+Kp_{i+1}^{am}}{2tK}} \theta d\lambda d\theta + \int_{\hat{\theta}^{am}}^{1}\int_{-\frac{v_l-p_i^{am}}{t}}^{\frac{v_l-p_i^{am}}{t}} (1-\theta)d\lambda d\theta\Big)s\Big] ,$$

$$MF^{am} = (1-\hat{\theta}^{am})M^{am} .$$

We can calculate the retail platform profit using the formula $\pi_R^{am} = NR^{am} + MF^{am} - SC^{am} - f(1-\hat{\theta}^{am})^2$, and then solve for the optimal membership base given as follows:

$$\hat{\theta}^{am*} = 1 - \frac{\sqrt{-Ks^2(t(50f+23s)+54Ks(s-v_l))}}{4Ks^2}$$

It is easily verified that $\hat{\theta}^{am*} < 1$ if and only if $t(50f + 23s) + 54Ks(s - v_l) < 0$ and then the equilibrium retail platform profit equals:

$$\pi_R^{am*} = \frac{1}{64}(84s + \frac{t(100f^2 + 92fs + 25s^2)}{Ks^2} + \frac{216f(s - v_l)}{s} + \frac{132K(s - v_l)^2}{t} - 84v_l) - K\mu \ . \tag{B.23}$$

The retail platform profit gain equals:

$$\Delta\pi_R^{a*} = \frac{(t(50f + 23s) + 54Ks(s - v_l))^2}{1600tKs^2} \ . \tag{B.24}$$

Proof of Proposition 14

(a) To ensure interior solutions, we assume $t(10f + 7s) + 6Ks(s - v_l) < 0$. The difference between the retail platform profit gain under the agency model and that under the wholesale model can be calculated by taking the difference of Equations B.24 and B.21 as follows:

$$\Delta\pi_R^{a*} - \Delta\pi_R^{w*} = \frac{3(t(10f + 3s) + 14Ks(s - v_l))(t(70f + 37s) + 66Ks(s - v_l))}{1600tKs^2} \ .$$

It is easy to see that $t(10f + 3s) + 14Ks(s - v_l) < t(10f + 7s) + 6Ks(s - v_l) < 0$, given that $t(10f + 7s) + 6Ks(s - v_l) < 0$. Similarly, $t(70f + 37s) + 66Ks(s - v_l)) < t(70f + 49s) + 42Ks(s - v_l) < 0$. Therefore $\Delta\pi_R^{a*} - \Delta\pi_R^{w*} > 0$ is true.

(b) $\frac{\partial(\Delta\pi_R^{a*} - \Delta\pi_R^{w*})}{\partial K} = \frac{693(s-v_l)^2}{400t} - \frac{3t(10f+3s)(70f+37s)}{1600K^2s^2}$. From $t(10f + 7s) + 6Ks(s - v_l) < 0$, we know that $K > \frac{t(10f+7s)}{6s(v_l-s)}$. Thus, $\frac{\partial(\Delta\pi_R^{a*} - \Delta\pi_R^{w*})}{\partial K} > \frac{9(f+s)(70f+43s)(s-v_l)^2}{5t(10f+7s)^2} > 0$.

Analysis of Membership-based Price Discrimination

Under the wholesale model, when there is no MFS, the equilibrium outcomes remain the same as those of the main model. When the retail platform implements the MFS program, its optimization problem in stage 4 is formulated as the following:

$$
\begin{aligned}
\arg \max_{p_n^{wm}, p_m^{wm}} \ \pi_R^{wm} = & \Big(\int_0^{\hat{\theta}^{wm}} \int_{-\frac{v_h - p_n^{wm} - s}{t}}^{\frac{v_h - p_n^{wm} - s}{t}} \theta d\lambda d\theta + \int_0^{\hat{\theta}^{wm}} \int_{-\frac{v_l - p_n^{wm} - s}{t}}^{\frac{v_l - p_n^{wm} - s}{t}} (1-\theta) d\lambda d\theta \Big) (p_n^{wm} - w^{wm}) \\
& + \Big(\int_{\hat{\theta}^{wm}}^{1} \int_{-\frac{v_h - p_m^{wm}}{t}}^{\frac{v_h - p_m^{wm}}{t}} \theta d\lambda d\theta + \int_{\hat{\theta}^{wm}}^{1} \int_{-\frac{v_l - p_m^{wm}}{t}}^{\frac{v_l - p_m^{wm}}{t}} (1-\theta) d\lambda d\theta \Big) (p_m^{wm} - w^{wm} - s) \\
& + MF^{wm} - f(1 - \hat{\theta}^{wm})^2 \ .
\end{aligned}
$$

Solving the first-order conditions, we obtain the equilibrium retail prices for members and non-members as follows:

$$
p_n^{wm} = \frac{(v_h - v_l)\hat{\theta}^{wm} + 2(w^{wm} + v_l - s)}{4} \ ,
$$

$$
p_m^{wm} = \frac{(v_h - v_l)\hat{\theta}^{wm} + v_h + v_l + 2(w^{wm} + s)}{4} \ .
$$

It is easy to see that $p_m^{wm} - p_n^{wm} = \frac{v_h - v_l}{4} + s > s$. Therefore, no consumer would join the membership program under the wholesale model if price discrimination is anticipated.

Similarly, under the agency model, when there is no MFS, the equilibrium outcomes remain the same as those of the main model. When the retail platform implements the MFS program, the manufacturer's optimization problem in stage 4 is formulated as the following:

$$
\begin{aligned}
\arg \max_{p_n^{am}, p_m^{am}} \ \pi_M^{am} = & \Big(\int_0^{\hat{\theta}^{am}} \int_{-\frac{v_h - p_n^{am} - s}{t}}^{\frac{v_h - p_n^{am} - s}{t}} \theta d\lambda d\theta + \int_0^{\hat{\theta}^{am}} \int_{-\frac{v_l - p_n^{am} - s}{t}}^{\frac{v_l - p_n^{am} - s}{t}} (1-\theta) d\lambda d\theta \Big) p_n^{am} (1 - \alpha^{am}) \\
& + \Big(\int_{\hat{\theta}^{am}}^{1} \int_{-\frac{v_h - p_m^{am}}{t}}^{\frac{v_h - p_m^{am}}{t}} \theta d\lambda d\theta + \int_{\hat{\theta}^{am}}^{1} \int_{-\frac{v_l - p_m^{am}}{t}}^{\frac{v_l - p_m^{am}}{t}} (1-\theta) d\lambda d\theta \Big) p_m^{am} (1 - \alpha^{am}) \ .
\end{aligned}
$$

Solving the first-order conditions, we obtain the equilibrium retail prices for members and non-members as follows:

$$p_n^{am*} = \frac{(v_h - v_l)\hat{\theta}^{am} + 2(v_l - s)}{4} ,$$

$$p_m^{am*} = \frac{(v_h - v_l)\hat{\theta}^{am} + v_h + v_l}{4} .$$

For the marginal member, the expected surplus with the membership can be calculated as:

$$\int_{-\frac{v_h - p_m^{am}}{t}}^{\frac{v_h - p_m^{am}}{t}} \hat{\theta}^{am}(v_h - p_m^{am} - t \mid \lambda \mid) d\lambda + \int_{-\frac{v_l - p_m^{am}}{t}}^{\frac{v_l - p_m^{am}}{t}} (1 - \hat{\theta}^{am})(v_l - p_m^{am} - t \mid \lambda \mid) d\lambda .$$

The expected surplus for the same consumer without the membership can be calculated as:

$$\int_{-\frac{v_h - p_n^{am} - s}{t}}^{\frac{v_h - p_n^{am} - s}{t}} \hat{\theta}^{am}(v_h - p_n^{am} - s - t \mid \lambda \mid) d\lambda + \int_{-\frac{v_l - p_n^{am} - s}{t}}^{\frac{v_l - p_n^{am} - s}{t}} (1 - \hat{\theta}^{am})(v_l - p_n^{am} - s - t \mid \lambda \mid) d\lambda .$$

The membership fee M^{am} equals the surplus gain which is the difference of the above two equations. Besides the program administration cost f, the profit of the retail platform consists of three parts: retail platform's net revenue collected from the manufacturers (**NR**), membership fee paid by subscribing consumers (**MF**), and absorbed shipping cost (**SC**). These three parts are calculated as follows:

$$\begin{aligned} NR^{am} = & \Big(\int_0^{\hat{\theta}^{am}} \int_{-\frac{v_h - p_n^{am} - s}{t}}^{\frac{v_h - p_n^{am} - s}{t}} \theta d\lambda d\theta + \int_0^{\hat{\theta}^{am}} \int_{-\frac{v_l - p_n^{am} - s}{t}}^{\frac{v_l - p_n^{am} - s}{t}} (1 - \theta) d\lambda d\theta\Big) p_n^{am} \\ & + \Big(\int_{\hat{\theta}^{am}}^{1} \int_{-\frac{v_h - p_m^{am}}{t}}^{\frac{v_h - p_m^{am}}{t}} \theta d\lambda d\theta + \int_{\hat{\theta}^{am}}^{1} \int_{-\frac{v_l - p_m^{am}}{t}}^{\frac{v_l - p_m^{am}}{t}} (1 - \theta) d\lambda d\theta\Big) p_m^{am} - \mu , \end{aligned}$$

$$SC^{am} = \Big(\int_{\hat{\theta}^{am}}^{1}\int_{-\frac{v_h-p_m^{am}}{t}}^{\frac{v_h-p_m^{am}}{t}} \theta d\lambda d\theta + \int_{\hat{\theta}^{am}}^{1}\int_{-\frac{v_l-p_m^{am}}{t}}^{\frac{v_l-p_m^{am}}{t}} (1-\theta) d\lambda d\theta\Big)s \ ,$$

$$MF^{am} = (1-\hat{\theta}^{am})M^{am} \ .$$

We can calculate the retail platform profit using the formula $\pi_R^{am} = NR^{am} + MF^{am} - SC^{am} - f(1-\hat{\theta}^{am})^2$, and then solve for the optimal membership base given as follows:

$$\hat{\theta}^{am*} = \frac{23tf + 12s^2 + 4s(3v_h - 5v_l) - (5v_h - 9v_l)(v_h - v_l)}{8(4tf + (v_h - v_l)(3s - v_h + v_l))} \ .$$

