Spring 5-15-2019

Firms’ Strategies for Technology and Platform-based Markets

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by

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A dissertation presented to
The Graduate School
of Washington University in
partial fulfillment of the
requirements for the degree
of Doctor of Philosophy

May 2019
St. Louis, Missouri

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Acknowledgments

I would like to thank my advisor and committee chair Dr. Baojun Jiang for navigating me through my five years of doctoral program. His support and guidance have helped me greatly in finishing my doctoral study and becoming a better scholar. I would never be able to fully repay his effort and time spent on me. He is an exemplar of an outstanding advisor and professor to emulate.

I would also like to thank Dr. K. Sudhir and Dr. Bo Zhou for their inputs as coauthors on two of my research articles (maybe more in the future). My research and I myself have benefited extensively from their wisdom and expertise.

I would also like to thank Dr. Chakravarthi Narasimhan, Dr. Seethu Seetharaman, Dr. Raphael Thomadsen, and Dr. Bo Zhou for serving as my committee members and providing insightful feedbacks on improving my dissertation. I would also thank other faculty members and students at Marketing Department of Washington University in St. Louis, especially Dr. Tat Chan and Dr. Arun Gopalakrishnan, for the inspiration and assistance they have provided.

I want to thank my parents and family for everything they have rendered to me. Last but not least, I thank my girlfriend, Guangying Chen, for her support and encouragement in the last two years. Wish her the best for her own doctoral study at Olin Business School.

Tianxin Zou

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May 2019

ABSTRACT OF THE DISSERTATION

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Doctor of Philosophy in Business Administration

Marketing

Washington University in St. Louis, 2019

Professor Baojun Jiang, Chair

In this dissertation, I build game-theoretic frameworks to study how new Internet-enabled technologies can change the strategies of firms and online platforms.

The first chapter studies how the integration of primary and resale concert ticket platforms can affect consumers and musicians. Consumers can buy concert tickets from primary platforms (e.g., Ticketmaster) or from resale platforms (e.g., StubHub) where tickets are resold by other consumers. Recently, Ticketmaster has also been developing its resale business and attempting to control the resale market by blocking consumers from reselling on competing resale platforms. Legislation in many states in the US requires consumers should be able to freely resell tickets on any resale sites. The rationale is that Ticketmaster's stronger pricing power will lead to increases in its service fees and final ticket prices, making musicians and consumers worse off. In this paper, we establish a game-theoretic framework and show that the opposite can happen: if some consumers are uncertain of whether they can attend the concert when buying tickets, the primary platform's control of the resale market can lower the prices and service fees in both the primary and the resale markets. The musician and consumers will be better off as a result. Moreover, we

find that, when the primary platform controls the resale market, the presence of a small group of scalpers can counterintuitively reduce the final ticket prices and increase the musician's profit and the consumer surplus. We also show that competition in the resale market may harm the consumers. Using data from Ticketmaster.com and StubHub.com, we provide some suggestive empirical support for the theoretical predictions.

The second chapter studies how new technologies that reduce the consumer's search cost will affect online retail platforms, third-party sellers, and consumers. We show that a lower search cost can *increase* sellers' expected profits even though it will increase price competition among sellers. A lower search cost always benefits the platform when it optimally adjusts its fee. When the search cost decreases, the platform should reduce its fee if demand elasticity increases significantly, in which case the platform, the sellers and the consumers can all be better off. By contrast, if the lowered search cost does not significantly increase demand elasticity, the platform's optimal fee will increase, potentially leading to *higher* retail prices but making consumers and sellers worse off. Furthermore, when the market has a premium seller with higher base quality than non-premium sellers, a decrease in search cost will increase non-premium sellers' profits but has a *non-monotonic* effect on the premium seller's profit. When consumers can filter some product attributes on the platform, their direct benefit from searching the unfilterable attributes is reduced but the expected consumer surplus will increase.

The third chapter studies how cost transparency will impact a firm's intertemporal pricing and innovation decisions. We show that cost transparency stymies the low-cost firm's ability to intertemporally price-discriminate because consumers now correctly anticipate the future price drops and delay purchases, as it is no longer feasible to pool price with the high-cost firms, whose future prices drop less because of the high cost. Thus, cost transparency will benefit the high-cost firms but hurt the low-cost firms. Surprisingly, consumers can also be hurt by cost transparency if the firm has a high cost. However, cost transparency leads to an expected increase in both firm profits and consumer surplus—a win-win for both firms and consumers. This increase in expected firm profits facilitates greater investment by firms in new-product innovation.

Chapter 1 Can Musicians and Fans Benefit When a Primary Ticket Platform Controls the Resale Market?

1.1 Introduction

In 2017, the revenue of the concert-ticket industry in the U.S. reached over three billion dollars, and more than twenty million consumers in the U.S. have attended at least one concert in that year.[1] Ticketmaster, with an over 80% of the U.S. market share, is the dominant ticket platform in the primary ticket market (Roberts 2013). It has contracted with 80 out of the top 100 concert venues, and has become the exclusive ticket outlet for many top musicians (Sisario and Bowley 2018). Ticketmaster mainly profits from the service fees paid by ticket buyers. For example, it charges a $17.85 service fee for a $61 ticket of Justin Timberlake's *The Man of The Woods Tour* at the Madison Square Garden, New York. The peer-to-peer ticket resale market (a.k.a. the secondary market) is also growing rapidly. StubHub, with an over 50% share of the ticket resale market in the U.S., has seen a 30% annual growth rate in revenue in 2015 (Thomas 2016).

Over the past few years, Ticketmaster has expanded its business to the resale market. In 2008, it acquired TicketsNow, an online ticket resale platform, for $256 million. In 2013, Ticketmaster introduced its own "Fan-to-Fan" resale system, Ticketmaster Resale (formerly known as TM+). Musicians can enroll in Ticketmaster Resale so that consumers can resell their tickets on Ticketmaster. For concerts with Ticketmaster Resale, the primary and resale ticket availability will be shown on the same seat map (see Figure 1.1 for example). In 2014, Ticketmaster received $900 million from the ticket resale market (Ingham 2015). Moreover, Ticketmaster has been trying to extend its monopoly power in the primary market to the resale market by blocking competing resale platforms. For example, after signing on as the exclusive resale partner of the Golden State

Warriors (GSW) in 2012, Ticketmaster warned GSW season-ticket owners that their tickets could be revoked if they resold the tickets outside Ticketmaster. Consequently, StubHub saw an 80 percent decrease in resale transactions of GSW season tickets. Ticketmaster also introduced the "Paperless Ticket" system (also known as Credit Card Entry) for some events, which requires consumers to show the credit card used to buy the ticket and a photo ID to enter the concert. Because few consumers would like to give their credit card and photo ID to others, Paperless Ticket system make it very difficult for consumers to resell tickets via other resale platforms, e.g., StubHub. Consumers can resell their paperless tickets only through Ticketmaster's resale system.

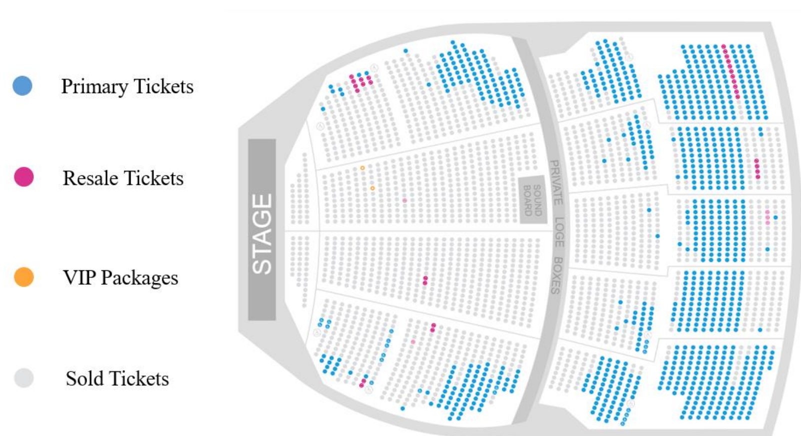

Figure 1.1 Seat Map of a Concert with Ticketmaster Resale

The public reacted negatively to Ticketmaster's "anti-competitive" practices. StubHub sent e-mails to its customers to caution that "companies 'like Ticketmaster' are moving to restrictive paperless systems, which could kill the secondary market for tickets" (Indiviglio 2011). StubHub also sued Ticketmaster and GSW in 2015 for creating illegal market conditions, although the lawsuit was later dismissed (Rovell 2015). The Paperless Ticket system has also led to a drastic dispute among consumers. For example, a spokesman for Consumer Action argues that "[it] is wrong to deprive consumers of the right to fairly sell, trade or give away the ticket" (Pender 2017).

A news article in *The Atlantic* also blames Ticketmaster for “extend[ing] its near monopoly of ticketing to the secondary market” (Indiviglio 2011). Several states in the U.S., including Colorado, Connecticut, Massachusetts, Missouri, New Jersey, New York, and Virginia, have passed or are debating bills requiring ticket issuers to offer tickets in a freely transferable format that can be sold on any resale sites. The Virginia bill, the Ticket Resale Rights Act, was proposed by state delegate David B. Albo, who lost $400 because he was unable to resell his two paperless tickets for Iron Maiden (Vozzella 2017). Albo argues that Ticket Resale Rights Act “would help consumers, given Ticketmaster’s near-monopoly over big-venue ticket sales nationwide.” It is generally believed that Ticketmaster’s entry into the resale business will create a ticket-intermediary monolith and will harm the welfare of musicians and consumers.

This paper builds an analytical framework to examine how the primary ticket platform’s entry into the resale market and its attempts to block competing resale platforms will affect the musicians, the primary ticket platform, the resale platform, and the consumers. In the main analysis, we consider two scenarios. In the independent-platforms case, the primary ticket platform and the resale platform are owned by independent parties. This scenario reflects the situation in which Ticketmaster has not entered the resale market controlled by independent platforms such as StubHub. In the integrated-platform case, an integrated platform monopolizes both the primary and the resale markets. This setting captures the situation in which Ticketmaster enters the resale market and uses Paperless Ticket to prevent consumers from reselling tickets on other resale platforms. In Section 5.3, we examine a third case, where the integrated platform competes with an independent resale platform in the resale market (i.e., the integrated platform does not preclude other resale platforms). See Figure 1.2 for an illustration of the market structures in these three cases.

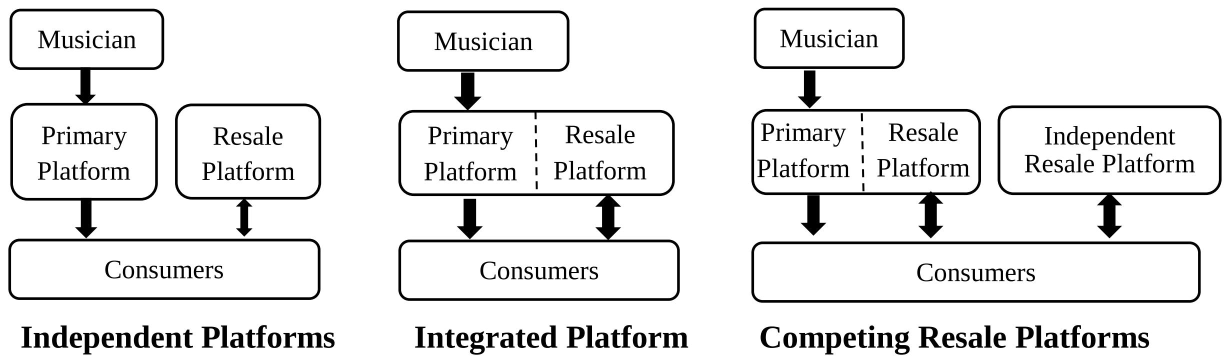

Figure 1.2 Three Types of Market Structures

We consider a two-period model where some consumers are uncertain of whether they will have a time conflict with the concert in the first period, and the uncertainty is resolved in the second period. Consumers are heterogeneous in their probability of being able to attend the concert and their valuation of the concert. If a consumer buys a ticket in the first period, she can resell the ticket to other consumers on the resale platform in the second period. Consumers can buy tickets from either the primary platform or the resale platform, but if the demand for a concert exceeds its supply on one platform, consumers may be unable to get a ticket from that platform. The musician chooses the ticket's face price and the venue size (i.e., the number of available tickets) in the first period. In the independent-platforms case, the primary platform and the resale platform set their service fees respectively. In the integrated-platform case, the integrated platform sets service fees on both platforms altogether. The final price paid by consumers on the primary market is the sum of the face price and the service fee on the primary platform. The equilibrium resale price is jointly determined by the demand and supply in the resale market. Consumers have rational expectations on the future prices and the probabilities of being able to get a ticket from either the primary or the resale markets.

The conventional wisdom would predict that if the primary ticket platform (Ticketmaster) has better control of the resale market, it will have stronger pricing power. As a result, the service fees in the primary and resale markets will be higher and the consumers and the musician will become worse off. However, we show that the conventional wisdom may not hold in some situations: both the consumers and the musician can be better off when the primary and the resale platforms are owned and operated by one firm (as in the integrated-platform case) compared with when the two platforms are independent (as in the independent-platforms case). The intuition hinges on the spillover effect from the primary market to the resale market. When the ticket primary-market price is lower, consumers with lower likelihood of attending the concert will buy tickets in the first period. These consumers are more likely to resell tickets, so the transaction volume in the resale market will increase. In other words, lowering the price in the primary market has a positive spillover to the resale market, leading to higher profits from the resale market. By contrast, in the integrated-platform case, the integrated platform will internalize the positive spillover by lowering the final price in the primary market. As a result, the profit in the resale market increases. Hence, the double-marginalization problem in the primary retail channel will be alleviated. The final price will be lower, leading the musician to choose a larger venue size, so more consumers will be served. As a result, both the musician and consumers can be better off. We also find that when the integrated platform competes with a third-party resale platform whose market share is significant, the musician and consumers can become better off if the integrated platform can successfully block its competitor and thus monopolize both the primary and the resale markets. Furthermore, we show that an integrated platform tends to choose a lower resale percentage fee in order to boost sales in the primary market. To summarize, when the primary platform also controls the resale market, it tends to charge lower price and service fee on both the primary and the resale market due to the spillovers between these two markets. The double-marginalization problem in the primary market can be alleviated, and both the musician and consumers can become better off. We also discuss how our insights can be generalized to other markets, e.g., used-goods and peer-to-peer product-sharing markets.

We also demonstrate that, interestingly, consumers could be worse off when the final ticket price or the resale percentage fee decreases. This is because low prices and service fees can attract consumers with a lower probability of attending the concert to buy tickets early. Therefore, more consumers with a higher likelihood to attend the concert will be crowded out from the primary market and have to buy tickets from the resale market, in which case some consumer surplus will be seized by the resale platform via the resale service fee.

Finally, we discuss the impact of the presence of some scalpers, who buy tickets with the sole intention of reselling them at higher prices. We also show that in the integrated-platform case, the existence of a small group of scalpers may lead to lower ticket prices and higher musician’s profit and consumer surplus. This is because scalpers are more likely to resell tickets than ordinary consumers. Thus, the integrated platform can earn more profit from the resale market by selling tickets to scalpers, so it has an incentive to keep the ticket price in the primary market low enough to make it profitable for scalpers to scalp tickets. The integrated platform’s extra incentive to reduce the final ticket price will further alleviate the double-marginalization problem in the primary market, which may potentially make the musician and the consumers better off.

We provide some suggestive empirical support for some of our theoretical predictions from the data collected on Ticketmaster.com and StubHub.com. Some musicians enroll in the Ticketmaster Resale system which allows consumers to resell tickets on Ticketmaster. Others do not enroll, so consumers cannot resell tickets on Ticketmaster. For concerts with Ticketmaster Resale, Ticketmaster tends to charge a lower resale percentage fee than StubHub for the same concert. Ticketmaster is also more likely to charge a lower service fee for primary tickets of concerts with Ticketmaster Resale than concerts without Ticketmaster Resale. This is consistent with our theoretical prediction that Ticketmaster's optimal service fee in the primary market is lower when it also operates its own resale platform, and that Ticketmaster's optimal service fee for resale transactions is lower than that of an independent resale platform.

1.2 Literature Review

This paper contributes to the economics and marketing literature on secondary markets for event tickets. Most of the studies focus on whether allowing consumers or scalpers to resell tickets is beneficial to event organizers and consumers. Courty (2003a) shows that, in a setting where consumers are uncertain about their valuations at the time of purchase, allowing reselling cannot strictly increase the ticket agency's profit. Geng et al. (2007) examine a similar setting and show that "partial allowance" of resales, i.e., allowing consumers to resell only before the event organizer's announcement of the second-period price, can strictly increase the event organizer's profit. Courty (2003b) shows that the existence of ticket brokers will reduce the primary event organizer's profit because brokers can arbitrage when the event organizer raises its price over time, which limits the event organizer's ability to exercise intertemporal price discrimination. Karp and Perloff (2005) find that the primary event organizer can benefit from the entry of resellers if they can perfectly price-discriminate consumers. Su (2010) shows that the presence of speculators will increase an event organizer's expected profit because the event organizer can sell tickets to speculators early and transfer the inventory risk to them. Cui et al. (2014) find that an event organizer can benefit from lower transaction costs in the resale market and further improve its profit by selling consumers an option for buying tickets later.

Several studies have empirically examined how the existence of resale markets can affect the primary market. Cusumano et al. (2008) show that the entry of Craigslist into the musical ticket resale market raises the prices of popular musicians but lowers the prices of less popular ones. They also argue that musicians will be better off if the primary market and the secondary market have separate opening time windows. Leslie and Sorensen (2014) find that the existence of resale markets can on average increase the allocation efficiency by 5% for major rock concerts, but a third of the increase is offset by the ticket brokers' costly efforts of getting tickets early and the transaction costs in the resale market. Lewis et al. (2018) show that the presence of a secondary market for season tickets of a Major League Baseball team increases the season ticket purchase rate in the primary market. By contrast, secondary-market regulations, such as minimum list price policies, will reduce the purchase rate of season tickets.

Our paper differs from the aforementioned literature in two fundamental aspects. First, all of those papers consider a direct selling setting. To the best of our knowledge, our paper is the first to consider how the resale market can influence the strategic interaction between different channel members in the primary market, i.e., the (upstream) musician and the (downstream) ticket platform. Second, most of the extant studies focus on whether the firm or the social planner should allow consumers or scalpers to resell tickets. By contrast, our research examines how the musician and consumers are affected by whether the primary platform and the resale platform are owned and operated by the same entity or independent entities. We find that the integration of the primary and the resale platforms can lead to lower equilibrium service fees on both platforms and can benefit all channel members (i.e., the musician, the primary platform and consumers) at the same time.

Our paper also relates to the literature on retail competition. The general finding of this literature is that a merger between retailers will reduce the competition between retailers, so the final retail price will increase. Reduced retail competition can exacerbate the double-marginalization problem in the distribution channel, making both the upstream manufacturers and the consumers worse off (Harutyunyan and Jiang 2018; Li 2002; Padmanabhan and Png 1998; Tirole 1988; Zhang 2002). This is the rationale for some anti-trust regulations against horizontal mergers that would give the merged firm too much market power. In contrast, our paper shows that when the primary platform and the resale platform are integrated rather than independent, the final ticket price in the primary market can be lower and the musician and consumers can be better off. Furthermore, we also find that consumers can actually be better off when the primary platform deprives them of their ability to resell tickets on other resale platforms. The difference in results reflects that the relationship between primary platforms and resale platforms is fundamentally different from the relationship between competing retailers. The spillover effect between the primary and the resale markets are positive: a lower price in one market can lead to more transactions in the other market. By contrast, the spillover effect between retailers are negative: a lower price of one retailer will reduce the sales of competing retailers.