We further verify the second-order condition:

$$\frac{\partial^2 \pi_R^{am}}{\partial \hat{\theta}^{am2}} = \frac{(v_h - v_l)(v_h - v_l - 3s)}{2t} - 2f < 0$$
$$for \ any \ f > \tfrac{(v_h - v_l)(v_h - v_l - 3s)}{4t} \ .$$

Meanwhile, we know that $\hat{\theta}^{am*} < 1$ requires $\frac{v_h - v_l}{2} < s < \frac{3v_h + v_l}{6}$. Assume it is the case, then the equilibrium retail platform profit equals:

$$\begin{aligned}\pi_R^{am*} = \ & [144s^4 + 96s^3(v_h - 3v_l) + 8s(v_h - v_l)(19v_h^2 + 24v_h v_l - 3v_l^2) \\ & +8s^2(31v_l^2 + 14v_h v_l - 37v_h^2) - (v_h - v_l)^2(23v_h^2 + 58v_h v_l + 31v_l^2) \\ & +128tf(v_h + v_l - 2s)^2][256t(4tf + (v_h - v_l)(3s - v_h + v_l))]^{-1} - \mu \ .\end{aligned}$$

The retail platform profit gain equals:

$$\Delta\pi_R^{a*} = \frac{(v_h + v_l - 2s)^2(3v_h + v_l - 6s)^2}{256t(4tf + (v_h - v_l)(3s - v_h + v_l))} > 0 \ . \tag{B.25}$$

Meanwhile, we can verify that $p_m^{am} - p_n^{am} = \frac{v_h - v_l + 2s}{4} < s$ so that subscribing consumers' IC constraint is satisfied.

Proof of Lemma 7

Clearly from the above analysis, we know that no consumer will join the MFS program under the wholesale model if the retail platform does not commit to no price discrimination. In order to induce consumer participation, the retail platform has to commit not to price discriminate based on membership status. In contrast, under the agency model, the retail platform will choose to make the commitment when the profit gain from MFS implementation under no price discrimination given by Equation B.14 is higher than that under price discrimination given by Equation B.25; otherwise it will not make the commitment, and price discrimination would occur in the equilibrium.

Proof of Proposition 15

(a) The retail platform will commit to no price discrimination under the wholesale model when it is profitable to implement the MFS program as in the main model. Under the agency model, if the retail platform also commits to no price discrimination, we know the profit gain from implementing the MFS program is higher under the agency model than that under the wholesale model, as illustrated by Proposition 10. On the other hand, if the retail platform chooses not to make the commitment under the agency model, it must be true that the profit gain from MFS implementation under price discrimination is higher than the profit gain from MFS implementation without price discrimination, which is still higher than the profit gain from MFS implementation under the wholesale model. Therefore, regardless of whether the retail platform commits to no price discrimination or not, the profit gain from implementing the MFS program is higher under the agency model than under the wholesale model.

(b) We know from Proposition 9 that without price discrimination the retail platform will implement the MFS program if and only if $s < \frac{v_h+v_l}{4}$. Meanwhile, under price discrimination, the retail platform will implements the MFS program if and only if $\frac{v_h-v_l}{2} < s < \frac{3v_h+v_l}{6}$. It is easily verified that $\frac{3v_h+v_l}{6} > \frac{v_h+v_l}{4}$. Thus, the ability to commit to price discrimination or not enlarges the parameter space where the retail platform implements the MFS program under the agency model.

Analysis of Perks in addition to Free Shipping under MFS

Under the wholesale model, when there is no MFS, the equilibrium outcomes remain the same as those of the main model. When the retail platform implements the MFS program, a consumer's participation decision is driven by the summation of the surplus gain related to purchases and her valuation towards the additional perks from the MFS program. Consequently, the marginal member's type θ depends on her valuation towards the additional perks γ. Denoting the marginal member with $\gamma = 0$ as $\hat{\theta}_0^{wm}$, and then the type of any marginal member $\hat{\theta}_\gamma^{wm}$ can be derived by solving the following equation:

$$
\begin{aligned}
&\int_{-\frac{v_h-p^{wm}}{t}}^{\frac{v_h-p^{wm}}{t}} \hat{\theta}_\gamma^{wm}(v_h - p^{wm} - t \mid \lambda \mid)d\lambda + \int_{-\frac{v_l-p^{am}}{t}}^{\frac{v_l-p^{wm}}{t}} (1-\hat{\theta}_\gamma^{wm})(v_l - p^{wm} - t \mid \lambda \mid)d\lambda \\
&- \int_{-\frac{v_h-p^{wm}-s}{t}}^{\frac{v_h-p^{wm}-s}{t}} \hat{\theta}_\gamma^{wm}(v_h - p^{wm} - s - t \mid \lambda \mid)d\lambda \\
&- \int_{-\frac{v_l-p^{wm}-s}{t}}^{\frac{v_l-p^{wm}-s}{t}} (1-\hat{\theta}_\gamma^{wm})(v_l - p^{wm} - s - t \mid \lambda \mid)d\lambda + \gamma
\end{aligned}
$$

$$
\begin{aligned}
= &\int_{-\frac{v_h-p^{wm}}{t}}^{\frac{v_h-p^{wm}}{t}} \hat{\theta}_0^{wm}(v_h - p^{wm} - t \mid \lambda \mid)d\lambda + \int_{-\frac{v_l-p^{wm}}{t}}^{\frac{v_l-p^{wm}}{t}} (1-\hat{\theta}_0^{wm})(v_l - p^{wm} - t \mid \lambda \mid)d\lambda \\
&- \int_{-\frac{v_h-p^{wm}-s}{t}}^{\frac{v_h-p^{wm}-s}{t}} \hat{\theta}_0^{wm}(v_h - p^{wm} - s - t \mid \lambda \mid)d\lambda \\
&- \int_{-\frac{v_l-p^{wm}-s}{t}}^{\frac{v_l-p^{wm}-s}{t}} (1-\hat{\theta}_0^{wm})(v_l - p^{wm} - s - t \mid \lambda \mid)d\lambda \,.
\end{aligned}
$$

Solving the above equation yields $\hat{\theta}_\gamma^{wm} = \hat{\theta}_0^{wm} - \frac{t\gamma}{2s(v_h-v_l)}$, which is the type, in terms of θ, of marginal member of type γ.

In stage 4 of the game, the retail platform's optimization problem is formulated as the following:

$$\arg\max_{p^{wm}} \ \pi_R^{wm} = \Big(\int_0^{\Gamma}\int_0^{\hat{\theta}_\gamma^{wm}}\int_{-\frac{v_h-p^{wm}-s}{t}}^{\frac{v_h-p^{wm}-s}{t}} \frac{\theta}{\Gamma} d\lambda d\theta d\gamma$$
$$+\int_0^{\Gamma}\int_0^{\hat{\theta}_\gamma^{wm}}\int_{-\frac{v_l-p^{wm}-s}{t}}^{\frac{v_l-p^{wm}-s}{t}} \frac{(1-\theta)}{\Gamma} d\lambda d\theta d\gamma\Big)(p^{wm}-w^{wm})$$
$$+\Big(\int_0^{\Gamma}\int_{\hat{\theta}_\gamma^{wm}}^{1}\int_{-\frac{v_h-p^{wm}}{t}}^{\frac{v_h-p^{wm}}{t}} \frac{\theta}{\Gamma} d\lambda d\theta d\gamma$$
$$+\int_0^{\Gamma}\int_{\hat{\theta}_\gamma^{wm}}^{1}\int_{-\frac{v_l-p^{wm}}{t}}^{\frac{v_l-p^{wm}}{t}} \frac{(1-\theta)}{\Gamma} d\lambda d\theta d\gamma\Big)(p^{wm}-w^{wm}-s)$$
$$+MF^{wm} - f\Big(\int_0^{\Gamma}\int_{\hat{\theta}_\gamma^{wm}}^{1} \frac{1}{\Gamma} d\theta d\gamma\Big)^2 .$$

Solving the first-order condition, we obtain the equilibrium retail price in terms of the wholesale price and the membership base given as follows:

$$p^{wm*} = \frac{t\Gamma + (v_h - v_l)(2s + v_h + v_l + 2w^{wm}) - 4s(v_h - v_l)\hat{\theta}_0^{wm}}{4(v_h - v_l)} .$$

We further verify the second-order condition:

$$\frac{\partial^2 \pi_R^{wm}}{\partial p^{wm2}} = -\frac{4}{t} < 0 .$$

In stage 3 of the game, the manufacturer maximizes its profit by solving for the optimal wholesale price in the following model:

$$\arg\max_{w^{wm}} \ \pi_M^{wm} = \Big(\int_0^{\Gamma}\int_0^{\hat{\theta}_\gamma^{wm}}\int_{-\frac{v_h-p^{wm}-s}{t}}^{\frac{v_h-p^{wm}-s}{t}} \frac{\theta}{\Gamma} d\lambda d\theta d\gamma + \int_0^{\Gamma}\int_0^{\hat{\theta}_\gamma^{wm}}\int_{-\frac{v_l-p^{wm}-s}{t}}^{\frac{v_l-p^{wm}-s}{t}} \frac{(1-\theta)}{\Gamma} d\lambda d\theta d\gamma$$
$$+ \int_0^{\Gamma}\int_{\hat{\theta}_\gamma^{wm}}^{1}\int_{-\frac{v_h-p^{wm}}{t}}^{\frac{v_h-p^{wm}}{t}} \frac{\theta}{\Gamma} d\lambda d\theta d\gamma + \int_0^{\Gamma}\int_{\hat{\theta}_\gamma^{wm}}^{1}\int_{-\frac{v_l-p^{wm}}{t}}^{\frac{v_l-p^{wm}}{t}} \frac{(1-\theta)}{\Gamma} d\lambda d\theta d\gamma\Big) w^{wm} \ .$$

Solving the above equation, we can get the equilibrium wholesale price as follows:

$$w^{wm*} = \frac{v_h + v_l - 2s}{4} \ .$$

We also verify the second-order condition on the manufacturer's sides:

$$\frac{\partial^2 \pi_M^{wm}}{\partial w^{wm2}} = \frac{2}{t} < 0 \ .$$

For the marginal member with $\gamma = 0$, the expected surplus with the membership can be calculated as:

$$\int_{-\frac{v_h-p^{wm}}{t}}^{\frac{v_h-p^{wm}}{t}} \hat{\theta}_0^{wm}(v_h - p^{wm} - t \mid \lambda \mid) d\lambda + \int_{-\frac{v_l-p^{wm}}{t}}^{\frac{v_l-p^{wm}}{t}} (1-\hat{\theta}_0^{wm})(v_l - p^{wm} - t \mid \lambda \mid) d\lambda \ .$$

The expected surplus for the same consumer without the membership can be calculated as:

$$\int_{-\frac{v_h-p^{wm}-s}{t}}^{\frac{v_h-p^{wm}-s}{t}} \hat{\theta}_0^{wm}(v_h - p^{wm} - s - t \mid \lambda \mid) d\lambda + \int_{-\frac{v_l-p^{wm}-s}{t}}^{\frac{v_l-p^{wm}-s}{t}} (1-\hat{\theta}_0^{wm})(v_l - p^{wm} - s - t \mid \lambda \mid) d\lambda \ .$$

The membership fee M^{wm} equals the surplus gain which is the difference of the above two equations. Besides the program administration cost f, the profit of the retail platform consists of three parts: retail platform's net revenue collected from the manufacturers (**NR**), membership fee paid by subscribing consumers (**MF**), and absorbed shipping cost (**SC**). These three parts are calculated as follows:

$$NR^{wm} = \Big(\int_0^{\Gamma}\int_0^{\hat{\theta}_{\gamma}^{wm}}\int_{-\frac{v_h-p^{wm}-s}{t}}^{\frac{v_h-p^{wm}-s}{t}} \frac{\theta}{\Gamma} d\lambda d\theta d\gamma + \int_0^{\Gamma}\int_0^{\hat{\theta}_{\gamma}^{wm}}\int_{-\frac{v_l-p^{wm}-s}{t}}^{\frac{v_l-p^{wm}-s}{t}} \frac{(1-\theta)}{\Gamma} d\lambda d\theta d\gamma$$
$$+ \int_0^{\Gamma}\int_{\hat{\theta}_{\gamma}^{wm}}^{1}\int_{-\frac{v_h-p^{wm}}{t}}^{\frac{v_h-p^{wm}}{t}} \frac{\theta}{\Gamma} d\lambda d\theta d\gamma + \int_0^{\Gamma}\int_{\hat{\theta}_{\gamma}^{wm}}^{1}\int_{-\frac{v_l-p^{wm}}{t}}^{\frac{v_l-p^{wm}}{t}} \frac{(1-\theta)}{\Gamma} d\lambda d\theta d\gamma\Big)(p^{wm} - w^{wm}) \ ,$$

$$SC^{wm} = \Big(\int_0^{\Gamma}\int_{\hat{\theta}_{\gamma}^{wm}}^{1}\int_{-\frac{v_h-p^{wm}}{t}}^{\frac{v_h-p^{wm}}{t}} \frac{\theta}{\Gamma} d\lambda d\theta d\gamma + \int_0^{\Gamma}\int_{\hat{\theta}_{\gamma}^{wm}}^{1}\int_{-\frac{v_l-p^{wm}}{t}}^{\frac{v_l-p^{wm}}{t}} \frac{(1-\theta)}{\Gamma} d\lambda d\theta d\gamma\Big) s \ ,$$

$$MF^{wm} = \Big(\int_0^{\Gamma}\int_{\hat{\theta}_{\gamma}^{wm}}^{1} \frac{1}{\Gamma} d\theta d\gamma\Big) M^{wm} \ .$$

We can calculate the retail platform profit using the formula $\pi_R^{wm} = NR^{wm} + MF^{wm} - SC^{wm} - f\Big(\int_0^{\Gamma}\int_{\hat{\theta}_{\gamma}^{wm}}^{1} \frac{1}{\Gamma} d\theta d\gamma\Big)^2$, and then solve for the optimal membership base given as follows:

$$\hat{\theta}_0^{wm*} = \frac{1}{8}[9 + \frac{2t\Gamma}{s(v_h - v_l)} - \frac{t(f + 2\Gamma) + 2s(v_h - 3s)}{tf - s(v_h - v_l)}] \ .$$

For any interior solution $\hat{\theta}_0^{wm*} < 1$, it has to be the case that $\Gamma < \frac{s^2(v_h+v_l-6s)(v_h-v_l)}{2t^2 f}$. We also know that $\Gamma > 0$. Thus, we must have $s < \frac{v_h+v_l}{6}$.

We further verify the second-order condition:

$$\frac{\partial^2 \pi_R^{wm}}{\partial \hat{\theta}_0^{wm2}} = -\frac{2tf + s(v_h - v_l)}{t} < 0 \ .$$

The equilibrium retail platform profit equals:

$$
\begin{aligned}
\pi_R^{wm*} = \; & [4t^3 f\Gamma^2 + 16t^2 s\Gamma^2(v_h - v_l) + 6ts(v_h - v_l)(2s\Gamma(v_h + v_l - 6s) + f(v_h + v_l - 2s)^2) \\
& +3s^2(v_h - v_l)(36s^3 - s(7v_h - 9v_l)(v_h + v_l) + 2(v_h - v_l)(v_h + v_l)^2 \\
& -4s^2(v_h + 5v_l))][192ts(tf + s(v_h - v_l))(v_h - v_l)]^{-1} \; .
\end{aligned}
$$

The retail platform profit gain equals:

$$
\begin{aligned}
\Delta\pi_R^{w*} = \; & [4t^3 f\Gamma^2 + 16t^2 s\Gamma^2(v_h - v_l) + 12ts^2\Gamma(v_h + v_l - 6s)(v_h - v_l) \\
& +3s^3(v_h - v_l)(v_h + v_l - 6s)^2][192ts(tf + s(v_h - v_l))(v_h - v_l)]^{-1} > 0 \; , \\
& \textit{for any } s < \frac{v_l + v_h}{6} \; .
\end{aligned} \tag{B.26}
$$

Similarly, under the agency model, when there is no MFS, the equilibrium outcomes remain the same as those of the main model. When the retail platform implements the MFS program, denoting the marginal member with $\gamma = 0$ as $\hat{\theta}_0^{am}$, and then the type of any marginal member $\hat{\theta}_\gamma^{am}$ can be derived by solving the following equation:

$$
\begin{aligned}
& \int_{-\frac{v_h - p^{am}}{t}}^{\frac{v_h - p^{am}}{t}} \hat{\theta}_\gamma^{am}(v_h - p^{am} - t \mid \lambda \mid) d\lambda + \int_{-\frac{v_l - p^{am}}{t}}^{\frac{v_l - p^{am}}{t}} (1 - \hat{\theta}_\gamma^{am})(v_l - p^{am} - t \mid \lambda \mid) d\lambda \\
& - \int_{-\frac{v_h - p^{am} - s}{t}}^{\frac{v_h - p^{am} - s}{t}} \hat{\theta}_\gamma^{am}(v_h - p^{am} - s - t \mid \lambda \mid) d\lambda \\
& - \int_{-\frac{v_l - p^{am} - s}{t}}^{\frac{v_l - p^{am} - s}{t}} (1 - \hat{\theta}_\gamma^{am})(v_l - p^{am} - s - t \mid \lambda \mid) d\lambda + \gamma \\
& = \int_{-\frac{v_h - p^{am}}{t}}^{\frac{v_h - p^{am}}{t}} \hat{\theta}_0^{am}(v_h - p^{am} - t \mid \lambda \mid) d\lambda + \int_{-\frac{v_l - p^{am}}{t}}^{\frac{v_l - p^{am}}{t}} (1 - \hat{\theta}_0^{am})(v_l - p^{am} - t \mid \lambda \mid) d\lambda \\
& - \int_{-\frac{v_h - p^{am} - s}{t}}^{\frac{v_h - p^{am} - s}{t}} \hat{\theta}_0^{am}(v_h - p^{am} - s - t \mid \lambda \mid) d\lambda - \int_{-\frac{v_l - p^{am} - s}{t}}^{\frac{v_l - p^{am} - s}{t}} (1 - \hat{\theta}_0^{am})(v_l - p^{am} - s - t \mid \lambda \mid) d\lambda \; .
\end{aligned}
$$

Solving the above equation yields $\hat{\theta}_{\gamma}^{am} = \hat{\theta}_0^{am} - \frac{t\gamma}{2s(v_h - v_l)}$, which is the type, in terms of θ, of marginal member of type γ.