This paper also contributes to the general literature on secondary markets for used goods. Swan (1970, 1972, 1975) prove that the existence of the secondary market will not limit a monopoly seller's profits. Rust (1986) shows that if consumers endogenously decide when to resell their durable goods, the monopolist firm may have an incentive to purposely reduce the durability of its product. Anderson and Ginsburgh (1994) find that when consumers have heterogeneous preferences over new and used goods, a used-goods market can benefit a monopoly seller because it allows the seller to achieve a form of second-degree price discrimination. Purohit and Staelin (1994) consider a car manufacturer selling to both end consumers and rental companies, both of whom resell their used cars on the resale market. They compare the manufacturer's and the dealer's profits under different market structures, and show that in general a higher substitutability between used rental cars and new cars will reduce the manufacturer's profit, but dealers are generally better off. Desai and Purohit (1998) consider a car manufacturer's leasing and selling decisions where consumers can resell their used cars and find that the manufacturer may choose leasing, selling or both, depending on the depreciation rates of sold versus leased cars. Hendel and Lizzeri (1999) find that a monopolist can benefit from the secondary market even though the used-goods market will compete with the new-goods product. Shulman and Coughlan (2007) study a monopoly manufacturer's optimal pricing decision in a market where the retailer can buy back and resell used products. They find that under certain conditions, the manufacturer may find it optimal not to sell any new goods in the second period. Jiang and Tian (2018) show that, similar to secondary markets, consumer-to-consumer product sharing has a value-enhancement effect, which can increase a monopolist's optimal quality and price of its product. Tian and Jiang (2018) find that the consumer-to-consumer sharing market is more likely to benefit the downstream retailer than the upstream manufacturer. These papers mostly consider that consumers use a durable product for a period time before they resell it. By contrast, in our model, concert tickets can be used only once even though they may be purchased at different times. More importantly, we model a new market dynamic that has not been studied. Consumers are uncertain about their valuations in the early period (i.e., whether they can attend the concert); some earlier buyers may want to resell their tickets in the later period if they find out that they will not be able to attend the concert. In addition, we study a novel research question not studied by past research: how the integration of the primary and the resale platforms will affect the musician, the platform, and the consumers.

1.3 Model

Consider a musician who plans to organize a concert for his performance in a city at some time in the future. The musician (denoted by M) will sell the tickets via a primary ticket platform (e.g., Ticketmaster), denoted by P.[2] The musician needs to choose the size of performance venue to rent; his cost for renting the venue is $c \cdot N$, where N is the venue size (total number of available seats) and c is a constant. Let $\overline{N}$ denote the size of the largest venue in the city, so $N \leq \overline{N}$. As is typically the case on Ticketmaster in practice, the musician will choose the (ticket's) face price f for the tickets, and then the primary platform will charge consumers a service fee for the ticket. Let p denote the final price that a consumer pays for a ticket. Equivalently, the primary platform's per-ticket service fee is $p - f$.[3]

Without loss of generality, we assume that there is a unit mass of consumers (indexed by i) in the market. Consumers are heterogeneous in their valuations of the concert. There are two types of consumers. A fraction α of consumers are "avid fans," denoted by A, who have valuation V_A for the concert if they can attend it. The rest of the consumers (a fraction $1 - \alpha$) are "casual fans," denoted by C, whose valuation for the concert conditional on attending, is $V_C < V_A$. Consumers ex ante may be uncertain about whether they will be able to go to the concert, e.g., there could be other activities in the future that may conflict with the concert (e.g., a friend's party). Since avid fans value the concert more than casual fans, they are probably more likely than casual fans to attend the concert rather than other activities. Let ρ_i be the probability that consumer i can attend the concert. For tractability, we assume that $\rho_i = 1$ for avid fans and $\rho_i \sim \text{uniform}(0,1)$ across the population of casual fans. Each consumer knows ex ante her own ρ_i, but the platforms cannot identify each consumers' type. If a consumer does not attend the concert, her utility from the concert is normalized to zero. Therefore, a type-i consumer has probability ρ_i of having $v_i = V_i$, and a probability $1 - \rho_i$ of having $v_i = 0$, where $i \in \{A, C\}$. Each consumer buys at most one ticket.

To capture the reality that consumers' uncertainty about whether they can attend the concert may get resolved over time, we model two distinctive time periods in which consumers can buy tickets. In the first period, casual fans are uncertain about whether they can attend the concert, but in the second period they will know whether they can attend it. Consumers who bought tickets in the first period can choose to resell their tickets on the resale platform (denoted by R) in the second period, even if they can attend the concert themselves. Let r denote the resale price of tickets on the resale platform. Consumers can buy a ticket from the primary platform by paying the final price p, or buy a ticket from the resale platform by paying the resale price r, if tickets are not sold out on these platforms. In practice, the resale platform (e.g., StubHub) charges a percentage fee for transactions on it. Let $k \in [0,1]$ denote the resale platform's percentage service fee, so a consumer will receive $(1-k)r$ for reselling her ticket. Section 4 analyzes the case of exogenous service fee k and discusses the main insights. In Section 5.2, we consider the endogenous decisions on k by the independent resale platform and by the integrated platform. Most results from our main model will remain qualitatively the same when the service fee k is endogenously decided.

Next we introduce how the equilibrium resale price r^* is determined in our model. An intuitive candidate for r^* is the market-clearing resale price, i.e., at this price, the number of consumers willing to resell their tickets (the supply) is equal to the number of those willing to buy resale tickets (the demand). However, such a market-clearing resale price may not exist in our setting. This is because in the second period, consumers will know whether they can attend the concert and their ex post valuations of attending the concert can only possibly be V_A, V_C, or zero. Hence, neither the demand function nor the supply function in the resale market is continuous in general. To determine the unique equilibrium resale price, we use an alternative notion that is conceptually similar to the market-clearing price. Specifically, we assume that the equilibrium resale price r^* is the maximum resale price that clears the supply in the resale market, and that all resale tickets are sold at r^*. Although this is a simplifying assumption, we suggest that it is reasonable. On the one hand, if the resale price is higher than r^*, there will be excess supply in the resale market, so some consumers unable to resell their tickets may have an incentive to lower their listed resale price to guarantee a sale. On the other hand, if the resale price is lower than r^*, a reseller may want to raise her listed resale price slightly and still be guaranteed to successfully resell her ticket. We further assume $r^* = 0$ if there will be some resale tickets unsold for *any* positive r, and $r^* = V_A$ if there will be no consumers willing to resell tickets at any $r \leq V_A$. Note that consumers' realized valuation v_i in the second period is either V_A, V_C or 0, so r^* will be one of these three values in equilibrium. Table 1.1 exhibits several examples of the equilibrium resale price in different scenarios.

Table 1.1 Examples of Equilibrium Resale Prices r^*

Demand of resale tickets	Supply of resale tickets	Equilibrium r^*
10 fans with willingness-to-pay \$10; 20 fans with willingness-to-pay \$5.	5 fans want to resell tickets	\$10
	25 fans want to resell tickets	\$5
	35 fans want to resell tickets	\$0

When the maximum venue size $\overline{N} \leq \alpha$, i.e., the largest venue in the city cannot hold all avid fans, one can show that the musician will set the ticket's face price f to be the avid fan's valuation, V_A, and the primary platform and the resale platform will always receive zero surplus. We will focus on the more interesting case of $\overline{N} > \alpha$ in the rest of the paper. For closed-form solutions, we also assume that the maximum venue size is not too large such that $\overline{N} \leq \frac{2\alpha}{1+\alpha}$.[4]

The timeline of the game is as follows. Prior to the first period, the musician decides the venue size $N \in [0, \overline{N}]$ and the ticket face price f. The primary platform subsequently sets the final ticket price p, (i.e., it effectively charges a service fee $p - f$ per ticket). In the first period, consumers will decide whether to buy the ticket from the primary platform. In the second period, consumers learn whether they can attend the concert. Those who bought tickets in the first period can choose to resell their tickets in the resale market. Those without a ticket can choose to buy a ticket from either the primary platform (if tickets have not sold out) or from the resale market. On either the primary platform or the resale platform, if there are more consumers demanding the ticket than the total number of tickets available, tickets will sell out, in which case consumers are assumed to have equal chances of getting a ticket. If the price on one platform is lower than the other platform, consumers will first try to buy tickets from the cheaper platform. Consumers who fail to get a ticket from that platform can then decide whether to buy from the other platform.

In the main analysis, we consider two cases regarding whether the primary and the resale platforms are operated by the same entity. In the case of independent platforms (denoted by IDP), the primary and the resale platform are operated by independent entities who maximize their respective profits. This case reflects the situation where Ticketmaster (the primary platform) has not entered the resale market. In the case of integrated platform (denoted by INT), the primary and the resale platforms are owned by the same entity that maximizes the joint profit of two platforms. This case reflects the situation where Ticketmaster enters the resale market and can use its Paperless Ticket system to prevent consumers from reselling on other platforms. Comparing these two cases helps us to examine how Ticketmaster's entry and control of the resale market will affect the musician and consumers. In Section 5.3, we will also examine the case of competing resale platforms where an integrated platform and an independent resale platform compete with each other in the resale market.

1.4 Analysis

We solve for rational expectation subgame-perfect equilibria. In such equilibria, the musician, the primary platform, the resale platform and consumers have rational expectations about the resale price and the consumers' probability of getting a ticket from a platform. There may exist multiple rational expectation subgame-perfect equilibria differing in consumers' belief on how many consumers will buy tickets in the first period, given the final price p and the venue size N. If all consumers believe that many consumers will buy tickets in the first period, they may also want to buy tickets early because they believe that there will be few tickets left in the second period. However, if all consumers believe that only a small number of consumers will buy tickets in the first period, they may also postpone buying the ticket, anticipating that there will be many leftover tickets in the second period. To pin down the unique equilibrium outcome when multiple rational expectation equilibria exist, we introduce the concept of the "buying-spree equilibrium" to our setting. We define the buying-spree equilibrium as the rational expectation subgame-perfect equilibrium that, among all possible rational expectation subgame-perfect equilibria, has the highest number of consumers *trying to buy* tickets in the first period. This is a reasonable scenario, especially for more popular concerts. In reality, consumers often rush to buy tickets as soon as tickets are released and many concerts sell out in the first few hours. For example, The Rolling Stone sold out 75,000 tickets in 51 minutes for their *"14 on Fire"* tour in Paris in 2014.[5]

LEMMA 1. *The buying-spree equilibrium in our setting is unique.*

Lemma 1 shows that the buying-spree equilibrium is unique. All proofs are relegated to Appendix A.

One can easily show that it is not optimal to choose $N < \alpha$, i.e., a venue that cannot contain all avid fans, because the musician can receive a strictly higher profit by choosing $N = \alpha$ and $f =$

V_A to reap all the surplus of avid fans. For the rest of this section, we will analyze the more interesting parameter range of $\frac{2\alpha}{1+\alpha} \geq \bar{N} \geq N \geq \alpha$.

One can find the derivation of consumers' utility function in Appendix A. We now examine the consumer's buying and reselling decisions. Note that when $k < 1 - \frac{V_C}{V_A}$, or equivalently $(1-k)V_A > V_C$, a casual fan will resell her ticket when the resale price is $r = V_A$, even if her realized v_i is V_C. By contrast, when $k \geq 1 - \frac{V_C}{V_A}$, or equivalently $(1-k)V_A \leq V_C$, a causal fan will never resell her ticket when she has $v_i = V_C$. In this section, we assume the resale percentage fee k to be exogenous, and divide our analysis into the case of a high resale percentage fee ($k \geq 1 - \frac{V_C}{V_A}$) and that of a low percentage fee ($k < 1 - \frac{V_C}{V_A}$). We show that both the musician and the consumers can be better off under the integrated platform than under the independent platforms. In Section 5.2, we analyze the case of endogenous resale percentage fee k and show that the primary platform's entry into the resale market can lower k in equilibrium, which can even further increase the musician's profit and the consumer surplus.

1.4.1 The Case of High Resale Percentage Fee

This section considers the case with $k \geq 1 - \frac{V_C}{V_A}$. In this case, the casual fans will not resell their tickets when their realized valuation is $v_i = V_C$. With a final ticket price $p \in (V_C, V_A]$, avid fans will buy tickets in the first period and casual fans will not buy tickets from the primary market because $p > V_C$. Thus, there will be no transactions in the resale market.

We proceed to consider the case of $p \in [(1-k)V_A, V_C]$. Part (a) of Lemma 2 summarizes the equilibrium outcome with the ticket's final price $p = V_C$, and part (b) of Lemma 2 characterizes the range of p where the concert is expected to sell out in the first period and the equilibrium resale price is $r^* = V_A$.

LEMMA 2. *Suppose that* $(1-k)V_A \leq p \leq V_C$ *and* $\alpha < N < \frac{2\alpha}{1+\alpha}$.

(a) When $p = V_C$*, there exists a unique equilibrium: all avid fans buy tickets from the primary market in the first period, and all casual fans with realized valuation* $v_i = V_C$ *will try to buy tickets in the second period. Tickets do not sell out in the primary market and no consumer will resell tickets.*

(b) There exists an equilibrium in which the concert will sell out in the first period and the equilibrium resale price is $r^* = V_A$ *if and only if* $(1-k)V_A \leq p \leq \theta V_C + (1-\theta)(1-k)V_A$, *where* $0 < \theta = \frac{(1-\alpha)(N-\alpha)+\sqrt{(1-\alpha)\alpha[\alpha(1+2N)-\alpha^2-2N^2]}}{(1-\alpha)N} < 1$.

In Appendix A, we show that if there is an equilibrium in which the concert sells out in the first period and the equilibrium resale price is $r^* = V_A$, this equilibrium is the (unique) buying-spree equilibrium. Therefore, the equilibrium described in part (b) of Lemma 2 is the buying-spree equilibrium. For conciseness, we will use "equilibrium" to refer to the "buying-spree equilibrium" for the rest of the paper.

Lemma 2 characterizes the equilibrium consumer choice when p belongs to the intervals $[(1-k)V_A, \theta V_C + (1-\theta)(1-k)V_A]$ or $[V_C, V_A]$. In Appendix A, we show that it is *not* optimal for the primary platform to choose any p outside these two intervals. Thus, we will discuss the consumer's choice decisions only in the subgame with p being inside these intervals.

Decisions of the platform and the musician

Having discussed the consumers' buying and reselling decisions, we will now examine the optimal strategies of the primary platform (or the integrated platform) and the musician. We compare the equilibrium outcomes under two platform structures. In the independent-platforms case, the primary and the resale platforms are operated by independent entities. In the integrated-platform case, an integrated platform operates in both the primary and the resale markets and maximizes their joint profit.

We start with the case of independent platforms. In this case, the primary platform maximizes its own profit π_P, and the musician maximizes his profit π_M. Note that $\pi_P = N(p - f)$ when $p \leq V_C$ and $\pi_P = \min\{\alpha, N\} \cdot (p - f)$ if $V_A \geq p > V_C$. Hence, in equilibrium, the primary platform's optimal final price p will be either V_C or V_A, at which *no* casual fans will buy tickets in the first period, therefore precluding any resale transaction in the second period. We will show later that an integrated platform can have incentives to set $p < V_C$, which will induce some casual fans to buy in the first period. In that case, there may be resale transactions in the second period, since some casual fans who bought tickets may not be able to attend the concert and some fans who can go to the concert may not have successfully bought a ticket in the first period.

LEMMA 3. *Let* $\alpha_{IDP} \equiv \bar{N}(1 - \sqrt{\frac{V_A - V_C}{V_A - c}})$*. In the independent-platforms (IDP) case:*

(a) If $\alpha \geq \alpha_{IDP}$*, the musician will choose the venue size* $N_{IDP}^* = \alpha$ *and the face price* $f_{IDP}^* = V_A$*. The primary platform will set the final price* $p_{IDP}^* = f_{IDP}^* = V_A$*. Avid consumers will buy tickets from the primary platform and casual fans will not buy tickets in either periods. Consumer surplus is zero.*

(b) If $\alpha < \alpha_{IDP}$*, the musician will choose* $N_{IDP}^* = \bar{N}$ *and* $f_{IDP}^* = \frac{\bar{N}V_C - \alpha V_A}{\bar{N} - \alpha}$*. The primary platform will set* $p_{IDP}^* = V_C$*. All avid fans will buy tickets from the primary platform in the first period. Casual fans with realized* $v_i = V_C$ *will try to buy tickets from the primary platform in the second period. Consumer surplus is* $\alpha(V_A - V_C)$*.*

Lemma 3 summarizes the equilibrium outcome in the independent-platforms case. Note that a large number of avid fans will give the primary platform a stronger incentive to serve only the avid fans and extract all their surplus by setting $p = V_A$. Anticipating this, the musician would rather himself set a high face price $f = V_A$ to extract the avid fans' surplus. Lemma 3 shows that when $\alpha > \alpha_{IDP}^*$, the musician will indeed find it optimal to choose such a high face price (V_A). In this case, the musician will choose a small venue size ($N = \alpha < \bar{N}$) and only avid fans will be served. By contrast, if there are not many avid fans (when $\alpha < \alpha_{IDP}^*$), the primary platform is more inclined to choose $p = V_C < V_A$ to serve both the avid and the casual fans. Thus, anticipating the primary platform's optimal targeting decision, the musician will choose a low f (lower than V_C) and a large venue size $N = \bar{N}$.

We want to point out that Lemma 3 indicates that regardless of the value of α, the primary market will choose the final price $p \geq V_C$ so no casual fans will buy tickets in the first period. As a result, there will be no transactions in the resale market in the second period. Note that this result relies on our assumption that avid fans will always be able to attend the concert. In Section 5.2., we examine an extension in which the avid fans also have a small probability of unable to attend the concert. We find that, in that extension, some avid fans who find themselves unable to attend the concert in the second period will resell their tickets in the case of independent platforms. One should interpret the "no resale" result in Lemma 3 as that in the independent-platforms case the primary platform will have a limited incentive to encourage first-period purchase from casual fans. We will see how this result is different in the integrated-platform case.

We proceed to discuss the integrated-platform case. Let $\pi_I \equiv \pi_P + \pi_R$ be the total profit of the integrated platform. Define $\alpha_0 \equiv \frac{(2-k)V_A - 2V_C}{kV_A}$. We begin by analyzing the subgame where the musician has already chosen N and f, and the integrated platform is making its optimal final price decision.

PROPOSITION 1. *When* $N > \alpha$, $f < \frac{N\left[1-\frac{k(1+\alpha)}{2}\right]-\alpha}{N-\alpha} V_A$, *and* $\alpha < \alpha_0$, *the integrated platform will set* $p = (1-k)V_A < V_C$ *so all consumers will try to buy tickets in the first period. A strictly positive number of casual consumers will resell their tickets in the second period at resale price* $r^* = V_A$.

Proposition 1 shows that different from the case of independent platforms, if the musician chooses a low enough face price f and a large enough venue size N, it is possible for the integrated platform to choose some $p < V_C$. At this price point, some casual consumers will want to buy tickets in the first period and resell their tickets if they cannot attend the concert in the second period. The intuition hinges on the spillover effect *from the primary market to the resale markets*. In particular, in our framework, a lower final price p will attract more casual fans with a lower likelihood to attend the concert (ρ_i) to buy tickets in the first period (from the primary market). These casual fans are more likely to resell their tickets, so there will be more transactions in the resale market. To put it differently, lowering p will have a positive spillover effect into the resale market. When the population of casual fans is larger (i.e., α is smaller), the positive spillover is more significant. Therefore, when $\alpha < \alpha_0$, the integrated platform may want to reduce its final ticket price p in the primary market to reap the benefit from more transactions in the resale market, provided that the musician chooses a large enough venue size $N > \alpha$ and a low enough face price $f < \frac{N\left[1-\frac{k(1+\alpha)}{2}\right]-\alpha}{N-\alpha} V_A$. This contrasts with the case of independent platforms, where the primary platform charges a high final price ($p \geq V_C$) that precludes resale transactions. This happens because the primary platform cannot directly receive profits from the resale transactions and will hence have limited incentives to lower its price to convince casual consumers to buy in the first period (i.e., before they know whether they can attend the concert). To summarize, Proposition 1 shows that, compared with the case of independent platforms, an integrated platform will be more likely to reduce p to attract early purchase from casual consumers. Corollary 1 shows that this result is more likely to be true when the resale percentage fee (k) is smaller.

COROLLARY 1. *A lower resale percentage fee* (k) *will expand the parameter region* ($\frac{2\alpha}{1+\alpha} > N > \alpha$, $f < \frac{N\left[1-\frac{k(1+\alpha)}{2}\right]-\alpha}{N-\alpha} V_A$, *and* $\alpha < \alpha_0$) *in which the integrated platform will choose* $p = (1-k)V_A < V_C$ *to induce first-period purchases from casual consumers.*

Intuitively, when the resale percentage fee (k) is larger, the integrated platform can keep a great portion of the resale transaction price, so it will be more likely to set $p < V_C$ to induce more casual consumers buying in the first period and thus generate more resale transactions. Interestingly, Corollary 1 shows the opposite: A *smaller* k makes the integrated platform more likely to choose $p < V_C$. The intuition is as follows. When k is smaller, casual consumers will tend to buy tickets in the first period (from the primary market), because they will pay a lower resale service fee if they cannot attend the concert. As a result, the integrated platform can convince the casual fans to buy tickets in the first period by only slightly reducing p (to $(1-k)V_A$), which will not negatively affect its profit in the primary market too much. Hence, the integrated platform is more likely to set $p = (1-k)V_A < V_C$.

Next, we investigate the musician's optimal decisions on the face price f and the venue size N. Let $\alpha_{INT} \equiv \bar{N}[1 - \frac{\sqrt{V_A k[V_A k \bar{N}^2 + 8(1+\bar{N})(V_A - c)]} - V_A k \bar{N}}{4(V_A - c)}]$. If $\alpha_0 \leq 0$, the integrated platform will never choose $p < V_C$, and the equilibrium outcomes in the integrated-platform case will be the same as those for the independent-platforms case (as described in Lemma 3). If $\alpha_0 > 0$, the musician's decisions and the equilibrium outcome depend on the relative magnitude of α, α_{INT}, α_{IDP} and α_0. Table 2 summarizes the optimal decisions of the musician and the integrated platform as well as the equilibrium outcomes. An important observation is that when $\alpha < \min\{\alpha_0, \alpha_{INT}\}$, corresponding to the first and the fourth rows of Table 2, the equilibrium final price $p_{INT}^* < V_C$ and the integrated platform will receive a strictly positive profit from the resale market. By contrast, as shown in Lemma 3, in the case of independent platforms, the resale platform's equilibrium profit is zero regardless of the value of α.

An interesting finding from Table 1.2 is on how the resale percentage fee k will affect the consumer surplus. Intuitively, when k decreases, consumers can pay less for buying and reselling tickets. Moreover, more consumers will want to buy tickets, and the musician tends to choose a larger venue size to serve more consumers. As a result, consumers should be better off. However, Proposition 2 shows that if the musician has already chosen the largest possible venue size $N = \bar{N}$, a further drop in k can *reduce* the consumer surplus.

Table 1.2 Equilibrium Outcomes of the Integrated Platform Case with $V_A > \frac{2}{2-k} V_C$

	$\alpha \in$	N_{INT}^*	f_{INT}^*	p_{INT}^*	$\pi_{M,INT}^*$	$\pi_{I,INT}^*$	$\pi_{R,INT}^*$
$\alpha_0 < \alpha_{INT}$	$(0, \alpha_0]$	$\bar{N}$	$[1 - \frac{\bar{N}k(1+\alpha)}{2(\bar{N}-\alpha)}]V_A$	$(1 - k)V_A$	$\{[1 - \frac{\bar{N}k(1+\alpha)}{2(\bar{N}-\alpha)}]V_A - c\}\bar{N}$	$\frac{k\bar{N}V_A\alpha(1+\alpha)}{2(\bar{N}-\alpha)}$	$\frac{kV_A\bar{N}(1-\alpha)}{2}$
	$(\alpha_0, \alpha_{IDP}]$	$\bar{N}$	$\frac{\bar{N}V_C-\alpha V_A}{\bar{N}-\alpha}$	V_C	$\left[\frac{\bar{N}V_C-\alpha V_A}{\bar{N}-\alpha} - c\right]\bar{N}$	$\frac{\bar{N}\alpha}{\bar{N}-\alpha}(V_A - V_C)$	0
	$(\alpha_{IDP}, 1)$	α	V_A	V_A	$(V_A - c)\alpha$	0	0
$\alpha_0 \geq \alpha_{INT}$	$(0, \alpha_{INT}]$	$\bar{N}$	$[1 - \frac{\bar{N}k(1+\alpha)}{2(\bar{N}-\alpha)}]V_A$	$(1 - k)V_A$	$\{[1 - \frac{\bar{N}k(1+\alpha)}{2(\bar{N}-\alpha)}]V_A - c\}\bar{N}$	$\frac{k\bar{N}V_A\alpha(1+\alpha)}{2(\bar{N}-\alpha)}$	$\frac{kV_A\bar{N}(1-\alpha)}{2}$
	$(\alpha_{INT}, 1)$	α	V_A	V_A	$(V_A - c)\alpha$	0	0

* The intervals α belongs to (the second column) may or may not be empty.

PROPOSITION 2. *A lower resale percentage fee* (k) *can possibly lead to a lower consumer surplus. The result happens only if the musician chooses the largest possible venue size* ($N = \bar{N}$) *before* k *decreases.*

Corollary 1 has shown that α_0 decreases with k. Thus if $\alpha_0 < \alpha_{INT}$, it is possible that when k is relatively high, $\alpha_0 < \alpha \leq \alpha_{IDP}$, but $\alpha \leq \alpha_0$ after k declines. In this case, when k is relatively high such that $\alpha_0 < \alpha \leq \alpha_{IDP}$, in equilibrium the musician will choose the largest-possible venue size $N = \bar{N}$, the integrated platform will choose the final price $p_{INT}^{*} = V_C$ so casual fans will buy tickets only in the second period if their realized valuation $v_i = V_C$, and the consumer surplus is $\bar{N}(V_A - V_C)$. After k decreases such that $\alpha \leq \alpha_0$, the musician will still choose $N = \bar{N}$, the integrated platform may find it optimal to choose $p_{INT}^{*} = (1-k)V_A$ so all casual fans will try to buy tickets in the first period, and the consumer surplus becomes $\bar{N} \cdot [\alpha V_A k + \frac{(1-\alpha)[V_C-(1-k)V_A]}{2}]$, which may be lower than its value before k drops.

The underlying reason of Proposition 2 is that when the musician has already chosen the largest-possible venue size $\bar{N}$, although a further decrease in k can make more casual fans with lower probability of attendance (ρ_i) willing to buy tickets, the musician will not be able to choose a larger venue size to serve all of them. These consumers will also try to buy tickets in the first period, reducing the chance that the (high-valuation, high-attendance-probability) avid fans can successfully get tickets from the primary market. Hence, more avid fans need to buy tickets from the resale market, so some consumer surplus will be extracted by the integrated platform via the resale service fee.

Comparison of the independent-platforms case and the integrated-platform case

Having characterized the equilibrium outcomes in the independent-platforms case and in the integrated-platform case, we now proceed to compare the equilibrium outcomes to determine how the integration of the primary and the resale platforms will affect the market. The following proposition summarizes the comparison of the equilibrium outcomes between the two cases.

PROPOSITION 3. *Suppose that* $\alpha \in (\alpha_{IDP}, \min\{\alpha_{INT}, \alpha_0\})$.[6] *Compared to the independent-platforms case (IDP), in the integrated-platform case (INT):*

(a) The musician will choose a strictly lower ticket face price and a strictly larger venue size ($f_{INT}^* < f_{IDP}^*$ *and* $N_{INT}^* > N_{IDP}^*$) *and the final price will be strictly lower* ($p_{INT}^* < p_{IDP}^*$).

(b) The musician's profit is strictly higher ($\pi_{M,INT}^* > \pi_{M,IDP}^*$) *and the platform's profit in both markets are strictly higher, i.e.,* $\pi_{P,INT}^* > \pi_{P,IDP}^*$ *and* $\pi_{R,INT}^* > \pi_{R,IDP}^*$.

(c) Consumer surplus is also strictly higher in the integrated-platform case than the independent-platforms case.

At a first glance, since the integrated platform controls both the primary and the resale markets, it can raise the final price in the primary market with less concern about losing consumers to the resale market. So, in the integrated-platform case, the equilibrium final price will tend to be higher, and as a result, fewer consumers will be served and the musician's profit and consumer surplus will decrease relative to the independent-platforms case. Our analysis reveals that this is not necessarily true if the number of avid fans is in the intermediate range. As Proposition 3 shows, the integration of the primary and the resale platforms can actually lead to a *lower* final ticket price, *more* consumers attending the concert, a *higher* profit for the musician, and a *higher* consumer surplus. This is because the integrated platform has an incentive to lower the final price p to internalize the positive spillover effect, i.e., to create more transactions in the resale market (as shown in Proposition 1). This will reduce the double-marginalization problem in the distribution channel of the primary market, so the musician is more likely to choose a larger venue size N to serve more consumers. As a result, the integration of the primary and resale platforms can lead to a win-win-win outcome for the musician, the platforms, and the consumers.

The analysis in this section has focused on the case of high resale percentage fee, i.e., $k \geq 1 - \frac{V_C}{V_A}$. Under this condition, the resale percentage fee k is high enough such that the casual fans will not want to resell their tickets if their realized valuation is $v_i = V_C$. Next, we analyze the complementary case of low resale percentage fee, i.e., $k < 1 - \frac{V_C}{V_A}$.

1.4.2 The Case of Low Resale Percentage Fee

This section considers the case of $k < 1 - \frac{V_C}{V_A}$. In this case, all casual fans will be willing to resell their tickets when $r = V_A$ even if they can attend the concert, i.e., even when their realized valuation is $v_i = V_C$. However, if $r \leq V_C$, casual fans will not resell their tickets if they can attend the concert ($v_i = V_C$).

LEMMA 4. *If $k < 1 - \frac{V_C}{V_A}$ and $N > \alpha$, the equilibrium resale price $r^* \leq V_C$ as long as some consumers will resell their tickets in equilibrium.*

Lemma 4 reveals that with the percentage resale fee $k < 1 - \frac{V_C}{V_A}$, the equilibrium resale price r^* will also be no higher than V_C. This is because a lower k will allow consumers to keep more of their resale revenue, leading to more consumers buying tickets in the first period. Thus, more consumers will resell the ticket on the resale market, which will reduce the equilibrium resale price r^*, specifically $r^* \leq V_C$. Note that the resale platform's profit per resale transaction is $k \cdot r^*$. If $k < 1 - \frac{V_C}{V_A}$, $r^* \leq V_C$. Thus the integrated platform will have limited interest in lowering p, because doing so can only slightly increase the profit from the resale market per resale transaction.

It turns out that it is optimal for the integrated platform to choose $p_{INT}^* \geq V_C$ so that no casual fans will buy tickets in the first period. Therefore, the equilibrium outcomes of the independent-platforms case and of the integrated-platform case will be identical.

LEMMA 5. *If $k < 1 - \frac{V_C}{V_A}$, the equilibrium outcome in the independent-platforms case is identical to that in the integrated-platform case, which has been characterized in Lemma 3.*

1.5 Extensions

Thus far, we have demonstrated that when the primary platform controls the resale market, the integrated platform has an extra incentive to lower the final price. The price drop will alleviate the double-marginalization problem in the primary-market distribution channel, which can induce the musician to choose a larger venue size to serve more consumers. The musician and the consumers can be better off as a result. In this section, we consider three model extensions. In the first extension, we examine how the presence of scalpers will affect the market outcome. In the second extension, we study the optimal resale percentage fee for the resale platform in the independent-platforms case and for the integrated platform in the integrated-platform case. In the last extension, we consider the scenario that the integrated platform competes with an independent resale platform in the resale market.

1.5.1 The Impact of Scalpers

Oftentimes, many scalpers buy tickets from the primary market and resell them at higher prices. According to Scott Cutler, CEO of StubHub, nearly half of ticket resales on StubHub come from "professional" traders (Sullivan 2017). It is generally believed that the musician and consumers are worse off with scalpers in the market because they will raise the effective price paid by consumers. The official Twitter account of the rock band LCD Soundsystem derogated scalpers as "parasites" (Horowitz 2017). Scalpers usually use computer bots to buy hundreds of tickets within minutes after concerts start to sell. To combat scalpers, former President Barack Obama signed the Better Online Ticket Sales Act in 2016, which restricts the use of software bots to obtain and resell event tickets. Many states have also passed legislations banning or restricting scalping behaviors. Ticketmaster has also introduced the Verified Fan system, which can block 90% of buying attempts from ticket scalpers (Brooks 2017). In this section, we investigate how the existence of scalpers affects ticket prices, profits of the musician and platforms, and the consumers under different market structures, i.e., whether the primary and the resale platforms are independent or integrated.

In this extension, we assume that besides the unit mass of regular consumers (avid and casual fans), there are β number of scalpers who can also buy tickets from the primary platform and resell them on the resale platform. Scalpers have zero valuation for attending the concert, but move earlier than regular consumers in the first period when buying tickets from the primary platform. The main model in the previous section is the special case of $\beta = 0$. For closed-form analytical solutions, we focus on the parameter region of $\beta \leq \frac{2\alpha-(1+\alpha)\bar{N}}{1-\alpha}$, i.e., there are only a small group of scalpers. To illustrate the most interesting result, in this extension, we analyze the case with $k \geq 1 - \frac{V_C}{V_A}$ and $\alpha \leq \bar{N} \leq \frac{2\alpha}{1+\alpha}$. We will show that, even if scalpers have the ability to buy tickets earlier than regular consumers, the scalpers' presence can still result in *lower* ticket prices and *higher* consumer surplus, and make both the musician and the integrated platform better off.[7] This contrasts with the independent-platforms case, where one can show that, in the above assumed parameter region, the presence of scalpers has no effect on the market outcome, because the primary platform will find it optimal to set a high enough final ticket price (p) so that no scalpers will buy tickets in equilibrium.

First we analyze the case of integrated platform. We begin by examining the subgame where the musician has chosen N and f and the integrated platform is going to choose its optimal final price p. Similar to the previous section, it is not optimal for the musician to choose a venue size $N < \alpha$, so we focus on the case with $\overline{N} \geq N \geq \alpha$. Note that the scalpers will want to buy tickets from the primary market only if p is low enough so they can make positive profit from reselling, specifically when $p \leq (1-k)\widehat{r^*}$.[8] Lemma 6 shows that, in the integrated-platform case, it may be optimal for the integrated platform to choose p low enough such that scalpers will buy tickets in the primary market.

LEMMA 6. *Given the musician's choices of* N *and* f*, the integrated platform will choose* $p = (1-k)V_A$ *if and only if* $\alpha < \frac{2N(V_A - V_C)}{(N-\beta)kV_A} - 1$ *and* $f < V_A\left[1 - \frac{k(1+\alpha)(N-\beta)}{2(N-\alpha)}\right]$. *In that case, all scalpers and regular consumers will try to buy tickets in the first period, and the equilibrium resale price is* $r^* = V_A$. *The integrated platform's total profit is* $\pi_I = \frac{1+\alpha}{2}\beta k V_A + N\left[V_A\left(1 - \frac{k(1+\alpha)}{2}\right) - f\right]$.

It is worth of mentioning that when the conditions in Lemma 6 are satisfied, the integrated platform's profit, π_I, increases with the number of scalpers (β). The presence of scalpers tends to increase resale transactions in the market. This is because scalpers are more likely (with probability one) to resell the tickets compared to avid and casual fans, thus in expectation selling a ticket to a scalper will generate more profit in the resale market for the integrated platform than selling it to a regular consumer, i.e., the presence of the scalpers can strengthen the spillover effect. Therefore, the integrated platform has an incentive to let scalpers buy tickets from the primary market to create transactions in the resale market. To attract scalpers, the integrated platform needs to keep

$p \leq (1-k)\widehat{r^*}$ so scalpers can make a profit. In other words, the integrated platform will have an extra incentive to lower the final price on the primary platform.

Let us use a numerical example to illustrate why the integrated platform may want to lower its final price p when there are scalpers. Suppose that there are 1,000 regular consumers, 500 of whom are avid fans (with $V_A = 100$) and the rest 500 of them are casual fans (with $V_C = 80$), i.e., $\alpha = 0.5$.[9] To illustrate the key intuition, we consider the subgame where the musician has chosen $f = 20$ and a venue with 600 seats ($N = \overline{N} = 600$), and the integrated platform is to choose the final price p. Suppose $k = 0.25$. One can show that when there are no scalpers (i.e., $\beta = 0$), the integrated platform's optimal price is $p = 100$. By contrast, suppose that the market also has 200 scalpers (i.e., $\beta = 0.2$); in this case, one can show that it is optimal for the platform to choose $p = 75$, which is lower than the platform's optimal price $p = 100$ in the absence of scalpers. Note that, in this example, either when $\beta = 0$ or when $\beta = 0.2$, the equilibrium resale price will be $r^* = V_A = 100$ if the platform chooses $p = 75$.

To delineate the insight of how the integrated platform finds it optimal to reduce its price (p) when scalpers are present, Table 1.3 compares the platform's profit decompositions under the cases of $\beta = 0$ and $\beta = 0.2$. Note that if the platform charges $p = V_A = 100$, the market outcomes are the same under the two cases of β, and the platform's profit will be 40,000. Now, we examine why charging a lower final price of $p = (1-k)V_A = 75$ can have different profit implications to the platform depending on the presence of scalpers. Note that if the platform lowers its final price from $p = 100$ to $p = 75$, its profit from the primary market will drop by 40,000-33,000=7,000. When $p = 75$, all regular consumers and scalpers (if they exist) will try to buy tickets in the first period. Without scalpers ($\beta = 0$), 600 regular consumers will get the tickets from the primary market, and in expectation, 150 casual fans will not be able to attend the concert and hence will resell tickets. The integrated platform's expected profit from the resale market is 3,750, which is not enough to compensate the profit loss from the primary market. Thus, without scalpers ($\beta = 0$), the integrated platform will find it optimal to choose the high final price $p = 100$ and serve only the avid fans. By contrast, with scalpers in the market ($\beta = 0.2$), among 600 consumers and scalpers who get tickets from the primary platform, in expectation, 100 casual fans who will find themselves unable to attend the concert and 200 scalpers will resell their tickets. So, the integrated platform's profit from the resale market is 7,500, which is much more than the platform's resale-market profit in the absence of scalpers ($\beta = 0$) and can more than cover the platform's 7,000 profit loss from the primary market (due to the lowered final price p). Thus, with scalpers in the market, the platform will find it optimal to choose the lower final price $p = 75$.