In stage 4 of the game, the manufacturer's optimization problem is formulated as the following:

$$\begin{aligned}\arg\max_{p^{am}} \ \pi_M^{am} = & \Big(\int_0^{\Gamma}\int_0^{\hat{\theta}_{\gamma}^{am}}\int_{-\frac{v_h - p^{am} - s}{t}}^{\frac{v_h - p^{am} - s}{t}} \frac{\theta}{\Gamma} d\lambda d\theta d\gamma + \int_0^{\Gamma}\int_0^{\hat{\theta}_{\gamma}^{am}}\int_{-\frac{v_l - p^{am} - s}{t}}^{\frac{v_l - p^{am} - s}{t}} \frac{(1-\theta)}{\Gamma} d\lambda d\theta d\gamma \\ & + \int_0^{\Gamma}\int_{\hat{\theta}_{\gamma}^{am}}^{1}\int_{-\frac{v_h - p^{am}}{t}}^{\frac{v_h - p^{am}}{t}} \frac{\theta}{\Gamma} d\lambda d\theta d\gamma + \int_0^{\Gamma}\int_{\hat{\theta}_{\gamma}^{am}}^{1}\int_{-\frac{v_l - p^{am}}{t}}^{\frac{v_l - p^{am}}{t}} \frac{(1-\theta)}{\Gamma} d\lambda d\theta d\gamma\Big) p^{am}(1-\alpha^{am}) \ .\end{aligned}$$

Solving the first-order condition, we obtain the equilibrium retail price:

$$p^{am*} = \frac{1}{8}(2(v_h + v_l) + \frac{t\Gamma}{v_h - v_l} - 4s\hat{\theta}_0^{am}) \ .$$

We further verify the second-order condition:

$$\frac{\partial^2 \pi_M^{am}}{\partial p^{am2}} = -\frac{4(1-\alpha^{am})}{t} < 0 \ .$$

For the marginal member with $\gamma = 0$, the expected surplus with the membership can be calculated as:

$$\int_{-\frac{v_h - p^{am}}{t}}^{\frac{v_h - p^{am}}{t}} \hat{\theta}_0^{am}(v_h - p^{am} - t \mid \lambda \mid) d\lambda + \int_{-\frac{v_l - p^{am}}{t}}^{\frac{v_l - p^{am}}{t}} (1 - \hat{\theta}_0^{am})(v_l - p^{am} - t \mid \lambda \mid) d\lambda \ .$$

The expected surplus for the same consumer without the membership can be calculated as:

$$\int_{-\frac{v_h - p^{am} - s}{t}}^{\frac{v_h - p^{am} - s}{t}} \hat{\theta}_0^{am}(v_h - p^{am} - s - t \mid \lambda \mid) d\lambda + \int_{-\frac{v_l - p^{am} - s}{t}}^{\frac{v_l - p^{am} - s}{t}} (1 - \hat{\theta}_0^{am})(v_l - p^{am} - s - t \mid \lambda \mid) d\lambda \ .$$

The membership fee M^{am} equals the surplus gain which is the difference of the above two equations. Besides the program administration cost f, the profit of the retail platform consists of three parts: retail platform's net revenue collected from the manufacturers (**NR**), membership fee paid by subscribing consumers (**MF**), and absorbed shipping cost (**SC**). These three parts are calculated as follows:

$$NR^{am} = \Big(\int_0^{\Gamma}\int_0^{\hat\theta_\gamma^{am}}\int_{-\frac{v_h-p^{am}-s}{t}}^{\frac{v_h-p^{am}-s}{t}} \frac{\theta}{\Gamma} d\lambda d\theta d\gamma + \int_0^{\Gamma}\int_0^{\hat\theta_\gamma^{am}}\int_{-\frac{v_l-p^{am}-s}{t}}^{\frac{v_l-p^{am}-s}{t}} \frac{(1-\theta)}{\Gamma} d\lambda d\theta d\gamma$$
$$+ \int_0^{\Gamma}\int_{\hat\theta_\gamma^{am}}^{1}\int_{-\frac{v_h-p^{am}}{t}}^{\frac{v_h-p^{am}}{t}} \frac{\theta}{\Gamma} d\lambda d\theta d\gamma + \int_0^{\Gamma}\int_{\hat\theta_\gamma^{am}}^{1}\int_{-\frac{v_l-p^{am}}{t}}^{\frac{v_l-p^{am}}{t}} \frac{(1-\theta)}{\Gamma} d\lambda d\theta d\gamma\Big) p^{am} - \mu \ ,$$

$$SC^{am} = \Big(\int_0^{\Gamma}\int_{\hat\theta_\gamma^{am}}^{1}\int_{-\frac{v_h-p^{am}}{t}}^{\frac{v_h-p^{am}}{t}} \frac{\theta}{\Gamma} d\lambda d\theta d\gamma + \int_0^{\Gamma}\int_{\hat\theta_\gamma^{am}}^{1}\int_{-\frac{v_l-p^{am}}{t}}^{\frac{v_l-p^{am}}{t}} \frac{(1-\theta)}{\Gamma} d\lambda d\theta d\gamma\Big) s \ .$$

$$MF^{am} = \Big(\int_0^{\Gamma}\int_{\hat\theta_\gamma^{am}}^{1} \frac{1}{\Gamma} d\theta d\gamma\Big) M^{am} \ .$$

We can calculate the retail platform profit using the formula $\pi_R^{am} = NR^{am} + MF^{am} - SC^{am} - f\Big(\int_0^{\Gamma}\int_{\hat\theta_\gamma^{am}}^{1} \frac{1}{\Gamma} d\theta d\gamma\Big)^2$, and then solve for the optimal membership base given as follows:

$$\hat\theta_0^{am*} = \frac{1}{4}(5 + \frac{t\Gamma}{s(v_h - v_l)} - \frac{2t(f+\Gamma) + s(4v_h - 9s)}{2tf - s(s - 2v_h + 2v_l)}) \ .$$

We further verify the second-order condition:

$$\frac{\partial^2 \pi_R^{am}}{\partial \hat\theta_0^{am2}} = \frac{s(s - 2v_h + 2v_l)}{t} - 2f \ .$$

It requires $f > \frac{s(s-2v_h+2v_l)}{2t}$ for the solution to be local maximum.

The equilibrium retail platform profit equals:

$$\begin{aligned}\pi_R^{am*} = \; & [2t^3 f\Gamma^2 - t^2 s\Gamma^2(s - 8v_h + 8v_l) + 12ts(v_h - v_l)(s\Gamma(v_h + v_l - 4s) + f(v_h + v_l - 2s)^2) \\ & +12s^2(v_h - v_l)(6s^3 + 2s^2(v_h - 3v_l) + (v_h - v_l)(v_h + v_l)^2 + 4s(v_l^2 - v_h^2))] \\ & [48ts(v_h - v_l)(2tf - s(s - 2v_h + 2v_l))]^{-1} - \mu \; .\end{aligned}$$

The retail platform profit gain equals:

$$\begin{aligned}\Delta\pi_R^{a*} = \; & [2t^3 f\Gamma^2 + 12ts^2\Gamma(v_h + v_l - 4s)(v_h - v_l) + 6s^3(v_h - v_l)(v_h + v_l - 4s)^2 \\ & -t^2 s\Gamma^2(s - 8v_h + 8v_l)][48ts(v_h - v_l)(2tf - s(s - 2v_h + 2v_l))]^{-1} > 0 \; , \qquad \text{(B.27)} \\ & \textit{for any } f > \tfrac{s(s-2v_h+2v_l)}{2t} \; .\end{aligned}$$

Proof of Proposition 16

(a) Given the analysis above, assuming $s < \frac{v_h+v_l}{6}$ and $f > \frac{s(s-2v_h+2v_l)}{2t}$, the difference between the retail platform profit gain under the agency model and that under the wholesale model can be calculated by taking the difference of Equations B.27 and B.26 as follows:

$$\begin{aligned}\Delta\pi_R^{a*} - \Delta\pi_R^{w*} = \; & [4t^2 s^2\Gamma^2 + s\Gamma(8t^2 f(v_h + v_l - 2s) - 4ts(6s^2 + 3sv_h - 2v_h^2 - 5sv_l + 2v_l^2)) \\ & +s^2(2tf(2s - v_h - v_l)(14s - 3(v_h + v_l)) + s(36s^3 + s^2(44v_h - 68v_l) \\ & -s(39v_h - 41v_l)(v_h + v_l) + 6(v_h - v_l)(v_h + v_l)^2))] \\ & [64t(tf + s(v_h - v_l))(2tf - s(s - 2v_h + 2v_l)]^{-1} \; .\end{aligned}$$

Clearly, the denominator is positive. The numerator is a quadratic function of Γ with U shape. Thus, we know that $\Delta\pi_R^{a*} - \Delta\pi_R^{w*} < 0$ if and only if $\underline{\Gamma} < \Gamma < \overline{\Gamma}$, where

$$\begin{aligned}\underline{\Gamma} = \; & \frac{1}{2t^2 s}\Big(2t^2 f(2s - v_h - v_l) + ts(6s^2 + 3sv_h - 2v_h^2 - 5sv_l + 2v_l^2) \\ & -\sqrt{2t^2(tf + s(v_h - v_l))(v_h + v_l - 2s)^2(2tf - s(s - 2v_h + 2v_l))}\Big) \; , \\ \overline{\Gamma} = \; & \frac{1}{2t^2 s}\Big(2t^2 f(2s - v_h - v_l) + ts(6s^2 + 3sv_h - 2v_h^2 - 5sv_l + 2v_l^2) \\ & +\sqrt{2t^2(tf + s(v_h - v_l))(v_h + v_l - 2s)^2(2tf - s(s - 2v_h + 2v_l))}\Big) \; .\end{aligned}$$

It is easily verified that $6s^2 + 3sv_h - 2v_h^2 - 5sv_l + 2v_l^2 < 0$, given that $s < \frac{v_h+v_l}{6}$. Thus, $2t^2 f(2s - v_h - v_l) + ts(6s^2 + 3sv_h - 2v_h^2 - 5sv_l + 2v_l^2) < 0$. Similarly, we can show that

$$\mid 2t^2 f(2s - v_h - v_l) + ts(6s^2 + 3sv_h - 2v_h^2 - 5sv_l + 2v_l^2) \mid > \sqrt{2t^2(tf + s(v_h - v_l))(v_h + v_l - 2s)^2(2tf - s(s - 2v_h + 2v_l))}$$

In that case, we know that $\overline{\Gamma} < 0$ and therefore for any $\Gamma > 0$ it must be the case that $\Delta\pi_R^{a*} - \Delta\pi_R^{w*} > 0$.

(b) The derivative of the difference in retail platform profit gain with respect to the valuation towards additional perks equals:

$$\frac{\partial(\Delta\pi_R^{a*} - \Delta\pi_R^{w*})}{\partial\Gamma} = \frac{s(s(2v_h^2 - 6s^2 - 3sv_h + 5sv_l - 2v_l^2) + 2t(s\Gamma + f(v_h + v_l - 2s)))}{16(tf + s(v_h - v_l))(2tf - s(s - 2v_h + 2v_l))} .$$

Clearly, the denominator is strictly positive given that $f > \frac{s(s-2v_h+2v_l)}{2t}$ and $2v_h^2 - 6s^2 - 3sv_h + 5sv_l - 2v_l^2 < 0$ for any $s < \frac{v_h+v_l}{6}$. Thus, $\frac{\partial(\Delta\pi_R^{a*} - \Delta\pi_R^{w*})}{\partial\Gamma} > 0$.

Analysis of Lower Shipping Cost for Retailer compared to Consumers

Under the wholesale model, when there is no MFS, the equilibrium outcomes remain the same as those of the main model. When the retail platform implements the MFS program, its optimization problem in stage 4 is formulated as following:

$$\begin{aligned}\arg\max_{p^{wm}} \ \pi_R^{wm} = \ & \Big(\int_0^{\hat{\theta}^{wm}} \int_{-\frac{v_h - p^{wm} - s}{t}}^{\frac{v_h - p^{wm} - s}{t}} \theta d\lambda d\theta + \int_0^{\hat{\theta}^{wm}} \int_{-\frac{v_l - p^{wm} - s}{t}}^{\frac{v_l - p^{wm} - s}{t}} (1-\theta) d\lambda d\theta\Big)(p^{wm} - w^{wm}) \\ & + \Big(\int_{\hat{\theta}^{wm}}^1 \int_{-\frac{v_h - p^{wm}}{t}}^{\frac{v_h - p^{wm}}{t}} \theta d\lambda d\theta + \int_{\hat{\theta}^{wm}}^1 \int_{-\frac{v_l - p^{wm}}{t}}^{\frac{v_l - p^{wm}}{t}} (1-\theta) d\lambda d\theta\Big)(p^{wm} - w^{wm} - \gamma s) \\ & + MF^{wm} - f(1 - \hat{\theta}^{wm})^2 .\end{aligned}$$

Solving the first-order condition, we obtain the equilibrium retail price:

$$p^{wm*} = \frac{v_h + v_l + 2w^{wm} + 2s\gamma - 2s(1+\gamma)\hat{\theta}^{wm}}{4} .$$

The manufacturer's optimization problem in stage 3 is given by the following:

$$\begin{aligned}\arg\max_{w^{wm}} \ \pi_M^{wm} = \ & \Big(\int_0^{\hat{\theta}^{wm}} \int_{-\frac{v_h - p^{wm} - s}{t}}^{\frac{v_h - p^{wm} - s}{t}} \theta d\lambda d\theta + \int_0^{\hat{\theta}^{wm}} \int_{-\frac{v_l - p^{wm} - s}{t}}^{\frac{v_l - p^{wm} - s}{t}} (1-\theta) d\lambda d\theta \\ & + \int_{\hat{\theta}^{wm}}^1 \int_{-\frac{v_h - p^{wm}}{t}}^{\frac{v_h - p^{wm}}{t}} \theta d\lambda d\theta + \int_{\hat{\theta}^{wm}}^1 \int_{-\frac{v_l - p^{wm}}{t}}^{\frac{v_l - p^{wm}}{t}} (1-\theta) d\lambda d\theta\Big) w^{wm} .\end{aligned}$$

Plugging in the equilibrium retail price and solving the first-order condition, we obtain the equilibrium wholesale price:

$$w^{wm*} = \frac{v_h + v_l - 2s\gamma - 2s(1-\gamma)\hat{\theta}^{wm}}{4} .$$

Following the similar procedure of the main model, we can write down the retail platform profit as:

$$\begin{aligned}\pi_R^{wm} = \; & \frac{1}{32t}\Big((v_h + v_l)^2 - 32tf - 4s^2(8 + (4-\gamma)\gamma) - 4s(v_h(6+\gamma) - v_l(10-\gamma)) \\ & +4\hat{\theta}^{wm}(16tf + s((7v_h - 9v_l)(3-\gamma) + 2s(2-\gamma)(5+\gamma)) \\ & -(8tf + s(8(v_h - v_l)(2-\gamma) + s(1-\gamma)(11+\gamma)))\hat{\theta}^{wm}\Big) .\end{aligned}$$

Solving the first-order condition with respect to $\hat{\theta}^{wm}$ yields:

$$\hat{\theta}^{wm*} = \frac{16tf + s((7v_h - 9v_l)(3-\gamma) + 2s(2-\gamma)(5+\gamma))}{16tf + 2s(8(v_h - v_l)(2-\gamma) + s(1-\gamma)(11+\gamma))} .$$

It is easily verified that the interior solution requires $f > \frac{s((7v_h - 9v_l)(\gamma-3) - 2s(2-\gamma)(5+\gamma))}{16t}$ and $[(s < \frac{v_h(11-9\gamma)+v_l(7\gamma-5)}{14\gamma-2}$ and $14\gamma - 2 > 0)$ or $14\gamma - 2 < 0]$.

Then we can get π_R^{wm*} from the equilibrium outcomes and π_R^{wb*} from the main model, from which the retail platform profit gain can be obtained as the following:

$$\Delta\pi_R^{w*} = \frac{s^2(v_l(5-7\gamma) + 2s(7\gamma-1) + v_h(9\gamma-11))^2}{32t(8tf + s(8(v_h - v_l)(2-\gamma) + s(1-\gamma)(11+\gamma)))} .$$

Under the agency model, when there is no MFS, the equilibrium outcomes remain the same as those of the main model. When the retail platform implements the MFS program, the manufacturer's optimization problem in stage 4 is formulated as following:

$$\begin{aligned}\arg\max_{p^{am}} \pi_M^{am} = \; & \Big(\int_0^{\hat{\theta}^{am}} \int_{-\frac{v_h - p^{am} - s}{t}}^{\frac{v_h - p^{am} - s}{t}} \theta d\lambda d\theta + \int_0^{\hat{\theta}^{am}} \int_{-\frac{v_l - p^{am} - s}{t}}^{\frac{v_l - p^{am} - s}{t}} (1-\theta) d\lambda d\theta \\ & + \int_{\hat{\theta}^{am}}^{1} \int_{-\frac{v_h - p^{am}}{t}}^{\frac{v_h - p^{am}}{t}} \theta d\lambda d\theta + \int_{\hat{\theta}^{am}}^{1} \int_{-\frac{v_l - p^{am}}{t}}^{\frac{v_l - p^{am}}{t}} (1-\theta) d\lambda d\theta\Big) p^{am}(1-\alpha^{am}) .\end{aligned}$$

Solving the first-order condition, we obtain the equilibrium retail price:

$$p^{am*} = \frac{v_h + v_l - 2s\hat{\theta}^{am}}{4} .$$

Under the new configuration, we can derive the absorbed shipping cost (**SC**) as:

$$SC^{am} = \Big(\int_{\hat{\theta}^{am}}^{1} \int_{-\frac{v_h - p^{am}}{t}}^{\frac{v_h - p^{am}}{t}} \theta d\lambda d\theta + \int_{\hat{\theta}^{am}}^{1} \int_{-\frac{v_l - p^{am}}{t}}^{\frac{v_l - p^{am}}{t}} (1-\theta) d\lambda d\theta \Big) \gamma s ,$$

Following the similar procedure of the main model, we can write down the retail platform profit as:

$$\begin{aligned} \pi_R^{am} = \; & \frac{1}{8t}\Big((v_h + v_l)^2 - 8s^2 - 4s(v_h - 3v_l + (v_h + v_l)\gamma) - 8tf + 4\hat{\theta}^{am}(4tf + 4s(s + v_h - 2v_l) \\ & - s(2s + v_h - 3v_l)\gamma - (2tf + s(s + 4v_h - 4v_l - 2(s + v_h - v_l)\gamma))\hat{\theta}^{am}) \Big) - \mu . \end{aligned}$$

Solving the first-order condition with respect to $\hat{\theta}^{am}$ yields:

$$\hat{\theta}^{am*} = \frac{4tf + 4s(s + v_h - 2v_l) - s(2s + v_h - 3v_l)\gamma}{4tf + 2s(s + 2(v_h - v_l)(2-\gamma) - 2s\gamma)} .$$

It is easily verified that the interior solution requires $f > \frac{s(v_l(8-3\gamma) + v_h(\gamma-4) + 2s(\gamma-2))}{4t}$ and $s < \frac{4v_h - 3v_h\gamma + v_l\gamma}{2+2\gamma}$.

Then we can get π_R^{am*} from the equilibrium outcomes and π_R^{ab*} from the main model, from which the retail platform profit gain can be obtained as the following:

$$\Delta\pi_R^{a*} = \frac{s^2(2s(1+\gamma) - v_l\gamma + v_h(3\gamma - 4))^2}{8t(2tf + s(s + 2(v_h - v_l)(2-\gamma) - 2s\gamma))} .$$

Proof of Proposition 17

Let's denote $\Delta\pi^i_{R|\hat{\theta}}$, where $i \in \{a, w\}$, as the retailer profit gain from the MFS program with membership base represented by $\hat{\theta}$ under each pricing model.

$$\begin{aligned} \Delta\pi^a_{R|\hat{\theta}^{wm*}} - \Delta\pi^w_{R|\hat{\theta}^{wm*}} = \; & \frac{s(1-\hat{\theta}^{wm*})}{8t}[(v_h + v_l)(5 - 3\gamma) - s((3-\gamma)(1-\gamma) \\ & + (7 - \gamma(2+\gamma))\hat{\theta}^{wm*})] \\ > \; & \frac{s(1-\hat{\theta}^{wm*})}{8t}[2s(5-3\gamma) - s((3-\gamma)(1-\gamma) + (7 - \gamma(2+\gamma)))] \\ > \; & 0 . \end{aligned}$$

Therefore, we have $\Delta\pi_R^{a*} = \Delta\pi^a_{R|\hat{\theta}^{am*}} \geq \Delta\pi^a_{R|\hat{\theta}^{wm*}} > \Delta\pi^w_{R|\hat{\theta}^{wm*}} = \Delta\pi_R^{w*}$.