Table 1.3 Profit Decomposition with $\boldsymbol{\beta = 0}$ and $\boldsymbol{\beta = 0.2}$ ($\boldsymbol{f = 20, N = 600}$)

		$\boldsymbol{\beta = 0}$		$\boldsymbol{\beta = 0.2}$	
		$\boldsymbol{p = 100}$ **(optimal)**	$p = 75$	$p = 100$	$\boldsymbol{p = 75}$ **(optimal)**
Number of consumers who get tickets from primary market	Avid fans	500	300	500	200
	Casual fans	0	300	0	200
	Scalpers	0	0	0	200
	Total	500	600	500	600
Integrated platform's profit from primary market		$500 \times (100 - 20) = 40{,}000$	$600 \times (75 - 20) = 33{,}000$	$500 \times (100 - 20) = 40{,}000$	$600 \times (75 - 20) = 33{,}000$
Number of consumers reselling tickets in the second period	Avid fans	0	0	0	0
	Casual fans	0	150	0	100
	Scalpers	0	0	0	200
	Total	0	150	0	300
Integrated platform's profit from resale market		0	$150 \times 0.25 \times 100 = 3{,}750$	0	$300 \times 0.25 \times 100 = 7{,}500$
Integrated platform's total profit		40,000	36,750	40,000	40,500

Another way to explain why the presence of scalpers can induce the integrated platform to charge lower prices is that scalpers can help the platform exercise partial price discrimination in the primary market. Without scalpers, if the platform wants to target more consumers, it has to lower the final price for all targeted customers, in which case the avid fans who can get the tickets will enjoy a large surplus (relative to casual fans). In contrast, with scalpers in the market, when the platform charges the low final ticket price, *more* avid fans will not be able to get tickets in the first period compared to the case without scalpers. Note that the avid fans who failed to obtain tickets from the primary market will turn to the resale market to acquire tickets at *higher* prices (from scalpers or casual fans who cannot attend the concert). Since the integrated platform receives service fees for resale transactions, it in essence has charged these avid fans higher prices for the tickets than those consumers who successfully obtained tickets in the primary market. Hence, the presence of scalpers will help the platform increase the expected number of avid fans who will end up paying higher prices for the tickets. Put differently, scalpers can effectively increase integrated platform's ability to exercise price discrimination. The integrated platform can take advantage of this potential benefit from the presence of scalpers only if it charges a low enough ticket price $p \leq (1-k)\widehat{r^*}$ to ensure some profit for the scalpers. Therefore, the presence of scalpers tends to induce lower final ticket prices in the primary market.

Define $\alpha_{SCP} \equiv \bar{N}[1 - \frac{\sqrt{1-\frac{\beta}{\bar{N}}}\sqrt{V_A k[V_A k\bar{N}(\bar{N}-\beta)+8(1+\bar{N})(V_A-c)]}-V_A k(\bar{N}-\beta)}{4(V_A-c)}]$ and $\alpha_1 \equiv \frac{2\bar{N}(V_A-V_C)}{(\bar{N}-\beta)V_A k} - 1$. We characterize the impact of scalpers on the final prices and different parties' surplus in Proposition 4.

PROPOSITION 4. *Suppose* $V_A > \frac{2}{2-k}V_C$, $\min\{\alpha_0, \alpha_{INT}\} < \alpha \leq \min\{\alpha_1, \alpha_{SCP}\}$ *and* $\beta < \frac{2\alpha-(1+\alpha)\bar{N}}{1-\alpha}$. *In the integrated-platform case, compared to the case without scalpers* ($\beta = 0$)*, the* *presence of scalpers will strictly reduce the final ticket price p^*, and strictly increase the musician's profit, the integrated platform's profit and the consumer surplus in equilibrium.*

Contrary to the conventional belief that scalpers will raise the effective ticket prices paid by consumers and thus reduce consumer surplus, Proposition 4 shows that scalpers can possibly result in lower final prices and higher consumer surplus if the musician's and the platform's strategic pricing decisions are taken into account. Moreover, because the presence of scalpers can make the integrated platform more inclined to charge a lower final price, the musician will be more willing to increase the venue size. As a result, the double-marginalization problem in the primary market can be alleviated, making the platform, the musician, and the consumers possibly all better off.

We want to point out that Proposition 4 does not suggest that scalpers will *always* benefit consumers and the musician. Indeed, there are several boundary conditions for the presence of scalpers to be beneficial. For example, if the segment size of avid fans is smaller than a threshold ($\alpha < \min\{\alpha_0, \alpha_{IDP}\}$), the platform will find it optimal to set a low final price to target both casual fans and avid fans even when there are no scalpers. Under this condition, scalpers will strictly reduce the consumer surplus. Moreover, the segment size of scalpers (β) cannot be too high. If there are too many scalpers, consumers are worse off because fewer tickets will be available for regular consumers in the primary market, forcing more consumers to buy resale tickets at higher prices. It is also important to point out that scalpers can benefit the consumers only when the primary and the resale platforms are integrated. In the independent-platforms case, the primary platform does not take the resale platform's profit into account, so it will not bother lowering the final ticket price to attract scalpers. Thus, with an independent resale platform, the presence of scalpers will not facilitate the channel coordination in the primary market and consumer surplus will generally decrease.

1.5.2 Endogenous Resale Percentage Fee

In our main model, we have assumed the resale percentage fee k to be exogenous. In this section, we will analyze the optimal choice of k for the resale platform. In the independent-platforms case, after the musician chooses the venue size N and the face price f, the primary platform will set the final price p and the resale platform will set the resale percentage fee k simultaneously. In the integrated-platform case, the integrated platform jointly chooses p and k to maximize its profit. Under the original assumption that avid fans are always able to attend the concert, in the independent-platforms case, the primary platform will always find it optimal to choose p high enough such that only avid fans will buy in the first period. Thus the resale platform will receive zero profit regardless of its choice of k. Therefore, to allow for a more meaningful comparison of how different market structures affect the equilibrium resale percentage fee k^*, we need both avid consumers and casual consumers to have some probability of not being able to attend the concert. One way to revise the model is to introduce *another* random interruption that can prevent a consumer from attending the concert (in addition to the random factors in the main model). Suppose that the new interruptive events (e.g., mandatory out-of-town travel or family emergency) have a probability δ of occurrence, in which case the consumer (whether avid or casual) will be unable to attend the concert. Thus, one can show that overall, avid fans can attend the concert with probability $\rho_A = 1 - \delta$, and the casual fans can attend with probability $\rho_C \sim \text{uniform}(0, 1 - \delta)$. Under this assumption, even if only avid fans will buy tickets in the first period, there can still be resale transactions because some avid fans unable to attend the concert will resell their tickets in the second period. To concisely present the results, we consider the case of $\delta \to 0^+$. The qualitative results will still hold true as long as δ is not too large. Define $\alpha_2 \equiv$

$\bar{N}[1 - \frac{\sqrt{(V_A - V_C)[(V_A - V_C)\bar{N}^2 + 8(1+\bar{N})(V_A - c)]} - (V_A - V_C)\bar{N}}{4(V_A - c)}]$. The next proposition reveals which platform will choose a lower resale percentage fee.

PROPOSITION 5. *When $\alpha < \alpha_2$, the integrated platform will choose a strictly lower resale percentage fee (k) than the independent resale platform will choose, i.e., $k^*_{INT} < k^*_{IDP}$.*

Proposition 5 reveals that when the population of avid fans is not too large (i.e., $\alpha < \alpha_2$), the integrated platform's optimal resale percentage fee k^*_{INT} will be lower than an independent resale platform's choice, k^*_{IDP}. The intuition is as follows. A lower resale percentage fee can incentivize consumers to buy tickets in the primary platform, because they expect to pay a lower resale service fee if they cannot attend the concert and need to resell their tickets. In other words, lowering k will have a positive spillover effect *from the resale market to the primary market*. An integrated platform can internalize the spillover and tends to charge a lower resale percentage fee in the resale market, unless the population of avid fans is very large ($\alpha \geq \alpha_2$), in which case the integrated platform will set $p = V_A$ and target only the avid fans.

1.5.3 Competition between Resale Platforms

Finally, we examine the case where the integrated platform competes with an independent resale platform in the resale market. The platform competition in the resale market will tend to reduce the resale percentage fee k. For tractability, we assume that the integrated platform and the independent resale platform have the same resale percentage fees k_{COMP} with $k_{COMP} < k$. A fraction ϕ of resale-ticket buyers buy from the integrated platform, and a fraction $1 - \phi$ of resale-ticket buyers buy from the independent resale platform. While we do not model how k_{COMP} and ϕ are endogenously determined in equilibrium, our assumptions reflect that the resale service fee will decrease under competition in the resale market, so we can analyze how competition in the resale market will affect the equilibrium prices, profits and consumer surplus.

One can show that when $k_{COMP} < 1 - \frac{V_C}{V_A}$, the integrated platform will choose a final ticket price such that only avid fans will buy in the primary market in the first period, so there will be no resale transactions in the second period. In other words, if the integrated platform anticipates that the presence of a competing resale platform would reduce the resale service fee from k to some $k_{COMP} < 1 - \frac{V_C}{V_A}$, then the integrated platform will not want to reduce its price in the primary market to attract casual fans in the first period. Below, we analyze the more interesting case of $k_{COMP} \geq 1 - \frac{V_C}{V_A}$.

Our analysis shows that when $k_{COMP} \geq 1 - \frac{V_C}{V_A}$, the integrated platform may choose $p < V_C$, and some casual fans will want to buy tickets in the first period and resell their tickets in the second period. Specifically, under the conditions of $\frac{2\alpha}{1+\alpha} > N > \alpha$, $V_A > \frac{2}{2-k_{COMP}(2-\phi)} V_C$, $f < \frac{N\left[1-k_{COMP}(1-\frac{1-\alpha}{2}\phi)\right]-\alpha}{N-\alpha} V_A$, and $\alpha < 1 - \frac{2[V_C-(1-k_{COMP})V_A]}{k_{COMP}\phi V_A}$, we find that the integrated platform will choose $p = (1-k_{COMP})V_A \leq V_C$ with a corresponding total profit $\pi_I = N\left[V_A\left(1 - k_{COMP}(1 - \frac{1-\alpha}{2}\phi)\right) - f\right]$. In this case, all consumers will try to buy tickets in the first period with a successful probability of N. In expectation $\frac{N(1-\alpha)}{2}$ casual consumers will resell their tickets at resale price $r^* = V_A$.

Note that a smaller k_{COMP} will make the parameter conditions above more likely to hold. In other words, the integrated platform is more likely to set a final price $p < V_C$ to induce some casual consumers to buy tickets in the first period and resell their tickets in the second period when they cannot attend the concert. We also show that, as expected, when the integrated platform's market share in the resale market, ϕ, is larger, the parameter region in which the conditions above are satisfied will be larger. This is because if a higher fraction of consumers resell their tickets on the integrated platform, the integrated platform will have a stronger incentive to reduce its price in the primary market (p) to increase the transaction volume in the resale market.

In the integrated-platform case, consumers can resell their tickets only through the integrated platform. By contrast, in the presence of a competing independent resale platform, consumers will face a lower resale service fee. One may expect the consumers to become worse off when the integrated platform can block the competing resale platforms and monopolize the resale market. Proposition 6 shows that, counterintuitively, the musician and the consumers can be possibly *better off*.

PROPOSITION 6. *In equilibrium, in the integrated-platform case, the final price p may strictly be lower and the musician's profit and consumer surplus may be strictly higher than in the competing-resale-platforms case if* $\phi < 1 - \frac{k-k_{COMP}}{k_{COMP}} \cdot \frac{1+\alpha}{1-\alpha}$.

When there is competition in the resale market and if the integrated platform's market share in the resale market is low (i.e., $\phi < 1 - \frac{k-k_{COMP}}{k_{COMP}} \cdot \frac{1+\alpha}{1-\alpha}$), the integrated platform will have little incentive to choose a low final price p to facilitate transactions in the resale market. Anticipating this, the musician will be more likely to choose a higher face price $f = V_A$ and a smaller venue size $N = \alpha$ to target only the avid fans. In this case, the musician's profit and the consumer surplus will be lower.

1.6 Discussion

One key message of this paper is that when the primary platform also controls the resale market, it is more likely to lower the final price p in the primary market to create more transactions in the resale market, and also to set a lower percentage fee k in the resale market to attract more buyers in the primary market. Moreover, because the integrated platform is more willing to choose a *lower price* in the primary market to target low-valuation casual fans, the double-marginalization problem in the primary-market channel tends to be alleviated (relative to the case of independent platforms). As a result, the musician is also willing to choose a larger venue size to serve more consumers, making both the musician and the end consumers *better off* as a result. A scenario that might seem similar to the integration of the primary and the resale ticket platform is a merger of two retailers who sell products from a common upstream manufacturer. However, the market outcome tends to be quite different. A merger between retailers generally *increases* the retail price and *reduces* the number of consumers served, making the consumers and the upstream manufacturer *worse off*. The key difference between these two settings is whether the spillover effect is positive or negative. Lowering the price or the service fee in the primary market will have a *positive* spillover to the resale market, and vice versa. An integrated platform operating in both markets will internalize the positive cross-market externalities and become more willing to charge lower prices and service fees in both markets than independent platforms would. Conversely, in a retail market with multiple retailers, one retailer's reduction of its retail price will generate a *negative* spillover to other competing retailers, i.e., *reducing* their sales. Hence, after the merger of retailers, the merged retailer tends to charge higher prices.

This paper focuses on the ticket market for concerts (or other performing arts), but the qualitative insight can be applied to other markets with similar spillover features, e.g., sports ticket markets, used product market, and peer-to-peer product-sharing market. For example, when a book retailer sells both new and used books, it may have an incentive to lower the retail price for new books so more people will buy new books and resell them later. Thus, the double-marginalization problem in the primary-market channel of the publisher and the retailer can be alleviated. However, we expect the effect of cross-market spillover effect in the physical publishing industry will be smaller than that in the concert ticket industry. First, reselling physical books usually involves some transaction costs, e.g., shipping and handling, which can prevent some consumers from reselling their books. By contrast, the transaction cost for reselling concert tickets is generally much lower. Resellers usually only need to upload a photo of the ticket to resell it on StubHub or Ticketmaster. Second, competition among new-book retailers and competition among used-book marketplaces are much more intense than that in the concert ticket industry. A retailer operating in both the new-book and the used-book markets is less willing to lower the primary market price because its new-book buyers may resell the books at other resale marketplaces. With some caution, our qualitative findings can also be applied to peer-to-peer product-sharing markets. Some car manufacturers provide their own peer-to-peer car-sharing services. For example, owners of Mercedes-Benz cars in Germany can rent out their cars to others on Croove, Mercedes-Benz's own peer-to-peer sharing platform. The insight of our research will predict that the car manufacturers with their own peer-to-peer sharing platforms may also have extra incentives to set a lower dealer price so more consumers will buy cars and rent them out on the manufacturers' sharing platforms, increasing the car manufacturer's profit from the sharing platform. We acknowledge that such markets have some differences from the concert ticket markets, e.g., cars are not single-use products and car buyers themselves may use the cars some of the time (with possible depreciation of value). Nevertheless, our qualitative insight that an integrated platform can be beneficial relative to independent platforms may still be useful since there exists some degree of cross-market spillover in those markets.

1.7 Empirical Study

In this section, we will provide some suggestive support for our theoretical findings with the data collected from Ticketmaster.com and StubHub.com. At the outset, we want to acknowledge that our empirical results only suggest correlational association rather than causal relationships.

When musicians contract with Ticketmaster to sell tickets on its platform, they can choose whether to enroll in Ticketmaster Resale. If they enroll their concerts in Ticketmaster Resale, then consumers will be able to resell their tickets on Ticketmaster in addition to third-party resale platforms such as StubHub. If they do not enroll in Ticketmaster Resale, then consumers will not be able to resell their tickets on Ticketmaster but can still resell on third-party resale platforms. Many musicians do not enroll in Ticketmaster Resale because they worry that doing so can encourage scalping and result in higher prices. For example, musician Tom Waits claimed that he "would not take advantage of Ticketmaster Resale because he does not want to take all of a person's disposable income just to go to one show" (Knopper 2014). Some other musicians, such as Ed Sheeran and Sigur Rós, do not enroll in Ticketmaster Resale and express similar concerns. It is plausible that many musicians' decisions on whether to enroll in Ticketmaster Resale are not always due to their profit-oriented concerns.

Ticketmaster can profit from both the primary market and the resale market for concerts with Ticketmaster Resale, but can profit only from the primary market for concerts without Ticketmaster Resale. Based on our theoretical predictions, Ticketmaster will set lower service fees in the primary market for concerts with Ticketmaster Resale than those without Ticketmaster Resale. Moreover, Ticketmaster's resale percentage service fee (for concerts with Ticketmaster

Resale) will be lower than that on StubHub for the same concert. We propose the following two hypotheses.

HYPOTHESIS 1. *Ticketmaster will set lower service fees on the primary platform for concerts with Ticketmaster Resale than for concerts without Ticketmaster Resale.*

HYPOTHESIS 2. *For concerts with Ticketmaster Resale, Ticketmaster will set lower resale percentage service fees than StubHub's for the same concerts.*

Table 1.4 Summary Statistics

Variable	Mean	Std. dev.	Median	Min	Max
Ticket face price	81.75	63.51	59.00	15.00	345.00
Primary-market service fee	12.26	5.37	10.35	4.85	29.80
Last.fm followers	898731	949743	635605	0	4328799
Songkick.com followers	513086	663277	222592	0	1791395
Ticketmaster Resale enrolled*	0.508	0.501	1	0	1

* Dummy variable, equaling to 1 if true, 0 otherwise.

We collected data for all pop and rock concerts in Missouri in 2018 that were on sale at Ticketmaster.com on Dec 20th, 2017. We excluded musicians promoted by Live Nation, which is the parent company of Ticketmaster. We also excluded concerts with general admission because the total number of available tickets is not explicitly determined. We obtained data for 62 concerts that satisfy the conditions above, 34 of which enrolled in Ticketmaster Resale. A concert usually has multiple ticket price levels. In our dataset, there are 199 price levels in total for all concerts, and we treat each price level of a concert as an observation in our empirical analysis. For each observation, we have the data on the ticket's face price and the primary-market service fee on Ticketmaster, whether the concert is enrolled in Ticketmaster Resale, and information on the concert's promoter and venue. In addition, we use, as a proxy for the musician's popularity, his or her numbers of followers on Last.fm—an online radio website—and on Songkick.com—an online music community. Table 1.4 presents the summary statistics of some variables.

Figure 1.3 compares the ratios of the ticket's primary-market service fee to its face price based on whether concerts are enrolled in Ticketmaster Resale. One can observe that, for concerts with Ticketmaster Resale, Ticketmaster tends to charge lower service fees as a portion of the ticket face price in the primary market, which is consistent with Hypothesis 1.

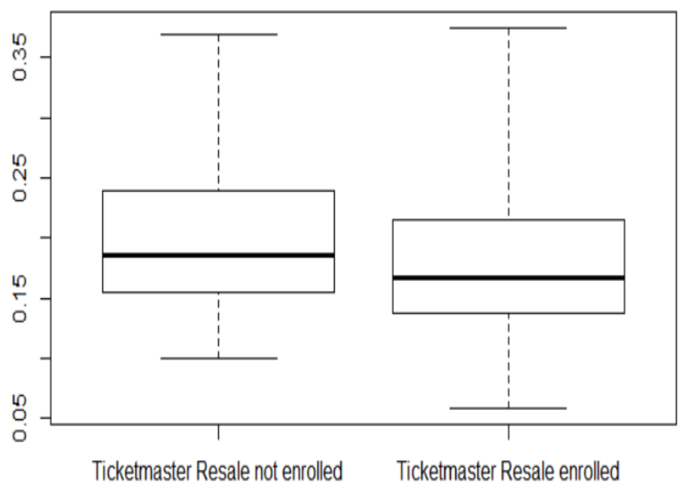

Figure 1.3 Primary-Market Service Fee Divided by Face Price[10]

We have confirmed the correlation with the following regression:

$$ServiceFee_i = \beta_0 + \beta_1 \cdot TicketmasterResale_i + h(FacePrice_i) + X_i\beta + \epsilon_i.$$

$TicketmasterResale_i$ is a dummy variable that equals to 1 if concert i enrolled in Ticketmaster Resale, and 0 if not. $h(\cdot)$ is a polynomial of the ticket's face price. More specifically, we specify $h(\cdot)$ as either a linear function or the polynomial leading to the lowest Bayesian Information Criterion. X_i represents control variables such as the musician's number of followers on Last.fm or on Songkick.com, and the event-promoter and venue dummies. Hypothesis 1 predicts that β_1 should be negative.

Table 1.5 Estimation Results

Variables	(1) OLS	(2) OLS	(3) OLS	(4) Robust Std. Dev.
Intercept	7.21*** (0.4269)	8.48*** (0.7944)	-	-
Ticketmaster Resale Enrolled?	**-0.88* (0.4967)**	**-1.77*** (0.5548)**	**-1.15** (0.4825)**	**-1.15** (0.4611)**
Face price	0.06*** (0.0039)	0.06*** (0.0029)	-	-
Higher-order polynomial of face price	No	No	Yes	Yes
Last.fm follower	-	-1.6×10^{-7} (3.4×10^{-7})	-1.6×10^{-7} (2.8×10^{-7})	-1.6×10^{-7} (3.2×10^{-7})
Songkick.com follower	-	7.0×10^{-7} (8.8×10^{-7})	7.2×10^{-7} (7.5×10^{-7})	7.2×10^{-7} (8.3×10^{-7})
Promoter and venue fixed effect	No	Yes	Yes	Yes
Number of Obs.	199	199	199	199
R^2	0.606	0.946	0.963	0.963

Standard deviation in parenthesis. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table 1.5 summarizes the estimation results. The results suggest that a concert's enrollment in Ticketmaster Resale is negatively correlated to its primary-market service fee charged by Ticketmaster. Enrollment in Ticketmaster Resale is associated with a $1.15 lower ticket service fee on the primary platform, which translates to 11.1% of the median primary-market service fee on Ticketmaster. The finding is consistent with Hypothesis 1 that Ticketmaster will set a lower service fee for concerts that are enrolled in Ticketmaster Resale.

We also collected the resale percentage fees on Ticketmaster and on StubHub for all concerts with Ticketmaster Resale between April 27th, 2018 and Dec 31st, 2018.[11] There are 16 such concerts. Figure 1.4 compares their resale percentage fees on Ticketmaster and on StubHub. For all these concerts, Ticketmaster charges lower percentage fees than StubHub does. A paired t-test also confirms that Ticketmaster's resale percentage fee is lower than StubHub's: $\mathrm{mean}(Ticketmaster) = 0.180$, $\mathrm{mean}(StubHub) = 0.219$, $t = 16.19$, $p < 0.001$. This is consistent with Hypothesis 2—for concerts with Ticketmaster Resale, Ticketmaster will charge a lower resale percentage fee than StubHub will.

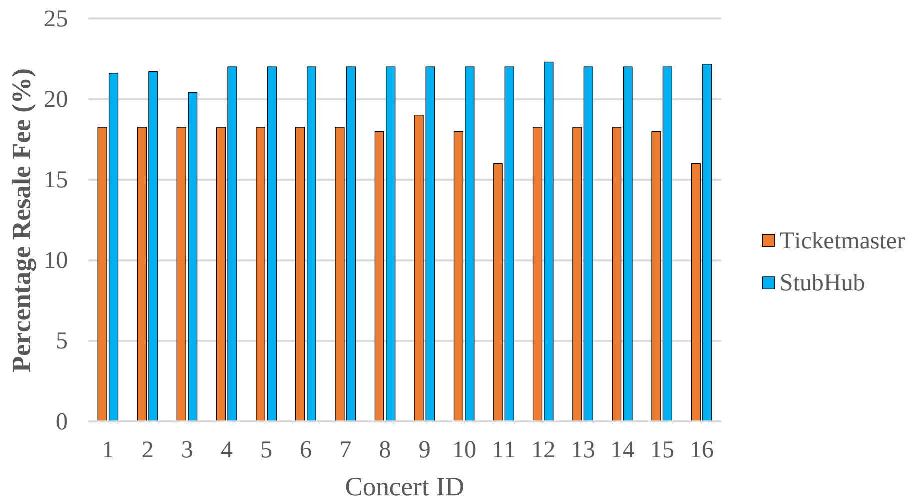

Figure 1.4 Resale Percentage Fee: Ticketmaster vs. StubHub

1.8 Conclusion

The main message of this paper is that musicians and consumers can benefit from the primary ticket platform's control of the resale market. This is due to the cross-market spillover effect between the primary market and the resale market: lowering the price or the service fee on one platform will lead to more transactions on the other platform. The integrated platform will tend to internalize the positive spillover effect by lowering the price and the service fee in both markets, which can alleviate the double-marginalization problem in the primary market channel so the musician is more willing to choose a larger venue size to serve more consumers. Consequently, the price in the primary market and the service fee in the resale markets are lower, more consumers will be served, and the musician, and consumers can be better off at the same time. We also find that lower service fees in the resale market may surprisingly reduce the consumer surplus, because more tickets will be misallocated to consumers who are less likely to attend the concert. Moreover, the presence of a small group of scalpers can lead to lower ticket prices, higher musician's profit, and higher consumer surplus. Using data from Ticketmaster and StubHub, we provide some empirical support for some of our theoretical predictions.

The result has important implications for legislation on restricting a primary ticket platform's ability to block competitors in the resale market, e.g., the Tickets Resale Rights Act banning Ticketmaster's Paperless Ticket system. Such legislation usually reasons that when the primary platform has more control of the resale market, it will have a stronger pricing power in the primary and the resale markets, thus will charge higher prices and service fees, making consumers and musicians worse off. In this paper, we argue that such reasoning may be flawed because it neglects the spillover effect between the primary and the resale markets and how the double-marginalization problem in the primary market can be alleviated with the integration of the primary and the resale platforms. Our policy suggestion is that legislation should be careful in restricting the primary platform's practices in controlling the resale market or the collusion between primary and resale platforms.

This paper is also related to anti-scalping laws. It has been long debated whether allowing scalping could benefit the ticket sellers and consumers or not. This paper provides another reason why scalpers could potentially be beneficial, i.e., they may incentivize the primary platform to set a lower final price if it also has a presence in the resale market. The double-marginalization problem in the primary market can be alleviated as a result, making the musician, the integrated platform, and the consumers better off.

This paper establishes an analytical framework to analyze the interaction among the musician, the primary platform, and the resale platform in the concert ticket market. The framework provides a foundation for future research on related topics. For example, although dynamic pricing is currently uncommon in concert ticket industry, it is used by several sports teams in National Football League and Major League Baseball. One can investigate how the primary ticket platform's optimal dynamic pricing decision would change when the platform also controls the resale market. We conjecture that an integrated platform has an incentive to increase its primary-market price over time, which can attract consumers who are uncertain of whether they can attend the concert to buy tickets early, leading to more transactions in the resale market. Our paper also provides some correlational empirical support for our theoretical prediction of the pricing patterns. Future empirical research could validate our predictions with more generalized methods and can further explore how the welfare of the musician and consumers will be affected.

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Endnotes:

[1] https://www.statista.com/outlook/264/109/event-tickets/united-states#market-users

[2] For ease of exposition, we will refer to a platform as "it," the musician as "he," and the consumer as "she."

[3] In practice, the prices of most tickets for most concerts are fixed over time. To be consistent, we also assume in our model that the ticket price is constant over time.

[4] Note that in the second period, all avid fans and half of casual fans, whose population adds up to $\frac{1+\alpha}{2}$, will have strictly positive valuations of attending the concert. Since $\frac{1+\alpha}{2} > \frac{2\alpha}{1+\alpha}$, the venue will not be able to hold all these consumers.

[5] http://y101fm.com/features/lifestyle/entertainment/5603-check-it-out-top-quickest-selling-concert-tickets-ever?limitstart=0

[6] The interval is non-empty if and only if $\overline{N} < \frac{2(V_A - V_C) - kV_A}{\left(1-\sqrt{\frac{V_A - V_C}{V_A - c}}\right)kV_A}$.

[7] Our results are qualitatively the same if scalpers and regular consumers have equal probability of getting tickets.

[8] We use "^" over a variable indicates a consumer's rational prediction of a variable that has not realized yet.

[9] Note that in this example, without loss of generality, we use the total market size of 1,000 rather than 1 to keep the figures integers.

[10] In the box plot, the minimum (maximum) of a group is represented by the end point of the lower (upper) whisker. The 25th-percentile (75th-percentile) is represented by the lower (upper) edge of the box. The median is represented by the bold line in the center of a box.

[11] We collected these data on April 26th, 2018, so we were unable to find the resale service fee on StubHub.com before this date.

Chapter 2 Consumer Search on Online Retail Platforms

2.1 Introduction

Online retailing is growing rapidly. In the United States, online retail sales as a percent of total retail sales have more than tripled from 2.7% in 2006 to 9.5% in 2018, and the estimated sales on online retail platforms (e.g., Amazon.com, eBay.com, and Taobao.com) reached $124 billion in Q1 2018.[1] In a survey covering 19 countries and territories, more than 95% of some 19,000 respondents have online shopping experience, and more than half of them shop online at least once a month (PwC 2015). Consumers often buy products from independent sellers on retail platforms. Take Amazon.com, which accounts for 43% of United States online retail sales.[2] In 2015, over two million independent sellers sold products on Amazon.com worldwide, contributing to 83% of revenue of Amazon.com.[3] A platform's profit typically comes from the referral fees, a.k.a. commissions paid by independent sellers, most commonly a percentage of the product prices. In Q1 2017, Amazon.com received $8 billion from referral fees collected from independent sellers.

Consumers search for products that match their preferences better or have lower prices. Consumers' search cost for product information on online retail platforms has significantly dropped in recent years. One driving force is technology advancements. Wider adoptions of high-speed Internet have significantly reduced the amount of time of loading webpages. The increasing popularity of smartphones and tablet computers has also lowered consumers' perceived search cost. In addition, many retail platforms also invest in reducing the search cost of their customers. Amazon has been continually improving its webpage design, thereby enabling its independent sellers to demonstrate their products with multimedia content formats (e.g., info-graphics, audios, and videos). For example, Amazon permitted some qualified independent sellers to upload "video shorts" to their product pages in 2014, and opened up this function to *all* independent sellers in 2017.[4] In 2009, Amazon debuted the camera search function in its mobile app, enabling consumers to shoot a photo of an item to search for similar products on Amazon.com. In 2017, Amazon partnered with Samsung to incorporate camera search in the camera app of Samsung's smartphones.[5] Amazon has also been developing its augmented-reality view technology, which allows consumers to see, for example, how a watch on Amazon.com would look like around their wrists before buying it.[6] Retail platforms invest billions of dollars in reducing consumers' search cost. For instance, in Q1 2016, Amazon spent over $1.2 billion on augmented reality and virtual reality, and a considerable fraction of this investment intended to improve consumers' search experience.[7]

Empirical academic research also suggests that consumers' online search cost has decreased over time. Many studies have estimated consumers' online search cost for hotels, books, tablets, computer parts, etc. (Bajari et al. 2003, Blake et al. 2016, Chen and Yao 2016, De los Santos 2008, De los Santos et al. 2017, Ghose et al. 2013, Hong and Shum 2006, Jiang et al. 2017, Jolivet and Turon 2017, Koulayev 2014, Moraga-Gonzaíez and Wildenbeest 2008, Moraga-González et al. 2013, Santos et al. 2012). Most of these studies indicate that consumers' online search cost per item is between 1 and 10 US dollars. Figure 2.1 plots their estimated search costs[8] against the years of their datasets used for estimation. The estimated search costs tend to decrease over time, although they are for different product categories on different platforms and are obtained with different methods.

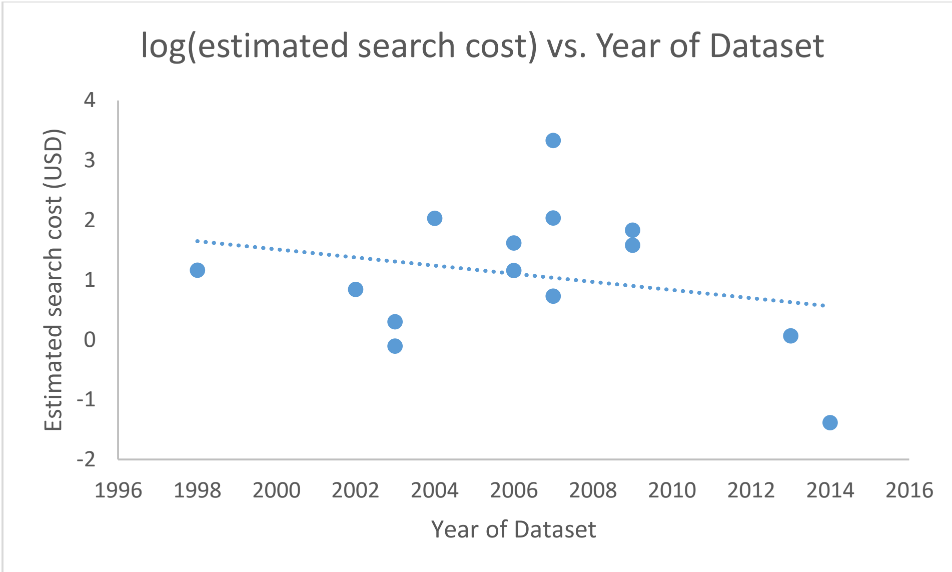


Figure 2.1 Estimated Search Cost vs Dataset Time

It is not obvious why retail platforms would spend billions of dollars on reducing consumers' search cost. Although doing so can attract more consumers, it will intensify the competition among sellers and hence reduce the platform's revenue from its referral fees. Extant literature provides little explanation on why and when a platform should invest in lowering consumers' search cost.

Extant literature also provides little insight on how the consumer's search cost will influence the platform's optimal referral-fee decisions. Most studies either assume the sellers sell directly to consumers—completely ignoring the retail platform—or treat the platform's referral fee as an exogenous variable. Because the referral fee is a major contributor to a retail platform's profit, it is practically important for a platform to understand how to optimally adjust its referral fee when the consumer's search cost changes.

Besides reducing the consumer's search cost for product information, online retail platforms also utilize other instruments to make consumer search easier. For example, many platforms allow consumers to filter the search results based on certain product attributes, e.g., shoe size and color when searching for shoes. However, consumers still need to search the information for other attributes that are harder to filter, e.g., shoe design and style. To our knowledge, the extant literature either ignores the filtering function or treats its effect on consumer search simply as a reduction in the consumer's search cost, except that Zhong (2017) considers a related setting of targeted search (We will discuss the difference between our paper and Zhong (2017) in the next section.). No research has studied how filtering affects the platform, independent sellers, and consumers and how its effect is different from that of a reduction in the search cost.

In summary, several important questions have not been well studied by the previous research:

- Why have many retail platforms been heavily investing in reducing the consumer's search cost, even though the lowered search cost may intensify sellers' competition and hurt platforms' profit?
- How will the consumer's search cost affect optimal pricing decisions of the sellers and the platform? How will their profits be influenced?
- How will filtering affect the platform, the sellers, and consumers? How is its impact different from that of a reduction of the consumer's search cost?

We develop a game-theoretic framework to address these research questions. In our model, many independent sellers sell horizontally differentiated products on a retail platform where consumers sequentially search for these products. Similar to Wolinsky (1986) and Anderson and Renault (1997), consumers initially do not know product prices or match levels—how well a product matches their preferences—and can learn a product's price and match level after incurring a search cost. The retail platform sets a percentage referral fee (also known as "commission" or "final value fee" in practice) that is charged to sellers. The sellers then simultaneously set their retail prices. We also model the filtering function on the platform. A product's (aggregate) match level consists of two parts: the filterable match level and the unfilterable match level. Filtering allows consumers to costless learn a product's filterable match level, but they still need to search for its unfilterable match level. In the analysis, we derive the equilibria in two scenarios. The first scenario constitutes our benchmark, where the platform's referral fee is exogenous, i.e., the platform does not adjust its fee when the consumer's search cost changes. This setting is more reasonable in the short term when the platform has not adjusted its referral fee after the search cost changes. In the second scenario, the referral fee is endogenously decided by the platform, i.e., the platform optimally chooses its referral fee as the consumer's search cost changes. This setting is more reasonable in the long term when the platform can adjust its referral fee responding to the change in search cost. By comparing the equilibrium outcomes in these two scenarios, we can determine how the effects of a search-cost decrease differ in the short term versus in the long term.

We highlight several interesting findings. First, contrary to the conventional wisdom that a lower search cost will reduce sellers' profits because it intensifies competition among them, we show that a decrease in the search cost can actually increase the sellers' profits, although the sellers receive less profit per unit sale. This is because a decrease in the search cost can attract more consumers to the platform (rather than choosing the outside option) and hence expand the market demand.

Second, we find that the retail platform can always benefit from a decrease in the consumer's search cost when it optimally sets the referral fee, although its profit may decrease when the referral fee is exogenous. When the referral fee is exogenous, a lower search cost will attract more consumers to the platform, but also intensify price competition between sellers and reduce the platform's referral fee revenue per unit sale. Therefore, the platform's profit can either increase or decrease in equilibrium. By contrast, by optimally adjusting the referral fee, the platform can expand its demand without heavily hurting its profit margin, so its profit always increases when the search cost declines. Our finding potentially explains why many retail platforms invest large amounts of money to reduce the consumer's search cost in reality.

Third, we investigate how the platform should adjust its referral fee as the consumer's search cost changes. One may expect that because a lower search cost tends to intensify sellers' competition and reduce the platform's profit margin, the platform should compensate it by raising its referral fee. Interestingly, we find that in equilibrium the platform may choose to lower its referral fee if the reduction in search cost significantly increases the demand elasticity of the referral fee. In this case, a lower the search cost makes the platform, the sellers, and the consumers all better off. By contrast, when a search-cost reduction does not significantly increase the demand elasticity, the platform will find it optimal to increase its referral fee. In this case, the decrease in the search cost can counterintuitively lead to *higher* retail prices. This result provides a possible explanation to the empirical puzzle that the prices in very competitive markets can be maintained much higher than marginal costs even when the search cost is sufficiently low (Clemons et al. 2002, Hortaçsu and Syverson 2004).

Fourth, we show that filtering has two opposite effects on how well the product bought by consumers matches their preferences in equilibrium. On the positive side, consumers can narrow their search set down to the products with better match on filterable attributes. On the negative side, because filtering has revealed the filterable match levels to consumers, conducting a search will uncover less information in expectation and bring less benefit to consumers. The negative effect makes consumers search fewer products and offsets the partially benefit of filtering in expectation. We also study how filtering will change the sellers' pricing strategies. We find that filtering will reshape the demand function for a product. Intuitively speaking, if the market demand tends to have a relatively longer (shorter) tail after filtering becomes available, the competition between sellers will be alleviated (intensified) and the equilibrium retail price is likely to increase (decrease). In other words, filtering can either strengthen or soften the competition between sellers. These results suggest that filtering can have very different marketing consequences compared to a search-cost reduction, which will encourage consumers to search *more* and always intensify the competition between sellers.