APPENDIX C

SUPPLEMENTAL MATERIAL FOR CHAPTER 4

Proof of Lemma 8

The first-order conditions for manufacturer's optimization problem in stage 1 are given by the following:

$$\frac{\partial \pi_M^{bc}}{\partial p_A^{bc}} = \frac{(1-\alpha)(t(1-\theta)+2\theta(v_l-s)-2(1+\theta)p_A^{bc}+2(1-\theta)p_B^{bc})((1-\sigma)\gamma_h+\sigma\gamma_l)}{2t} = 0 \ ,$$

$$\frac{\partial \pi_M^{bc}}{\partial p_B^{bc}} = \frac{(1-\alpha)(t(1-\theta)+2\theta(v_l-s)-2(1+\theta)p_B^{bc}+2(1-\theta)p_A^{bc})((1-\sigma)\gamma_h+\sigma\gamma_l)}{2t} = 0 \ .$$

Solving the above two equations simultaneously, we obtain the equilibrium retail prices given as follows:

$$p_A^{bc*} = p_B^{bc*} = \frac{t(1-\theta)+2\theta(v_l-s)}{4\theta} \ .$$

The demand functions for the two retailers are given by:

$$D_A^{bc} = ((1-\sigma)\gamma_h+\sigma\gamma_l)(\theta\frac{v_l-p_A^b-s}{t}+(1-\theta)\frac{t-p_A^b+p_B^b}{2t}) \ .$$

$$D_B^{bc} = ((1-\sigma)\gamma_h+\sigma\gamma_l)(\theta\frac{v_l-p_B^b-s}{t}+(1-\theta)\frac{t-p_B^b+p_A^b}{2t}) \ .$$

Substituting the equilibrium retail prices, we get equilibrium manufacturer profit as follows:

$$\pi_M^{bc*} = \frac{(1-\alpha)(t(1-\theta)^2+2\theta(v_l-s))^2((1-\sigma)\gamma_h+\sigma\gamma_l)}{8t\theta} \ .$$

Similarly, we can get the equilibrium retailer profits:

$$\pi_A^{bc*} = \pi_B^{bc*} = \frac{\alpha(t(1-\theta)^2+2\theta(v_l-s))^2((1-\sigma)\gamma_h+\sigma\gamma_l)}{16t\theta} \ . \tag{C.1}$$

Proof of Lemma 9

The first-order conditions for the manufacturer's optimization problem in stage 3 are given by the following:

$$\begin{aligned}
\frac{\partial \pi_M^{ac}}{\partial p_A^{ac}} = {} & [(1-\alpha)((1-\sigma)(2\theta v_l - 2(1+\theta)p_A^{ac} + (1-\theta)(t+s+2p_B^{ac}))\gamma_h \\
& +\sigma(t(1-\theta) - 2s\theta - 2(1+\theta)p_A^{ac} + 2(1-\theta)p_B^{ac} + 2\theta v_l)\gamma_l)][2t]^{-1} = 0 \ . \\
\frac{\partial \pi_M^{ac}}{\partial p_B^{ac}} = {} & [(1-\alpha)((1-\sigma)(2\theta v_l - 2(1+\theta)p_B^{ac} + (1-\theta)(t+s+2p_A^{ac}))\gamma_h \\
& +\sigma(t(1-\theta) - 2s\theta - 2(1+\theta)p_B^{ac} + 2(1-\theta)p_A^{ac} + 2\theta v_l)\gamma_l)][2t]^{-1} = 0 \ .
\end{aligned}$$

Solving the above two equations simultaneously, we obtain the equilibrium retail prices as follows:

$$\begin{aligned}
p_A^{ac*} = {} & \frac{t(1-\theta) + 2\theta(v_l - s)}{4\theta} + \frac{s(1-\sigma)\gamma_h}{2(1-\sigma)\gamma_h + 2\sigma\gamma_l} \ . \\
p_B^{ac*} = {} & \frac{t(1-\theta) + 2\theta(v_l - s)}{4\theta} \ .
\end{aligned}$$

The demand functions for the two retailers are given by:

$$\begin{aligned}
D_A^{ac} = {} & (1-\sigma)\gamma_h(\theta\frac{v_l - p_A^{ac}}{t} + (1-\theta)\frac{t+s-p_A^{ac}+p_B^{ac}}{2t}) \\
& +\sigma\gamma_l(\theta\frac{v_l - p_A^{ac} - s}{t} + (1-\theta)\frac{t - p_A^{ac} + p_B^{ac}}{2t}) \ . \\
D_B^{ac} = {} & (1-\sigma)\gamma_h(\theta\frac{v_l - p_B^{ac} - s}{t} + (1-\theta)\frac{t-s-p_B^{ac}+p_A^{ac}}{2t}) \\
& +\sigma\gamma_l(\theta\frac{v_l - p_B^{ac} - s}{t} + (1-\theta)\frac{t - p_B^{ac} + p_A^{ac}}{2t}) \ .
\end{aligned}$$

Substituting the equilibrium retail prices, we get equilibrium manufacturer profit as follows:

$$\begin{aligned}
\pi_M^{ac*} = {} & [(1-\alpha)((t(1-\theta) + 2\theta(v_l - s))((\sigma-1)(2s\theta(1+\theta) + t(1-\theta)(1-3\theta) \\
& +2(1-3\theta)\theta v_l)\gamma_h + \sigma(1-3\theta)(t(1-\theta) + 2\theta(v_l - s))\gamma_l))][32t\theta^2]^{-1} \\
& +\frac{(1+\theta)((1-\sigma)(t(1-\theta) + 2\theta v_l)\gamma_h + \sigma(t(1-\theta) + 2\theta(v_l - s))\gamma_l)^2}{32t\theta^2((1-\sigma)\gamma_h + \sigma\gamma_l)} \ .
\end{aligned}$$

Similarly, we get equilibrium profit for retailer B as follows:

$$\begin{aligned}
\pi_B^{ac*} = {} & [\alpha(t(1-\theta) + 2\theta(v_l - s))((1-\sigma)(t - s - \theta(s+t) + 2\theta v_l)\gamma_h \\
& +\sigma(t(1-\theta) + 2\theta(v_l - s))\gamma_l)][16t\theta]^{-1} \ .
\end{aligned} \tag{C.2}$$

The profit of retailer A consists of three parts: retailer's commission revenue collected from the manufacturer (**CR**), membership fee paid by subscribing consumers (**MF**), and absorbed shipping cost (**SC**). These three parts are calculated as follows:

$$\begin{aligned} CR_A^{ac} = \ & (\sigma\gamma_l(\theta\frac{v_l - p_A^{ac} - s}{t} + (1-\theta)\frac{t - p_A^{ac} + p_B^{ac}}{2t}) \\ & +(1-\sigma)\gamma_h(\theta\frac{v_l - p_A^{ac}}{t} + (1-\theta)\frac{t + s - p_A^{ac} + p_B^{ac}}{2t}))p_A^{ac}\alpha \ . \end{aligned}$$

$$SC_A^{ac} = \ (1-\sigma)\gamma_h(\theta\frac{v_l - p_A^{ac}}{t} + (1-\theta)\frac{t + s - p_A^{ac} + p_B^{ac}}{2t})s \ .$$

$$MF_A^{ac} = \ (1-\sigma)M_A^{ac} \ .$$

Calculating retailer A's profit using the formula $\pi_A^{ac} = CR_A^{ac} + MF_A^{ac} - SC_A^{ac}$, we obtain:

$$\begin{aligned} \pi_A^{ac*} = \ & [\alpha((1-\sigma)(t(1-\theta) + 2\theta v_l)\gamma_h + \sigma(t(1-\theta) + 2\theta(v_l - s))\gamma_l)((1-\sigma)((t+s)(1-\theta) \\ & +2\theta v_l)\gamma_h + \sigma(t(1-\theta) + 2\theta(v_l - s))\gamma_l)][16t((1-\sigma)\gamma_h + \sigma\gamma_l)]^{-1} \\ & -\frac{4s^2(1+\theta)(1-\sigma)\gamma_h}{16t} \ . \end{aligned} \tag{C.3}$$

Proof of Proposition 18

Retailer B's profit gain $\Delta\pi_B^{abc*} = \pi_B^{ac*} - \pi_B^{bc*}$. Substituting its equilibrium profits, we get its equilibrium profit gain as follows:

$$\Delta\pi_B^{abc*} = \ -\frac{s\alpha(1-\theta)(1-\sigma)(t(1-\theta) + 2\theta(v_l - s))}{16t\theta} < 0 \ . \tag{C.4}$$

Retailer A's profit gain $\Delta\pi_A^{abc*} = \pi_A^{ac*} - \pi_A^{bc*}$. Substituting its equilibrium profits, we get its equilibrium profit gain as follows:

$$\begin{aligned} \Delta\pi_A^{abc*} = \ & -\frac{2(1-\sigma)\gamma_h(2(1+\theta+\alpha\theta)(1-\sigma)\gamma_h + (2+\alpha+2\theta+3\alpha\theta)\sigma\gamma_l)}{(1-\sigma)\gamma_h + \sigma\gamma_l}s^2 \\ & +\frac{\alpha(1+3\theta)(1-\sigma)(t(1-\theta) + 2\theta v_l)\gamma_h}{\theta}s \ . \end{aligned} \tag{C.5}$$

Here, $\Delta\pi_A^{abc*}$ is a quadratic function of s with an inverted-U shape. Simple algebraic transformation shows that retailer A's profit gain is positive if and only if $0 < s < \overline{s}^c$.