Lastly, we show that our results are robust when consumers have heterogeneous search costs, when products have heterogeneous quality levels, and when the platform charges a fixed (instead of percentage) referral fee. We also provide guidance on how the sellers should optimally choose their prices when consumers have heterogeneous search costs, and investigate how the distribution of the consumer's outside options will affect the profits of the platform and sellers, as well as the platform's incentive to invest in reducing the consumer's search cost.

2.2 Literature Review

Our research is closely related to the literature on consumer search. Extensive literature has studied how the decrease in the consumer's search cost can influence product prices, firm profits, and consumer welfare. Many theoretical studies show that prices will drop to the marginal cost when the consumer's search cost diminishes to zero (Anderson and Renault 1999, Salop and Stiglitz 1977, Stahl 1989, Stigler 1961, Wolinsky 1986). Their predictions are supported by several empirical studies showing that the Internet has intensified price competition and reduced prices in markets for insurance (Brown and Goolsbee 2002), books and CDs (Brynjolfsson and Smith 2000), and prescription drugs (Sorensen 2000). To frustrate consumer search, some sellers engage in obfuscation (Ellison and Ellison 2009) to blur the product's price information. By contrast, there is evidence showing that many firms can still sell at prices considerably higher than marginal costs even in very competitive markets with low search costs (Clemons et al. 2002, Hortaçsu and Syverson 2004). Some of more recent analytical research finds that a decrease in search cost may not always lead to more intense market competition or lower profits. Kuksov (2004) suggests that a search-cost reduction may facilitate product differentiation and lead to higher prices and industry profit. Cachon et al. (2008) show that when consumers' search cost decreases, sellers may expand their product assortments, which can increase consumers' willingness-to-pay for their most-desired products, leading to higher equilibrium price and profit. Some research on consumer search studies different features in search markets. Armstrong et al. (2009) study the implication of "prominence" in a search market. A prominent seller will be searched first by all consumers in the search process. They show that the highest-quality sellers will have the highest incentive to become prominent. Recent research (Branco et al. 2012, 2016, Ke et al. 2016) has also considered consumers' decision on how much information to acquire for a single product or for a multi-period scenario.

An important research question of this paper is that how changes in search cost on the platform will affect the retail platform's optimal referral fee and market competition. By contrast, most of these studies assume that firms sell directly to consumers. An exception is Janssen and Shelegia (2015), who study consumer search in a distributional channel. In their model, a single manufacturer sells its product to two symmetric competing retailers at the same wholesale price, and consumers have perfect knowledge of product quality but need to search to find out the retailers' prices. They show that consumers' lack of knowledge about the manufacturer's wholesale price will make both the consumer and the manufacturer worse off. Our article is different from Janssen and Shelegia (2015). First, we consider a very different market setting. In their model, the manufacturer sells its *homogeneous* product to two symmetric retailers on the same *wholesale-price* contract, whereas in our model many sellers sell their respective *differentiated* products on the retail platform which charges the sellers a *percentage* fee for access to customers. Second, in our framework, consumers know neither the product's match level nor its price before searching, whereas in Janssen and Shelegia (2015) only price is not known ex ante (because both retailers sell the same product of known valuation).

To the best of our knowledge, there are only two analytical studies about how consumer search on retail platforms. Dukes and Liu (2016) examine how a platform should choose the optimal search cost level when the consumer optimally decides how many sellers to search and how deeply to evaluate each of them. However, they do not consider the platform's optimal referral-fee decision. By contrast, one of our main research questions is how the change in search cost will affect the platform's optimal referral fee. In addition, in our framework, consumers conduct sequential search for products, rather than simultaneous search in Dukes and Liu (2016). Zhong (2017) considers the setting where the platform knows partially about how products match each consumer's preference and adopts targeted search technology to show a consumer only products whose match levels are above a certain threshold. Zhong (2017) shows that an increase in the threshold is equivalent to a decrease in the search cost when the threshold is not too high, which will intensify price competition and decrease the price. By contrast, if targeted search is very precise, consumers will have no need to search in equilibrium, making sellers essential monopolists and leading to higher equilibrium prices and lower demand. Therefore, the platform wants to limit the precision of its targeted search, even if increasing the precision incurs no direct cost. Our paper proposes that filtering can be a very different mechanism than targeted search in Zhong (2017). Filtering will reduce the products' match-level uncertainty so consumers will enjoy less benefit per search. Conversely, targeted search technology will exclude less-relevant products from the search set so consumers will enjoy more benefit per search. Filtering and targeted search can also affect the equilibrium prices differently. Targeted search will be equivalent to a reduction in search cost and intensify competition between sellers for most of cases and will alleviate competition only in the extreme case where all consumers search only one product in equilibrium. In contrast, filtering is different from a reduction in search cost and can alleviate competition between sellers in more general situations where some consumers search multiple products in equilibrium. We also analyze research questions not considered by Zhong (2017), such as the effects of the consumer's search cost and the platform's optimal referral fee decision.

Our research also contributes to the general literature on online retail platforms. Research on retail platforms mainly focuses on two-sided markets (Armstrong 2006, Hagiu 2006, Rochet and Tirole 2003, 2005). Our research contributes to this literature by explicitly studying how the consumer's search cost will influence the platform's pricing decision and profitability. We show that as the consumer's search cost decreases, the platform's profit always increases if the platform optimally adjusts its fee. Whether the platform should raise or reduce its fee depends on how the change in search cost affects demand elasticity.

2.3 Model Setup

There are n independent sellers selling differentiated products on an online retail platform, which charges a percentage referral fee (r) for these sellers. We focus on the case when n is large, so the probability that consumers run out of sellers to search is negligible. Consumer j's utility of buying seller i's product is $u_{ij} = M_{ij} - p_i$, where M_{ij} is the "match level" of product i to consumer j, measuring how well product i matches consumer j's preference, and p_i is the price of product i. There are no systematic differences among sellers ex ante. All sellers have the same marginal production cost c. Consumer j also has an outside option with utility u_{0j}, distributed with the cumulative distribution function (c.d.f.) $F_0(u)$ and the probability distribution function (p.d.f.) $f_0(u)$. Without loss of generality, we normalize the total number of consumers to 1.

Filtering

Many retail platforms allow their customers to filter products based on certain product attributes. For example, if a consumer wants to buy a pair of Nike Lunarglide 8 running shoes, Amazon allows her to filter the search outcomes based on attributes such as shoe size, width, and color (See Figure 2.2 for an example.). Filtering enables consumers to find products that match their preferences better on these attributes. We define these attributes as a product's *filterable attributes*. In practice, however, filtering usually cannot exhaust all product attributes. There are some *unfilterable attributes*, e.g., shoe design and style, which consumers can learn only through searching.

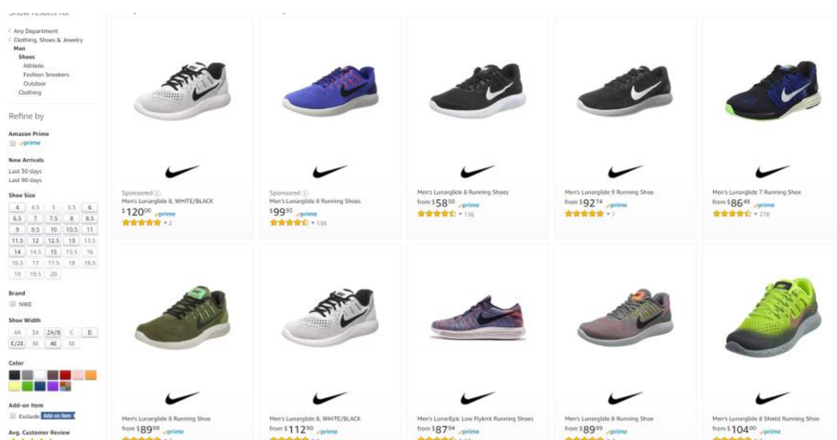


Figure 2.2 Screenshot of Search Results of "Nike Lunarglide 8" on Amazon.com

We decompose a consumer's match level, M_{ij}, into two parts: $M_{ij} = \mu_{ij} + m_{ij}$. The filterable match level, μ_{ij}, captures how well the filterable attributes match a consumer's preference. The unfilterable match level, m_{ij}, reflects how well the unfilterable attributes match the consumer's preference. The filtering function on the platform enables consumers to costless learn the filterable match level, μ_{ij}, before searching a product. However, consumers still need to search for a product's unfilterable match level, m_{ij}. μ_{ij} and m_{ij} are independently and identically distributed across products and consumers. To avoid confusion, we refer to M_{ij} as the product's *aggregate* match level henceforth.

In practice, the filters on the platform usually classify each filterable attribute into a finite number of categories. For example, Amazon classifies the color of men's running shoes into 12 categories. In our model, μ_{ij} follows a discrete distribution with $K(\geq 2)$ possible outcomes. μ_{ij} is equal to the k-th-lowest-possible filterable match level, μ_k, with probability ϕ_k, where $\mu_1 < \mu_2 < \cdots < \mu_K$ and $\sum_{k=1}^{K} \phi_k = 1$. The c.d.f. and p.d.f. of m_{ij} are $F(m)$ and $f(m)$, respectively. Without loss of generality, we assume $\mathbf{E}\left[\mu_{ij}\right] = 0$, [9] which implies that $\mu_1 < 0$ and $\mu_K > 0$.

We make several technical assumptions on the distributions of m_{ij} and u_{0j}. First, $f(m)$ and $f_0(u)$ have supports (m_{min}, m_{max}) and (u_{min}, u_{max}), where $-\infty \leq m_{min} < m_{max} \leq +\infty$ and $-\infty \leq u_{min} < u_{max} \leq +\infty$, are twice continuously differentiable and strictly positive. Second, to guarantee existence of a unique pure-strategy equilibrium, $F(m)$ is assumed to have a decreasing inverse hazard rate $h(m) = \frac{1-F(m)}{f(m)}$. Many commonly used distributions, e.g., normal distributions, uniform distributions, exponential distributions, and logistic distributions, satisfy these properties above. Third, we assume $\tau < \mathbf{E}[m] - \max\{m_{min}, u_{min}\}$ to exclude the trivial case in which no consumers will search after the first search.

Consumer search

Each consumer buys at most one product, and will either purchase from a seller on the platform or choose the outside option (not buying from any seller). A consumer *a priori* does not know a product's unfilterable match level, m_{ij}, nor its price, p_i. We assume that consumers do not know p_i ex ante (even after filtering) because in practice many online sellers do not immediately show their final transaction price until after a consumer visits their product pages or until the product is put in the shopping cart. For example, Ellison and Ellison (2009) document that many online sellers of computer parts on retail platforms post low prices to attract consumers to visit their product pages and postpone showing consumers the shipping-and-handling cost, taxes or add-on fees. The final transaction price can be much higher than the posted price that consumers see in the beginning. Moreover, a seller may set different prices for different variants of a product (e.g., the same design of shoes with different colors), and sometimes the platform will put all these variants together within the same webpage and only show their price range or the minimum price. Consumers can find the exact price of a specific product variant only after further searching. Moreover, filtering and sorting by product prices are often ineffective in practice. For example, if one sorts the search results of "Nike Lunarglide 8" by prices from low to high (see Figure 2.3), many irrelevant results appear at the top of the page. 20 out of the top 24 results are either non-Nike-Lunarglide-8 running shoes, or irrelevant products such as running socks and T-shirts.

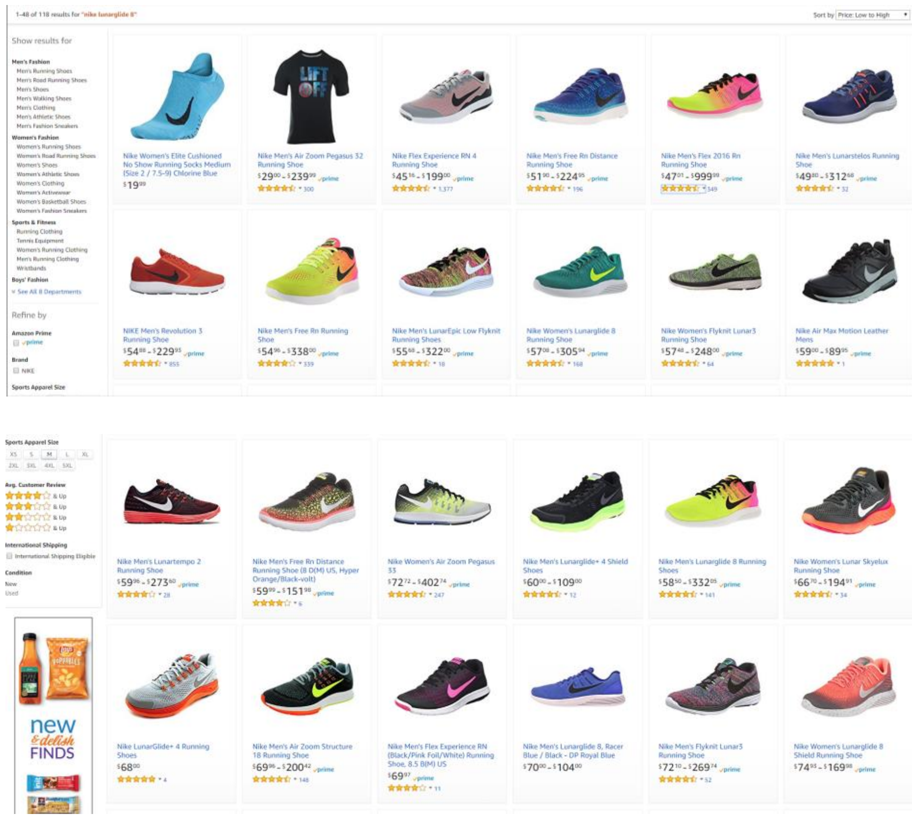


Figure 2.3 Screenshot of Search Results of "Nike Lunarglide 8" on Amazon.com, Sorted by Option "Price: Low to High"

Each consumer j *a priori* knows her utility of her own outside option u_{0j} and the filterable match level of every product, μ_{ij}. To find out p_i and the exact value of m_{ij} for a product, the consumer needs to incur a search cost τ. The search cost may include the consumer's time and effort in reading product introduction, understanding the information, and evaluating the product, etc. A consumer can decide whether to shop on the platform. If she does, she search the sellers sequentially. Specifically, after each search, the consumer learns the exact value of m_{ij} and p_i for the searched product i, then she can decide whether to buy it. If the consumer buys a product, she will stop searching and exit the market, otherwise she can continue searching another seller or leave the market without buying anything. If the consumer continues searching, one can show that she will next search the seller with the highest μ_{ij} not yet searched. If there are multiple unsearched sellers with the highest μ_{ij}, she will be equally likely to choose one from them to search.

Sellers, retail platform and time sequence

The timing of the game is as follows: First, the retail platform sets a percentage referral fee $r \in (0,1)$ for all sellers. We assume that the platform's marginal cost is zero. Then, given r, all sellers simultaneously decide their retail prices. For each unit of product i sold at retail price p_i, the retail platform earns rp_i and seller i's profit is $(1-r)p_i - c$. Last, consumers make search and purchase decisions.

Using backward induction, we determine the symmetric pure-strategy Nash equilibrium: given the platform's referral fee r, in equilibrium all sellers will charge the same retail price, p^*. Let $p^*(r)$ denote the seller's equilibrium retail price given the referral fee r, and let r^* denote the platform's optimal percentage referral fee. Consumers have rational expectations about sellers' prices, i.e., prior to a search they expect that the next seller's retail price will be $p^*(r)$.

2.4 Equilibrium Analysis

We start by analyzing the consumer's searching and purchasing strategies. Suppose that the platform's referral fee is r and the equilibrium retail price is $p^*(r)$. Let product i be the last product that consumer *j* has just searched and her utility of buying it is u_{ij}. Because the number of sellers (n) is large, consumers will only search sellers with the highest possible filterable match level, μ_K. It follows from Wolinsky (1986) that consumer j's optimal sequential-search strategy is to stop searching and purchase the *last* searched product i if and only if conducting another search will increase her expected utility beyond u_{ij} by an amount lower than the search cost τ; otherwise she will continue searching. We have the following two results.

RESULT 1. *In a symmetric equilibrium where all sellers charge prices* $p^*(r)$*, if consumer j faces product i with* $p_i = p^*(r)$ *and* m_{ij}*, she will purchase product i if and only if* $m_{ij} \geq \bar{m}(\tau)$*, where* $\bar{m}(\tau)$ *is defined by* $\int_{\bar{m}(\tau)}^{m_{max}} (m - \bar{m}(\tau)) dF(m) = \tau$.

RESULT 2. $\bar{m}$ *strictly decreases in the consumer's search cost* τ.

Result 1 suggests that $\bar{m}(\tau)$ is essentially the equilibrium acceptance threshold of the unfilterable match level. Note that the threshold is uniquely determined by the search cost, τ. In the rest of the article, we use $\bar{m}$ to represent $\bar{m}(\tau)$ for conciseness. Result 2 shows that when the search cost (τ) declines, searching another product becomes less costly to consumers. Therefore, they will have a higher purchase threshold $\bar{m}$.

It follows Wolinsky (1986) that seller i's profit as a function of its price p_i is:

$$\pi_i^S = \underbrace{\frac{\phi_K F_0(\bar{m} + \mu_K - p^*(r))}{\phi_K n \cdot (1 - F(\bar{m}))}}_{\text{Prob(a consumer visit seller } i)} \cdot \underbrace{[1 - F(\bar{m} - p^*(r) + p_i)]}_{\text{Prob(Consumer buys from seller } i)} \cdot \underbrace{[(1-r)p_i - c]}_{\text{Profit per sale}} \qquad (1)$$

where the superscript S represents the seller.

The platform's total demand, the number of consumers buying on the platform, is $D = F_0(\bar{m} + \mu_K - p^*(r))$. The expected consumer surplus is $CS(\tau, r) = \mathbf{E}_{u_0}[\max\{u_0, \bar{m} + \mu_K - p^*(r)\}]$.

2.4.1 Exogenous Referral Fee

We first analyze the benchmark case when the referral fee r is exogenous, that is, the platform's referral fee does not change with the search cost. In practice, platforms do not adjust the referral fee levels frequently. One reason is that platforms usually need to make announcements months before the fee change becomes effective. For example, on November 9th, 2016, Amazon announced that it would increase the referral fee for media products starting March 1st, 2017.[10] Similarly, on February 26th, 2017, eBay announced an increase in its fee for certain products to be effective after May 1st, 2017. Another reason is that frequently changing the referral fee will increase sellers' risk selling on the platform and lead to confusion, distrust, and frustration among them. Therefore, it is more reasonable to assume an exogenous referral fee in the short term.

Sellers' optimal decisions

We use "~" over variables to indicate the exogenous-referral-fee case.

LEMMA 1. *Given the platform's referral fee* r*, the sellers' equilibrium retail price is* $\tilde{p}^* = \frac{c}{1-r} + h(\bar{m})$*, a seller's per-unit-sale profit and total profit are* $(1-r)h(\bar{m})$ *and* $\tilde{\pi}_i^{S*} = \frac{F_0\left(\bar{m}+\mu_K-\frac{c}{1-r}-h(\bar{m})\right)}{n}(1-r)h(\bar{m})$*, respectively. The total demand on the platform is* $\widetilde{D}^* = F_0\left(\bar{m}+\mu_K-\frac{c}{1-r}-h(\bar{m})\right)$.

Lemma 1 summarizes the equilibrium retail price, the sellers' profit, and the total demand given the percentage referral fee r. When r increases, the platform charges a higher mark-up for a unit sale, so the retail price will increase in equilibrium. Thus, the total market demand on the platform and the sellers' profit will both decrease. Note that a seller's per-unit-sale profit is proportional to $h(\bar{m})$. Intuitively, a higher $h(\bar{m})$ corresponds to more intense competition among the sellers. If a consumer is searching a seller charging the equilibrium price, $\tilde{p}^*$, she will buy the product if and only if $m_{ij} > \bar{m}$. If this seller increases its price by a small amount to $\tilde{p}^* + \Delta p$, then the consumer will buy the product if and only if $m_{ij} > \bar{m} + \Delta p$. Thus, the small increase in price will reduce the seller's unit sales approximately by a fraction of $\frac{f(\bar{m})\Delta p}{1-F(\bar{m})} = \frac{\Delta p}{h(\bar{m})}$. When $h(\bar{m})$ is high, a seller will have stronger incentives to increase its price because doing so will only reduce sales slightly.

LEMMA 2. *When the consumer's search cost decreases, given that a consumer searches on the platform, the expected number of products that she will search before purchase will increase, and the expected aggregate match level of the product that she will purchase will also increase.*

When searching for another product becomes less costly, a consumer will stop searching at a higher match-level threshold, $\bar{m}$,. Hence, she will search more products and purchase a product with higher M_{ij} in expectation.

Proposition 1 summarizes how the equilibrium retail price, the market demand, and a seller's profit will change as the search cost (τ) decreases.

PROPOSITION 1. *When the referral fee (r) is exogenous, as the consumer's search cost (τ) decreases, (1) the equilibrium price $\tilde{p}^*$ decreases ($\frac{\partial \tilde{p}^*}{\partial \tau} > 0$), (2) the equilibrium total market demand strictly increases ($\frac{\partial \tilde{D}}{\partial \tau} < 0$), (3) each seller's expected profit $\tilde{\pi}_i^{S*}$ and the platform's expected profit $\tilde{\pi}^{P*}$ may either increase or decrease.*

One might intuit that a lower search cost will intensify the competition between sellers and reduce their prices and profits. We find that when the search cost decreases, although sellers' equilibrium prices decrease, they may receive higher profits. This is due to a market expansion effect: a decrease in the search cost will make consumers more likely to choose to shop on the platform rather than choosing the outside option, so a seller's market demand will increase. The platform's profit may either increase or decrease in equilibrium.

Example 1. To explore in detail how the consumer's search cost affects the sellers and the platform, we consider a special example where $\mu_K = 0.5$, m_{ij} follows the uniform distribution between -0.5 and 0.5, and the utility of the outside option u_{0j} is uniformly distributed between 0 and 1. The inverse hazard function of m_{ij} is $h(m) = 0.5 - m$. We consider the case with the consumer's search cost $\tau < \frac{\left(1-\frac{c}{1-r}\right)^2}{8}$, otherwise all consumers will search at most one product in equilibrium. One can easily show that $\bar{m} = 0.5 - \sqrt{2\tau}$ and the equilibrium retail price is $\tilde{p}^* = \frac{c}{1-r} + \sqrt{2\tau}$.

A seller's expected profit increases with τ when $\tau < \frac{\left(1-\frac{c}{1-r}\right)^2}{32}$ and decreases with τ when $\frac{\left(1-\frac{c}{1-r}\right)^2}{32} \leq \tau < \frac{\left(1-\frac{c}{1-r}\right)^2}{8}$. The platform's profit increases with τ when $\tau < \frac{\left(1-\frac{3c}{1-r}\right)^2}{32}$, and decreases with τ when $\frac{\left(1-\frac{3c}{1-r}\right)^2}{32} \leq \tau < \frac{\left(1-\frac{c}{1-r}\right)^2}{8}$. Therefore, in the case where the referral fee r is exogenous, both the firm's profit and the sellers' profit first increase and then decrease with τ (See Figure 2.4).

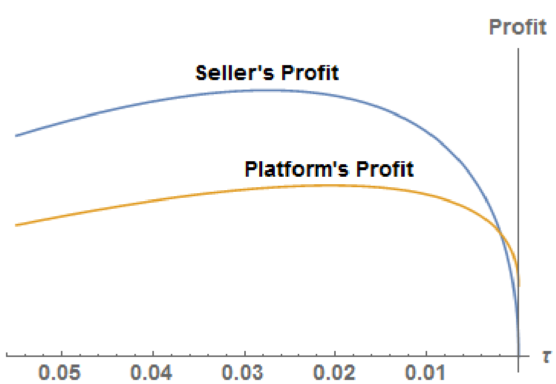


Figure 2.4 Seller's and Platform's Profits

Note. This figure is plotted using $c = 0.05$, and $r = 0.2$. The curves are rescaled to be fit in the same figure.

2.4.2 Endogenous Referral Fee

In this subsection, we study the case where the retail platform endogenously chooses its referral fee to maximize its expected profit. In the long term, the platform can strategically adjust its referral fee when the search cost changes, so it is more reasonable consider the case of endogenous referral fee. Denote $r^*(\tau)$ the platform's optimal percentage fee and $\pi^{P*} = \pi^P(r^*(\tau))$ the platform's optimal profit when the consumer's search cost is τ.

PROPOSITION 2. *When the platform endogenously sets the referral fee r, a decrease in the search cost will strictly increase the platform's expected profit, i.e.,* $\frac{d\pi^{P*}}{d\tau} < 0$.

A lower search cost may have either positive or negative impacts on the platform's profit. On the one hand, a lower search cost can benefit the platform because it expands market demand. On the other hand, it tends to intensify price competition among sellers, which can reduce the platform's per-unit-sale profit. Proposition 1 has shown that when the platform's referral fee is exogenous, a search-cost reduction can either increase or reduce the platform's profit. In contrast, Proposition 2 shows that the platform will *always* benefit from a lower search cost when it optimally chooses its referral fee because it can expand the total demand without heavily reducing its profit margin.

Proposition 2 suggests that if the retail platform can optimally adjust its referral fee in the long term, it should always try to reduce the consumer's search cost if doing so is not too costly. The result potentially explains why retail platforms, such as Amazon.com, have invested millions of dollars in improving consumers' search experience and reducing their search cost on the platform. Although the platform may see a profit drop in the short term (with the referral fee fixed), it will see a profit increase in the long term when it optimally adjusts its referral fee level.

Next, we study how the retail platform should optimally adjust its referral fee with the consumer's search cost. Intuitively, a reduction in the search cost tends to intensify the competition among sellers and hence reduce the platform's profit margin, so the platform would mitigate its profit-margin decrease by raising the referral fee. However, Proposition 3 shows that under some conditions, it may be optimal for the platform to *reduce* its referral fee as the consumer's search cost decreases. Let $\epsilon_{D,r}(r) \equiv \frac{\partial D}{\partial r} \cdot \frac{r}{D}$ be the platform's demand elasticity of referral fee r.

PROPOSITION 3. *When the consumer's search cost* τ *decreases (i.e., when* $\bar{m}$ *increases), the platform's optimal referral fee* r^**will increase if* $\frac{\partial|\epsilon_{D,r}(r^*)|}{\partial \bar{m}} < \frac{-cr^*(\bar{m})h'(\bar{m})}{\left(cr^*(\bar{m})+h(\bar{m})\right)^2}$, *and will decrease if* $\frac{\partial|\epsilon_{D,r}(r^*)|}{\partial \bar{m}} > \frac{-cr^*(\bar{m})h'(\bar{m})}{\left(cr^*(\bar{m})+h(\bar{m})\right)^2}$.

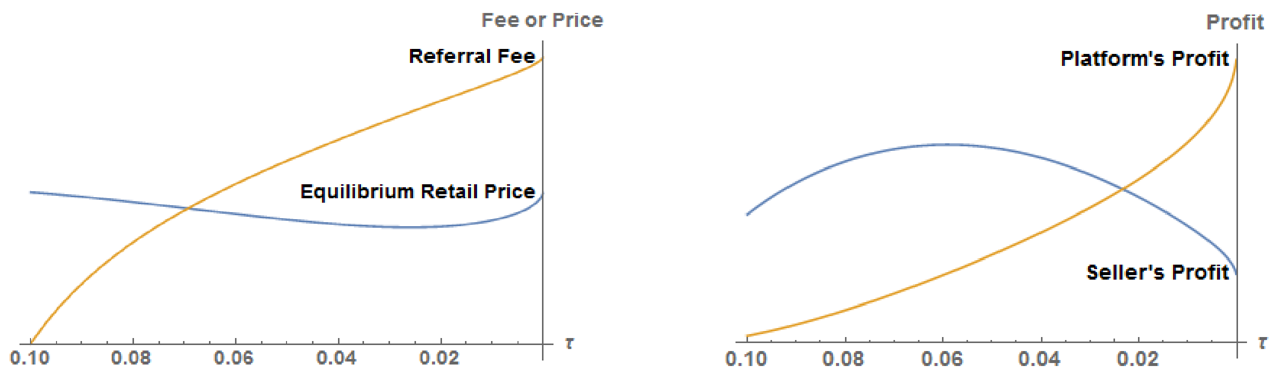
Proposition 3 characterizes the conditions under which the platform should raise or reduce its referral fee when the search cost decreases. If a decrease in the search cost significantly increases the (absolute value of) demand elasticity, the platform will find it optimal to reduce its referral fee because doing so can significantly increase the total demand. Note that the lowered referral fee will reduce the equilibrium retail price but could actually increase the sellers' profit margin. As a result, a lower search cost can be *all-win* for the platform, sellers and consumers if the platform chooses to reduce its referral fee in equilibrium.

Similarly, if a decrease in the search cost does not significantly raise the (absolute value of) demand elasticity, then the platform will find it optimal to raise its referral fee, leading to an increase in its profit margin. In this case, a decrease in the search cost can reduce sellers' profits and increase the equilibrium retail prices, making the consumers possibly worse off as well.

Proposition 3 suggests that when consumers' search cost declines, whether the retail platform should reduce or raise its referral fee depends on how the demand elasticity changes. If a decrease in the search cost will attract new customers who are relatively more price-sensitive compared to the platform's existing customers, the platform will have a more elastic demand, so the platform tends to reduce its referral fee. In reality, this can happen for a high-end platform (relative to other competing platforms) with a wealthier, price-insensitive customer base. By lowering consumers' search cost on the platform, it can attract some marginal consumers, who are relatively more price-sensitive than the platform's existing customers, from competing low-end platforms. In this case, the platform's demand elasticity will increase, so the platform may want to lower its referral fee to boost its sales volume. Conversely, if the decrease in the search cost will attract new customers who are less price-sensitive compared to the existing customer base, the platform's demand tends to become increasingly inelastic so the platform should increase its fee. In reality, this could happen for a relatively budget-friendly platform (compared to its competitors). A decrease in the search cost will help the platform to attract some wealthier customers from its competitors, which reduces the platform's overall demand elasticity.

In practice, it is easy for the platform to reduce the referral fee. However, the platform may receive complaints from sellers and consumers when raising the referral fees. In practice, when the platform finds it optimal to raise the referral fees, it should try to alleviate the sellers' and consumers' dissatisfaction. For example, the platform may want to announce a soon-to-be-in-effect fee increase at the same time as it introduces new search features and technologies on its website (e.g., augmented-reality technologies), and the platform can communicate to sellers and consumers that the fee increase will enable the platform to cover the cost of developing and offering such new technologies.

Example 2. To further study how the search cost's impact may be different when the referral fee is endogenous versus when it is exogenous, we consider the numerical example with the same distributions and parameters as those in Example 1 (the exogenous-referral-fee case), but allow the platform to endogenously choose its referral fee.



(a) Equilibrium Referral Fee and Retail Price **(b) Seller's and Platform's Profit**

Figure 2.5 Numerical Example with Endogenous Referral Fee

Note. This figure is plotted using $c = 0.05$. The curves are rescaled to be fit in the same figure.

Figure 2.5(a) plots how the platform's optimal referral fee and the equilibrium retail price changes with the search cost τ. In Example 1 where the referral fee is exogenous, the reduction in τ will always reduce the equilibrium retail price, p^*, because it intensifies the seller competition. Conversely, in Example 2 with endogenous referral fee, when τ is already low, further decreasing τ can lead to a higher p^*. This is because the platform will increase its referral fee when τ becomes lower, forcing the sellers to charge higher prices to cover their cost. Despite the increase in retail price, the sellers' profit per unit sale will decrease. In other words, the reduction in the consumer's search cost may intensify the double-marginalization problem in the channel and lead to higher final prices. Figure 2.5(b) depicts how the platform's and the sellers' profits will change with the consumer's search cost, τ. Echoing Proposition 2, although the decrease in τ can lower the platform's profit in the case with exogenous referral fee, r, the platform's profit will always increase if it can optimally adjust r.

2.5 Filtering

This section studies how the filtering function on the platform can affect the consumer's optimal search and the seller's pricing strategies, and how its effects can be different from that of a reduction in search cost. To this end, we compare the equilibrium outcome of the no-filtering case with that in the main model where filtering is available. In the no-filtering case, consumers do not observe a product's filterable match level (μ_{ij}) before searching, and searching a product informs a consumer of the aggregate match level $M_{ij} = \mu_{ij} + m_{ij}$.

Let $F_M(M)$ and $f_M(M)$ denote the c.d.f. and p.d.f. of M_{ij}. Note that $\mu_{ij} = \mu_k$ with probability ϕ_k and the c.d.f. of m_{ij} is $F(m)$, so $F_M(M) = \Pr(M_{ij} \leq M) = \Pr\left(\mu_{ij} + m_{ij} \leq M\right) = \sum_{k=1}^{K} \Pr\left(\mu_{ij} = \mu_k\right) \cdot \Pr(m_{ij} \leq M - \mu_k) = \sum_{k=1}^{K} \phi_k F(M - \mu_k)$, or equivalenty $F_M(M) = \mathbf{E}_\mu[F(M - \mu)]$. This equation reveals the relationship between the distributions of M_{ij}, μ_{ij}, and m_{ij}. Intuitively, when the filterable match level is μ_k, the aggregate match level (M_{ij}) exceeds M if and only if the corresponding unfilterable match level (m_{ij}) exceeds $M - \mu_k$. Hence, the overall probability of $M_{ij} > M$ will be the expected probability of $m_{ij} > M - \mu$, where the expectation is taken with respect to the filterable match level, μ.

Notice that $F_M(\cdot)$ is a convex combination of $F(\cdot)$, so $F_M(M)$ will be greater (smaller) than $F(M)$ when $F(\cdot)$ is "convex (concave) enough" around M. Similarly, $f_M(M) = \sum_{k=1}^{K} \phi_k f(M - \mu_k) = \mathbf{E}_\mu[f(M - \mu)]$, which will be greater (less) than $f(M)$ when $f(\cdot)$ is "convex (concave) enough" around M. The inverse hazard rate of M is:

$$h_M(M) = \frac{\mathbf{E}_\mu[1 - F(M-\mu)]}{\mathbf{E}_\mu[f(M-\mu)]} = \frac{\mathbf{E}_\mu[1 - F(M-\mu)]}{1 - F(M)} \cdot \frac{f(M)}{\mathbf{E}_\mu[f(M-\mu)]} \cdot h(M) \qquad (2)$$

We assume $F_M(M)$ is twice continuously differentiable and $h_M(M)$ is decreasing. A casual observation from Equation 2 is that $h_M(M)$ is greater than $h(M)$ if $1 - F(\cdot)$ is "sufficiently convex" and $f(\cdot)$ is "sufficiently concave", i.e., $f'(\cdot)$ and $f''(\cdot)$ are sufficiently small. Similarly, $h_M(M)$ is smaller than $h(M)$ if $f'(\cdot)$ and $f''(\cdot)$ are sufficiently large. As we will show later, the relative magnitude between $h_M(M)$ and $h(m)$ plays an important role in determining how filtering affects the sellers' pricing strategies.

Consumer's optimal search strategy

First, we examine the consumers' optimal search strategy under the no-filtering case. Similar to the main model, consumers will stop searching and buy the last product they searched if and only if its aggregate match level, M_{ij}, exceeds the equilibrium acceptance threshold, $\overline{M}_N$, where the subscript N indicates the no-filtering case. $\overline{M}_N$ is uniquely and implicitly defined by $\int_{\overline{M}_N}^{M_{max}} (M - \overline{M}_N) dF_M(M) = \tau$.

In the scenario without filtering, the consumer's acceptance threshold for the aggregate match level is $\overline{M}_N$. In the scenario with filtering, the threshold is $\overline{M} = \mu_K + \overline{m}$. Proposition 4 compares $\overline{M}$ and $\overline{M}_N$ and illustrates how the filtering function on the platform affects the consumer's optimal searching strategy.

PROPOSITION 4. *Filtering will increase the consumer's acceptance threshold of aggregate match level, but by less than μ_K, i.e.,* $0 < \overline{M} - \overline{M}_N < \mu_K$.

Filtering affects on the consumer's acceptance threshold for a product's aggregate match level in two opposite ways. First, filtering informs consumers of a product's filterable match level and narrows their consideration set down to those products with the best filterable attributes ($\mu_{ij} = \mu_K$). This effect raises the consumer's acceptance threshold for the aggregate match level by μ_K, so a consumer is more likely to end up buying a product with a better match level. Second, filtering reduces the direct benefit of searching. Because filtering has already revealed the filterable match level and resolved some of the consumer's uncertainty, conducting a search will uncover less information of match levels and thus bring less benefit to consumers, *ceteris paribus*. As a result, consumers tend to search less, stopping searching at lower acceptance thresholds. Overall, the second effect only partially offsets the first effect, so the consumer's acceptance threshold for M_{ij} will increase but by less than μ_K.

Sellers' pricing decisions

Next, we investigate how filtering affects the sellers' pricing. We show that the equilibrium retail price in the no-filtering case is $\tilde{p}_N^* = \frac{c}{1-r} + h_M(\bar{M}_N)$, as compared to $\tilde{p}^* = \frac{c}{1-r} + h(\bar{m})$ when filtering is available. Filtering will reduce the equilibrium price ($\tilde{p}^* < \tilde{p}_N^*$) when $\frac{h_M(\bar{M}_N)}{h(\bar{m})} = \frac{h_M(\bar{M}_N)}{h(\bar{M}_N)} \cdot \frac{h(\bar{M}_N)}{h(\bar{m})} > 1$. Earlier discussions reveal that, when $f'(\cdot)$ and $f''(\cdot)$ are low, $\frac{h_M(\bar{M}_N)}{h(\bar{M}_N)}$ is higher, so $\tilde{p}^* < \tilde{p}_N^*$ is more likely. Conversely, filtering tends to increase the equilibrium retail prices if $f'(\cdot)$ and $f''(\cdot)$ are large.

To formally illustrate this point, we consider the "marginal" effect of filtering on the seller's optimal pricing strategies, i.e., where filtering reveals only an infinitesimal amount of product match level information to consumers. In such a scenario, the magnitude of the filterable match level, μ_{ij}, is very small such that $\max_{1<k\leq K} |\mu_k| \rightarrow 0$. Proposition 5 characterizes when filtering can increase or decrease the equilibrium retail price.

PROPOSITION 5. *Suppose* $\max_{1<k\leq K} |\mu_k| \rightarrow 0$.

(1) If $h^2(\bar{m})f''(\bar{m}) + 2h(\bar{m})f'(\bar{m}) + f(\bar{m}) < 0$, *filtering will increase the equilibrium retail prices, i.e.,* $\tilde{p}^* > \tilde{p}_N^*$.