Proof of Lemma 10

The first-order conditions for the manufacturer's optimization problem in stage 3 are given by the following:

$$\begin{aligned}\frac{\partial \pi_M^{sc}}{\partial p_A^{sc}} =& \quad [(1-\alpha)((1-\sigma)((1-\theta)(t+2p_B^{sc})-2(1+\theta)p_A^{sc}+2\theta v_l)\gamma_h \\ & +\sigma(t(1-\theta)-2s\theta-2(1+\theta)p_A^{sc}+2(1-\theta)p_B^{sc}+2\theta v_l)\gamma_l)][2t]^{-1}=0 \ , \\ \frac{\partial \pi_M^{sc}}{\partial p_B^{sc}} =& \quad [(1-\alpha)((1-\sigma)((1-\theta)(t+2p_A^{sc})-2(1+\theta)p_B^{sc}+2\theta v_l)\gamma_h \\ & +\sigma(t(1-\theta)-2s\theta-2(1+\theta)p_B^{sc}+2(1-\theta)p_A^{sc}+2\theta v_l)\gamma_l)][2t]^{-1}=0 \ .\end{aligned}$$

Solving the above two equations simultaneously, we obtain the equilibrium retail prices as follows:

$$p_A^{sc*}=p_B^{sc*}= \quad d\tfrac{t(1-\theta)+2\theta(v_l-s)}{4\theta}+\frac{s(1-\sigma)\gamma_h}{2(1-\sigma)\gamma_h+2\sigma\gamma_l} \ .$$

The demand functions for the two retailers are given by:

$$\begin{aligned}D_A^{sc} =& \quad (1-\sigma)\gamma_h(\theta\tfrac{v_l-p_A^{sc}}{t}+(1-\theta)\tfrac{t-p_A^{sc}+p_B^{sc}}{2t}) \\ & +\sigma\gamma_l(\theta\tfrac{v_l-p_A^{sc}-s}{t}+(1-\theta)\tfrac{t-p_A^{sc}+p_B^{sc}}{2t}) \ . \\ D_B^{sc} =& \quad (1-\sigma)\gamma_h(\theta\tfrac{v_l-p_B^{sc}}{t}+(1-\theta)\tfrac{t-p_B^{sc}+p_A^{sc}}{2t}) \\ & +\sigma\gamma_l(\theta\tfrac{v_l-p_B^{sc}-s}{t}+(1-\theta)\tfrac{t-p_B^{sc}+p_A^{sc}}{2t}) \ .\end{aligned}$$

Substituting the equilibrium retail prices, we get equilibrium manufacturer profit as follows:

$$\pi_M^{sc*}= \quad \frac{(1-\alpha)((1-\sigma)(t(1-\theta)+2\theta v_l)\gamma_h+\sigma(t(1-\theta)+2\theta(v_l-s))\gamma_l)^2}{8t\theta((1-\sigma)\gamma_h+\sigma\gamma_l)} \ .$$

The profit of retailer A consists of three parts: retailer's commission revenue collected from the manufacturer (**CR**), membership fee paid by subscribing consumers (**MF**), and absorbed shipping cost (**SC**). These three parts are calculated as follows:

$$\begin{aligned}CR_A^{sc} =& \quad (\sigma\gamma_l(\theta\frac{v_l-p_A^{sc}-s}{t}+(1-\theta)\frac{t-p_A^{sc}+p_B^{s}}{2t}) \\ & +(1-\sigma)\gamma_h(\theta\frac{v_l-p_A^{sc}}{t}+(1-\theta)\frac{t-p_A^{sc}+p_B^{sc}}{2t}))p_A^{sc}\alpha \ .\end{aligned}$$

$$SC_A^{sc} = \quad (1-\sigma)\gamma_h(\theta\frac{v_l - p_A^{sc}}{t} + (1-\theta)\frac{t - p_A^{sc} + p_B^{sc}}{2t})s \ .$$

$$MF_A^{sc} = \quad (1-\sigma)M_A^{sc} \ .$$

Calculating retailer A's profit using the formula $\pi_A^{sc} = CR_A^{sc} + MF_A^{sc} - SC_A^{sc}$, we obtain:

$$\begin{aligned} \pi_A^{sc*} = \quad & \frac{\alpha((1-\sigma)(t(1-\theta)+2\theta v_l)\gamma_h + \sigma(t(1-\theta)+2\theta(v_l - s))\gamma_l)^2}{16t((1-\sigma)\gamma_h + \sigma\gamma_l)} \\ & -\frac{4s^2(1+\theta)(1-\sigma)\gamma_h}{16t} \ . \end{aligned} \tag{C.6}$$

Due to symmetry between the retailers, following a similar approach, we can get retailer B's equilibrium profit as:

$$\begin{aligned} \pi_B^{sc*} = \quad & \frac{\alpha((1-\sigma)(t(1-\theta)+2\theta v_l)\gamma_h + \sigma(t(1-\theta)+2\theta(v_l - s))\gamma_l)^2}{16t((1-\sigma)\gamma_h + \sigma\gamma_l)} \\ & -\frac{4s^2(1+\theta)(1-\sigma)\gamma_h}{16t} \ . \end{aligned} \tag{C.7}$$

Proof of Proposition 19

Retailer A or B's profit gain $\Delta\pi_i^{sbc*} = \pi_i^{sc*} - \pi_i^{bc*}$, where $i = A$ or B. Substituting the equilibrium profits, we get its equilibrium profit gain as follows:

$$\Delta\pi_i^{sbc*} = \quad -\frac{(1-\sigma)\gamma_h(1+\theta+\alpha\theta+\frac{\alpha\theta\gamma_l}{(1-\sigma)\gamma_h+\sigma\gamma_l})}{4t}s^2 + \frac{\alpha(1-\sigma)(t(1-\theta)+2\theta v_l)\gamma_h}{4t}s \ . \tag{C.8}$$

Here, $\Delta\pi_i^{sbc*}$ is a quadratic function of s with an inverted-U shape. Simple algebraic transformation shows that retailer A or B's profit gain is positive if and only if $0 < s < \widehat{s}^c$.

Proof of Proposition 20

Proposition 18 suggests that if one retailer chooses not to implement the MFS program, the other retailer's best response is to implement the MFS program if and only if $s < \overline{s}^{abc}$. Conversely, if one retailer chooses to implement the MFS program, the other retailer's payoff is π_B^{ac*} if it chooses not to implement the MFS program, and π_B^{sc*} if it implements the MFS program as well. The profit difference cal be calculated as follows:

$$\begin{aligned} \Delta\pi_B^{sac*} = \pi_B^{sc*} - \pi_B^{ac*} = \quad & -\frac{(1-\sigma)\gamma_h((2+\alpha)(1+\theta)+\frac{2\alpha\theta\sigma\gamma_l}{(1-\sigma)\gamma_h+\sigma\gamma_l})}{8t}s^2 \\ & +\frac{\alpha(1+3\theta)(1-\sigma)(t(1-\theta)+2\theta v_l)\gamma_h}{16t\theta}s \ . \end{aligned}$$

Here, $\Delta\pi_B^{sac*}$ is a quadratic function of s with an inverted-U shape. Simple algebraic transformation shows that $\Delta\pi_B^{sac*} > 0$ if and only if $0 < s < \underline{s}^c$. Therefore, if one retailer chooses to implement the MFS program, the other retailer's best response is to implement the MFS program if and only if $s < \underline{s}^c$. Next, we show that $\overline{s}^c > \underline{s}^c$ by taking the difference of the two terms:

$$\begin{aligned}\overline{s}^c - \underline{s}^c = \;& [\alpha^2(1-\theta)(1+3\theta)(1-\sigma)(t(1-\theta)+2\theta v_l)\gamma_h((1-\sigma)\gamma_h+\sigma\gamma_l)] \\ & [2\theta((2+\alpha)(1+\theta)(1-\sigma)\gamma_h+(2+\alpha+2\theta+3\alpha\theta)\sigma\gamma_l) \\ & (2(1+\theta+\alpha\theta)(1-\sigma)\gamma_h+(2+\alpha+2\theta+3\alpha\theta)\sigma\gamma_l)]^{-1}\ .\end{aligned}$$

It is easy to see that the term is positive, so $\overline{s}^c > \underline{s}^c$ holds and the equilibria specified by Proposition 20 are valid.

Proof of Proposition 21

By Proposition 19, we know that both retailers are better off with the MFS program in the case of MM if and only if $s < \widehat{s}^c$. Moreover, Proposition 20 tells us MM is the equilibrium if and only if $s < \underline{s}^c$. Then, we show that $\widehat{s}^c < \underline{s}^c$ by taking the difference of the two terms:

$$\begin{aligned}\underline{s}^c - \widehat{s}^c = \;& [\alpha(1-\theta)(t(1-\theta)+2\theta v_l)((1-\sigma)\gamma_h+\sigma\gamma_l)((1+(1-\alpha)\theta)(1-\sigma)\gamma_h+(1+\theta)\sigma\gamma_l)] \\ & [2\theta((1+\theta+\alpha\theta)(1-\sigma)\gamma_h+(1+\theta+2\alpha\theta)\sigma\gamma_l) \\ & ((2+\alpha)(1+\theta)(1-\sigma)\gamma_h+(2+\alpha+2\theta+3\alpha\theta)\sigma\gamma_l)]^{-1}\ .\end{aligned}$$

It is easy to see that the term is positive, so $\widehat{s}^c < \underline{s}^c$ holds and Proposition 21 is proved.

Proof of Proposition 22

When there is no MFS, the retailer's profit can be calculated as:

$$\pi_R^{bm*} = \pi_A^{bc*} + \pi_B^{bc*} = \frac{\alpha(t(1-\theta)^2+2\theta(v_l-s))^2((1-\sigma)\gamma_h+\sigma\gamma_l)}{8t\theta}\ .$$

In the case of asymmetric implementation, the retailer's profit can be calculated as:

$$\begin{aligned}\pi_R^{am*} = \pi_A^{ac*} + \pi_B^{ac*} = \quad & \Big[[\alpha((1-\sigma)(t(1-\theta)+2\theta v_l)\gamma_h + \sigma(t-(t+2s)\theta+2\theta v_l)\gamma_l) \\ & ((1-\sigma)((t+s)(1-\theta)+2\theta v_l)\gamma_h + \sigma(t-(t+2s)\theta+2\theta v_l)\gamma_l)] \\ & [\theta((1-\sigma)\gamma_h+\sigma\gamma_l)]^{-1} + [\alpha(t(1-\theta)-2s\theta+2\theta v_l) \\ & ((1-\sigma)(t-s-(t+s)\theta-2\theta v_l)\gamma_h + \sigma(t-(t+2s)\theta+2\theta v_l)\gamma_l)] \\ & [\theta]^{-1} - 4s^2(1+\theta)(1-\sigma)\gamma_h\Big]\Big[16t\Big]^{-1} .\end{aligned}$$

In the case of symmetric implementation, the retailer's profit can be calculated as:

$$\begin{aligned}\pi_R^{sm*} = \pi_A^{sc*} + \pi_B^{sc*} = \quad & \frac{\alpha((1-\sigma)(t(1-\theta)+2\theta v_l)\gamma_h + \sigma(t(1-\theta)+2\theta(v_l-s))\gamma_l)^2}{8t((1-\sigma)\gamma_h+\sigma\gamma_l)} \\ & -\frac{4s^2(1+\theta)(1-\sigma)\gamma_h}{8t} .\end{aligned}$$

Then we can show that:

$$\begin{aligned}\pi_R^{am*} - \pi_R^{bm*} = \quad & -\frac{(1-\sigma)\gamma_h((2-\alpha+2\theta+3\alpha\theta)(1-\sigma)\gamma_h + 2(1+\theta+2\alpha\theta)\gamma_l)}{8t((1-\sigma)\gamma_h+\sigma\gamma_l)}s^2 \\ & +\frac{\alpha(1-\sigma)(t(1-\theta)+2\theta v_l)\gamma_h}{4t}s .\end{aligned}$$

$$\begin{aligned}\pi_R^{sm*} - \pi_R^{am*} = \quad & -\frac{(1-\sigma)\gamma_h((2+\alpha)(1+\theta)(1-\sigma)\gamma_h + 2(1+\theta+2\alpha\theta)\sigma\gamma_l)}{8t((1-\sigma)\gamma_h+\sigma\gamma_l)}s^2 \\ & +\frac{\alpha(1-\sigma)(t(1-\theta)+2\theta v_l)\gamma_h}{4t}s .\end{aligned}$$

It is very easy to verify that $\pi_R^{am*} > \pi_R^{bm*}$ if and only if $0 < s < \overline{s}^m$ and $\pi_R^{sm*} > \pi_R^{am*}$ if and only if $0 < s < \underline{s}^m$. Newt, we also know that:

$$\begin{aligned}\overline{s}^m - \underline{s}^m = \quad & [4\alpha^2(1-\theta)(1-\sigma)(t(1-\theta)+2\theta v_l)\gamma_h((1-\sigma)\gamma_h+\sigma\gamma_l)] \\ & [((2+\alpha)(1+\theta)(1-\sigma)\gamma_h + 2(1+\theta+2\alpha\theta)\sigma\gamma_l) \\ & ((2-\alpha+2\theta+3\alpha\theta)(1-\sigma)\gamma_h + 2(1+\theta+2\alpha\theta)\sigma\gamma_l)]^{-1} .\end{aligned}$$

Clearly, this term is positive, so $\underline{s}^m < \overline{s}^m$ and the statements of Proposition 22 hold true.

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BIOGRAPHICAL SKETCH

Geng Sun was born in Tianjin, China. He earned his bachelor's degree in Mechanical Engineering from Huazhong University of Science and Technology (HUST), China, in 2008. After a few years working in the industry, he then attended The University of Texas at Dallas (UT Dallas) and received his MBA and MS degree in Information Technology Management in 2014. Geng joined the PhD program in Management Science with a concentration in Information Systems at UT Dallas under the supervision of Dr. Srinivasan Raghunathan and Dr. Huseyin Cavusoglu in 2014. His research primarily focuses on e-commerce, online platforms, technology diffusion, and multi-sided markets. At UT Dallas, he taught undergraduate courses, including Information Technology for Business, Introduction to Programming, and Object-Oriented Programming. He is going to start his new position as Assistant Professor of Information Systems at The University of Texas Rio Grande Valley in August 2020.

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BS, Mechanical Engineering, Huazhong University of Science and Technology, 2008
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PhD, Information Systems, The University of Texas at Dallas, 2020

Essays on the Economics of Membership-based
Free Shipping Programs in Online Marketplaces
PhD Dissertation
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Research

Research Interests

Economics of IS, E-commerce, Online Platforms, Technology Diffusion, Multi-sided Markets

Research Papers

"Is Free Shipping Really Free? Strategic Implications of Membership-Based Free Shipping Programs of Online Marketplaces." with Huseyin Cavusoglu and Srinivasan Raghunathan.
"Membership-Based Free Shipping Program of Online Marketplaces: Does a Shift from Wholesale to Agency Model Encourage its Adoption?" with Huseyin Cavusoglu and Srinivasan Raghunathan.
"Membership-Based Free Shipping Programs: A New Vehicle to Gain Competitive Advantage for Online Retailers?" with Huseyin Cavusoglu and Srinivasan Raghunathan.
"A Reexamination of Impacts of Reviewer Credibility on Online Review Helpfulness." solo work.
"Incentive Regulation and Capital Structure in Digital Networks: Theory, Evidence and Implications." with Sumit Majumdar.
"Technological Disruption that Redefines Consumption: An Examination of Digital Camera Market Through Diffusion Lens." with Byungwan Koh and Srinivasan Raghunathan.

Work-in-Progress

"Two-sided Platforms with Gigs: An Analysis of Online Food Delivery Market." with Yeongin Kim.

"Home Sharing or Commercial Listing? The Implications of Airbnb on Long-term Rental and Housing Markets." with Chenglong Zhang.

Presentation

"Technological Disruption that Redefines Consumption: An Examination of Digital Camera Market Through Diffusion Lens." *INFORMS Annual Meeting*, Seattle, WA, Oct 2019.

"Membership-Based Free Shipping Programs: A New Vehicle to Gain Competitive Advantage for Online Retailers?". *International Conference on Information Systems (ICIS)*, San Francisco, CA, Dec 2018. **Nominated for Best Paper Award**

"Technological Disruption that Redefines Consumption: An Examination of Digital Camera Market Through Diffusion Lens." *Conference on Information Systems and Technology (CIST)*, Phoenix, AZ, Nov 2018.

"Membership-Based Free Shipping Program via a Shift from Wholesale to Platform Model". *POMS 29th Annual Conference*, Houston, TX, May 2018.

"An Analysis of Membership-Based Free Shipping Programs of Online Marketplaces". *International Conference on Information Systems (ICIS)*, Seoul, South Korea, December 2017.

"Strategic Implications of Free Shipping Program of Electronic Marketplaces". *Big XII+ MIS Research Symposium*, Omaha, NE, April 2017.

Teaching

Teaching Interests

Business Analytics, Machine Learning, Database, Programming, Operations Management

Teaching Experience

Introduction to Programming, Undergraduate, Spring 2020
Object-Oriented Programming, Undergraduate, Spring 2019
Information Technology for Business, Undergraduate, Fall 2017

Teaching Assistant

Business Data Warehousing, Graduate, Summer 2018
System Analysis and Design, Undergraduate, Summer 2018
Enterprise Resource Planning, Undergraduate/Graduate, Summer 2018
Strategic Management, Undergraduate/Graduate, Spring 2018
Managing Digital Strategy, Graduate, Spring 2018
System Analysis and Project Management, Graduate, Summer 2017
Introduction to Programming, Undergraduate, Spring 2017
Object-Oriented Programming, Undergraduate/Graduate, Spring 2017/Fall 2016
Database Foundations, Graduate, Spring 2017
Advanced Business Intelligence, Spring 2015

Industry & Other Professional Experience

International Business Analyst, NCH Corporation, TX, 2013-2014
Assistant General Manager, I.M.F. Impianti Macchine Fonderia Srl, China, 2011-2012
Engineer, IGCC GreenGen, Huaneng Power International, China, 2008-2011
Internship Coordinator, Dongfang Electric Corporation (DEC), China, 2007

Selected Honors:

Nominated and Accepted for ICIS Doctoral Consortium, 2018
Doctoral Fellowship, University of Texas at Dallas, 2016-2017
Graduate Research Travel Funding, University of Texas at Dallas, 2014-2019
Cohort MBA Scholarship, University of Texas at Dallas, 2012-2014

Academic Service

International Conference on Information Systems (ICIS), Munich, Germany, 2019
International Conference on Web Services (ICWS), Honolulu, HI, 2017
Reviewer, Information Technology and Management, 2019-2020
Assistant Editor, Strategic Management Review, 2012-2015

Professional Memberships:

Association for Information Systems (AIS)
Institute for Operations Research and the Management Sciences (INFORMS)

Computational Skills

Programming Languages: R, Python, JAVA, SQL, VBA
Analytics Packages: STATA, SAS, Weka
DBMS: MS Access, MS SQL Sever, MySQL
Other: LaTeX, Mathematica, HTML