(2) If $h^2(\bar{m})f''(\bar{m}) + 2h(\bar{m})f'(\bar{m}) + f(\bar{m}) > 0$, *filtering will decrease the equilibrium retail prices, i.e.,* $\tilde{p}^* < \tilde{p}_N^*$.

How to interpret the conditions about $f(\cdot)$, $f'(\cdot)$ and $f''(\cdot)$ in Proposition 5 in business practice? Mathematically, a low $f''(\cdot)$ indicates that $f'(\cdot)$ will not increase fast within a certain range. Hence, if $f(x)$, $f'(x)$ and $f''(x)$ are low at point x, $f(x)$ is low at x and will stay low when x increases. The discussion of Proposition 1 shows that when the filtering is available, if seller i marginally increases its price, the corresponding unit-sale decrease of this product is approximately proportional to $f(\bar{m})$. Hence, when filtering is available and $h^2(\bar{m})f''(\bar{m}) + 2h(\bar{m})f'(\bar{m}) + f(\bar{m}) < 0$, i.e., $f(\bar{m})$, $f'(\bar{m})$ and $f''(\bar{m})$ are sufficiently low, the product's demand is insensitive to its price p_i and this sensitivity will remain low when p_i further increases. In other words, under the case of filtering, a product's demand tends to have a relatively long tail. Hence, filtering will alleviate competition between sellers and raise the equilibrium prices. An example product category is one-of-a-kind niche products whose unique features are hard to filter and some consumers have very high valuation for the unfilterable attributes. For these products, the platform will be more likely to allow consumers to filter the search results because doing so can increase the retail prices and the platform's revenue from the referral fee.

The reverse will happen when $h^2(\bar{m})f''(\bar{m}) + 2h(\bar{m})f'(\bar{m}) + f(\bar{m}) > 0$, i.e., when $f(\cdot)$, $f'(\cdot)$ and $f''(\cdot)$ are sufficiently high. In this case, filtering will make a product's demand more sensitive to price, i.e., it has a relatively short tail. Hence, competition between sellers will be stronger and the equilibrium retail price will decrease. An example product category is products whose major features can be filtered, so the search outcomes are limitedly differentiated on unfilterable attributes when filters are applied. For these product categories, the platform may be hesitant to adopt filtering because it would trigger keen competition between sellers and reduce the profits of sellers and the platform.

Although both filtering and a reduction in search cost make consumer search easier, our analysis above suggests that they can have very different marketing implications. For example, a reduction in search cost will always encourage consumers to search more products, but filtering will reduce the benefit of search and so consumers may search fewer products in expectation. Moreover, when the search cost decreases, the competition between sellers will always be intensified and the equilibrium retail price will always decrease (for a given referral fee). By contrast, filtering can possibly soften competition between sellers and lead to higher retail prices, which is desirable to the platform.

2.6 Extensions

2.6.1 Heterogeneous Search Cost

Consumers are different in their search efficiency, knowledge of products, and opportunity cost of searching. In this extension we investigate the case in which consumers are heterogeneous in their search cost, τ. Specifically, let $\Phi(\tau)$ denote the c.d.f. of τ, where $0 < \tau_{min} \le \tau \le \tau_{max}$, and $\tilde{p}^*$ denote the equilibrium price when consumers have heterogeneous search costs.[11] In addition, let $\tilde{p}_\tau^* = \frac{c}{1-r} + h(\overline{m}(\tau))$ denote the equilibrium retail price in the homogeneous-search-cost case where all consumers have the same search cost τ, which we have derived in the previous section.

How should a seller choose its price when facing consumers with different search costs? A naïve approach is to "weigh each consumer equally" and set the price to be $\mathbf{E}_\tau[\tilde{p}_\tau^*]$, the average of the homogeneous-search-cost prices (p_τ^*) weighted by the density of τ. By contrast, Proposition 6 suggests that this naïve choice of price is suboptimal for a seller, whose optimal price should "weigh low-search-cost consumers more" and be lower than $\mathbf{E}_\tau[\tilde{p}_\tau^*]$.

PROPOSITION 6. *When consumers have heterogeneous search cost, the seller's optimal retail price is a weighted average of the homogeneous-search-cost prices, i.e.,* $\tilde{p}^* = \mathbf{E}_\tau[a(\tau)\tilde{p}_\tau^*]$. *The weighting function* $a(\tau)$ *decreases with the consumer's search cost, i.e.,* $a'(\tau) < 0$.[12] *Moreover,* $\tilde{p}^* < \mathbf{E}_\tau[\tilde{p}_\tau^*]$.

Intuitively, because a low-search-cost consumer is more likely to shop on the platform instead of choosing the outside option, she is more likely to visit a seller than a high-search-cost consumer. Therefore, the distribution of a seller's visitors is skewed towards low-search-cost consumers, so the seller should target these consumers more by charging relatively lower prices.

We also examine a numerical example with heterogeneous consumer search cost, where τ is uniformly distributed on the interval $(0, \bar{\tau})$. We show that all the major results in the homogeneous-search-cost model are qualitatively robust. Please refer to Appendix B for details.

2.6.2 Heterogeneous Product Quality

Some products are systematically valued more by consumers than other products because of their better product or service quality. To capture the quality heterogeneity, we assume that there is one premium seller selling a premium product from which consumers on average derive higher match levels than the non-premium products sold by the other $n-1$ non-premium sellers. Without loss of generality, we assume that the seller $i=1$ sells the premium product, and sellers $i = 2, \dots, n$ sell the non-premium products. For analytical tractability, we consider the case where all product attributes are unfilterable, i.e., $\mu_i = 0, \forall i$. Specifically, let the aggregate match level of the premium product ($i = 1$) be $M_{1j} = \Delta q + m_{1j}$, where Δq is the premium product's quality premium i.e., the difference between the average aggregate match level of the premium product and that of non-premium products. The distribution of m_{1j} is the same as that of a non-premium product. The marginal costs of these two types of products are c_H and c_L, respectively. We assume $c_H - c_L < \Delta q$, so the premium seller is relatively cost effective.

One can show that a consumer's optimal search strategies depend on her outside options. Similar to the main model, if a consumer's outside option is low, she will search the premium product first and, if its match level is low, continue searching non-premium products. If a consumer's outside option is high, she will choose the outside option and not search any product on the platform. However, the search pattern for consumers with intermediate outside options is different from the main model where all products have homogeneous base quality. These consumers will search only the premium product and if its match level is low, they will choose the outside option. For these consumers, searching the premium product is better than the choosing the outside option in expectation, but the benefit of searching a non-premium product does not justify the search cost.

Next, we examine the sellers' pricing strategies. Let $\tilde{p}_1^*$ and $\tilde{p}^*$ be the equilibrium prices of the premium product (product 1) and the non-premium products, respectively. It is easy to prove that $\tilde{p}^* < \tilde{p}_1^*(r) < \tilde{p}^* + \Delta q$, i.e., the premium seller will charge a higher price than non-premium sellers, but the price difference will not exceed their quality difference so consumers will search the premium seller first in equilibrium. This result is similar to Armstrong et al. (2009), who find that the higher-quality firm has a stronger incentive to become prominent, i.e., being searched first by consumer. However, their paper assumes that consumers will always search the prominent product first, even though the consumers could be strictly better off in expectation by searching other items first. By contrast, the search sequence in our model is not exogenously imposed but endogenously determined by consumers' optimal decisions. Next, we examine the non-premium sellers' pricing strategies.

RESULT 3. *The equilibrium retail price of the non-premium products is* $\tilde{p}^*(r) = \frac{c}{1-r} + h(\bar{m})$, *which is independent of the quality premium of the premium product,* Δq.

Result 3 suggests that $\tilde{p}^*$ is independent of Δq. The intuition is as follows. The consumer's optimal search strategy indicates that consumers will always search the premium seller before they search any non-premium ones. Moreover, if a consumer has already searched the premium product and decided to continue searching the non-premium products, she will never go back to and buy the premium product in equilibrium. Thus, for consumers who have decided to search non-premium sellers, the premium product's quality premium and price will not affect their probability of buying from a specific non-premium seller. For other consumers, they will not search any non-premium sellers so a change in a seller's price will not affect the consumers' search decisions.

Therefore, the optimal price of non-premium products will be independent of the price and base quality of the premium product.

One can show that both the premium seller's and the non-premium sellers' optimal prices will decrease when the consumer's search cost (τ) decreases. When the platform's referral fee is exogenous, the profits of the premium seller, the non-premium sellers, and the platform can either increase or decrease with the search cost. When the platform endogenously chooses r, its optimal profit will always become higher when τ decreases. Thus, our results in the main model are robust when products have heterogeneous base quality levels.

2.6.3 Fixed Referral Fee

In the previous analysis, we assume that the platform charges a *percentage* referral fee for the sellers. In practice, some retail platforms may charge a *fixed* referral fee for each transaction. We proceed to examine whether our major results are robust to this alternative referral-fee structure. The platform charges a *fixed* referral fee per unit of sale, $d > 0$, instead of a percentage fee, r. All other model settings remain the same.

In Appendix B, we analytically derive the equilibrium outcome of the fixed-referral-fee setting. A decrease in the search cost will reduce the equilibrium retail price and increase the demand on the platform. A seller's profit can either increase or decrease. When the platform can endogenously choose the referral fee, d, a lower search cost will always increase the platform's profit. Hence, most results in the percentage-referral-fee setting can be qualitatively replicated in the fixed-referral-fee setting.

2.6.4 Outside Option and Retail Platform Competition

In practice, a consumer can choose whether to shop on the retail platform that we focus on or on some other competing platforms, and the latter can be considered as the consumer's outside option in our model. In this sense, our analytical framework could partially capture the competition between different retail platforms (e.g., Amazon.com versus eBay.com) although we do not explicitly consider the competitor's pricing decisions. When the focal platform faces stronger competition, consumers are more likely to have a better outside option. We analyze how the distribution of outside options affects consumers, sellers, and the platform. For analytical tractability, we assume that the platform endogenously chooses its *fixed* referral fee, d. We continue to adopt the distribution assumptions in Example 1 and 2: $\mu_K = 0.5$ and $m_{ij} \sim Uniform(-0.5,0.5)$. The consumer's outside option, u_0, follows a uniform distribution between l and $1 + l$. A larger l indicates that the outside option tends to be more attractive, i.e., the competing platform is stronger. We consider the nontrivial case with $-2\sqrt{2\tau} - c < l < 1 - 2\sqrt{2\tau} - c$, otherwise either no consumers or all consumers will shop on the platform.

We show that in equilibrium, the platform's optimal fixed referral fee is $d^* = \frac{1-2\sqrt{2\tau}-c-l}{2}$, a seller's profit is $\pi_i^{S*} = \frac{(1-2\sqrt{2\tau}-c-l)}{2n}\sqrt{2\tau}$, and the platform's profit is $\pi^{P*} = \frac{(1-2\sqrt{2\tau}-c-l)^2}{4}$. When the platform faces stronger competition, i.e., l is larger, it will charge a lower referral fee, and its profit as well as the sellers' will decline. The platform can always benefit from a lower search cost: $\frac{\partial \pi^{S*}}{\partial \tau} = -\frac{1-2\sqrt{2\tau}-c-l}{\sqrt{\tau}} < 0$.

Note that the absolute value of the above derivative decreases with l. To put it differently, when the platform competes with stronger competitors, it will receive less benefit from reducing the consumer's search cost. This result may sound surprising because one might conjecture that a platform facing stronger competition would be more inclined to lower its search cost in order to poach customers from competitors. However, our result suggests that it will be a platform facing weaker competitors (l is larger) which have a stronger incentive to reduce its search cost. This is because such a platform has a higher profit per unit sale so it can benefit more from acquiring an additional customer. This result explains why large retail platforms (e.g., Amazon.com and Overstock.com) invests heavily in search-cost-reduction technologies, e.g., camera search, barcode search, and augmented-reality view, whereas smaller shopping sites usually use less advanced search technologies. This will create a Matthew effect, allowing larger platforms to offer better search experience and attract even more customers.

2.7 Conclusion

This article studies how the consumer's search cost influences an online retail platform, independent sellers on it, and consumers. We explicitly model the consumer's search process and the pricing decisions of both the platform and the sellers. When the referral fee is exogenous, a lower search cost will reduce the equilibrium retail price due to stronger competition, but the seller's expected profit may actually increase. This is because a lower search cost attracts more consumers to shop on the platform instead of choosing the outside option. The platform's profit may either increase or decrease as the consumer's search cost decreases. However, when the platform endogenously chooses its referral fee, its expected profit will always increase as the search cost decreases. This result implies that the platform should always try to reduce the consumer's search cost as long as doing so is not too costly.

Our analysis shows that when the consumer's search cost decreases, the platform should reduce its referral fee to boost its sales volume if the demand elasticity of the referral fee significantly increases, otherwise the platform should raise the referral fee to increase its profit margin. If a lower search cost reduces the platform's optimal referral fee, sellers will pay less to the platform for a unit sale, possibly leading to a lower equilibrium retail price yet higher expected seller profits. In this case, a lower search cost can be *all-win* for the platform, sellers and consumers. In contrast, when a lower search cost increases the platform's optimal referral fee, the equilibrium retail price may increase but the seller's profit margin will shrink. Hence, a lower search cost can make both sellers and consumers worse off.

We also consider how the filtering function affect the consumer's search and the sellers' pricing decisions. We show that, after filtering becomes available, a consumer can filter out the products with better filterable attributes and hence is more likely to find a product with a better match level. At the same time, because filtering has already partially resolved the consumer's uncertainty, conducting a search will uncover less amount of information and generate less benefit for the consumer. Hence, she tends to search fewer products and buy a product with less good match. We also characterize the conditions when filtering will increase or reduce the sellers' equilibrium prices. If a product's demand tends to have a relative longer (shorter) tail when filtering is available, the competition between sellers will be alleviated (intensified) and the equilibrium retail price tends to increase (decrease). These results suggest that filtering can be very different from a search-cost reduction, for the latter always induces the consumers to search more and leads to stronger price competition among sellers.

Even though we assume that sellers sell differentiated products, our model can conceptually apply to the case where some sellers sell a common branded product. In essence, a product in our model is the totality of the core product and any seller attributed together as a whole. So, the differentiation among "products" comes from not only the core product attributes (e.g., shoes of different brands, style, color, size, etc.) but also the sellers' attributes (e.g., service, return policy, existence of physical stores close to the customers, etc.). For example, sellers on the east coast of the U.S. can ship their products to New York City within two days, but it may takes longer to ship to Los Angeles. Similarly, sellers on the west coast of the U.S. can ship products to Los Angeles faster than to New York City. Furthermore, whether the sellers have physical stores close to the customers can differentiate the sellers among consumers, because consumers may have more convenient options for product returns or exchanges if there is a physical store nearby.

This paper mainly focuses on the online context, but many results, including how the search cost will affect sellers and retail platforms' pricing strategies and profits, can be generalized to offline settings with caution. However, our research also captures several features that are unique to the online shopping environments. First, our paper analyzes the impact of filtering, which is commonly used on online retail platforms but is rarely adopted in offline stores. Second, most previous studies on consumer search in offline channels assume that the retailer carries a limited number of products (usually two) and consider the setting with wholesale contracts: the manufacturers first set the wholesale price and then the retailer determines the final retail prices (e.g., Gu and Liu 2013). Thus, the retailer will always benefit when the manufacturers charge lower wholesale prices. These assumptions are more reasonable for offline retail stores where the retailer can carry only limited product varieties due to the shelf-space restriction and is able to determine the final retail prices for each product. However, an online platform has very low operational costs of including an additional seller, so it usually carries a large assortment. As a result, the retail platform usually cannot optimize the final prices for each individual product. In practice, retail platforms usually charge a percentage referral fee applied to all sellers and let the sellers decide their final prices. Contrary to the offline setting, an online platform may benefit from a higher final price of sellers because it can lead to a higher referral-fee revenue.

We would like to point out a few caveats about our model. In our analysis, we do not explicitly study how sellers' entry decisions can be affected when the consumer's search cost changes. However, one can easily extend our model to analyze how the search cost affects sellers' entry on the platform. For example, one can assume that a seller needs to incur some positive fixed cost to sell on the platform. If in our model a seller's expected profit increases when the consumer's search cost decreases, then in that parameter region it will be more likely to observe sellers entering the market. Similarly, if a lower search cost reduces the seller's expected profit, then it is likely that some sellers will exit the market. We have assumed that each seller sells only one product. In practice, a seller may sell multiple differentiated products on the platform. One can study how the consumer's search cost affects the seller's product assortment decisions. Cachon et al. (2008) show that when sellers sell directly to the consumer, they will increase their product assortments when the consumer's search cost decreases. We conjecture that if the sellers sell their products through a retail platform, a decrease in the consumer's search cost will increase sellers' product assortments when the referral fee is exogenous. However, when the referral fee is endogenous, if a lower search cost induces the platform to increase the referral fee, sellers may provide fewer assortments as a result.

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Endnotes:

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[6] https://www.geekwire.com/2017/augmented-reality-shopping-phone-patent-hints-Amazon.coms-aspirations/

[7] https://nichehunt.com/Amazon.com-augmented-reality-patent-could-reshape-the-future-of-e-commerce/

[8] Different articles present estimated search costs in different formats. We use the median of their estimates whenever possible because the distributions of many estimates have long tails for very high search costs. For articles only reporting the range of the estimated search cost, we use the midpoint of the range. We take natural logarithm to mitigate the impact of extreme values.

[9] Our model decomposes consumers' valuation of a product into a vertical component (q_i) and a horizontal component (M_{ij}). q_i is the mean of consumers' valuation of the product, and M_{ij} is a demeaned random variable capturing consumers' idiosyncratic horizontal preference for the product.

[10] https://www.sellerlabs.com/blog/Amazon.com-policy-update-november-9th-2016-3-changes-selling-media/

[11] Without loss of generality, we assume the consumer with the largest search cost ($\tau = \tau_{max}$) will search on the platform with positive probability.

[12] The expression of $a(\tau)$ is given in the Online Appendix.

Chapter 3 The Bright Side of Cost Transparency: Facilitating Product Innovation

3.1 Introduction

A firm's cost information for its products is increasingly transparent to consumers. Many third-party infomediaries publish the cost information of products in the market. For example, consumers can get good estimates of car dealers' cost of a vehicle by referring to the factory invoice price disclosed by *truecar.com*. Many other websites provide cookbook guides or online calculators to help consumers gauge the dealer's true cost of getting a car from the manufacturer. Consumers can also find cost-breakdown reports for many electronic devices. For example, *Electronics360* provides a detailed cost-breakdown analysis of Jawbone Mini Jambox, a Bluetooth speaker, suggesting that a Mini Jambox, sold at $179.99, costs Jawbone only $24.32 to produce.[24] In addition to these third-party infomediaries, many firms, including Everlane, Oliver Cabell, and HonestBy, voluntarily disclose their own cost information. For example, Everlane reveals on its website that the cost of a $100 cashmere crew sweater is around $52 ($34.05 for materials, $1.90 for hardware, $13.00 for labor, $1.96 for duties, and $0.60 for transportation). Everlane also discloses the detailed information of the factories for each of its products. New technologies, e.g., blockchain, enable the firms to further convincingly communicate with their customers about their cost information. A survey of supply chain professionals shows that 56% of the respondents believe that firms should use blockchain to share information (such as production cost) with customers (Weinswig 2018).

It has been long debated whether cost-information transparency is a boon or a bane for firms. On the negative side, Sinha (2000) argues that cost transparency can be harmful because it can lower the firm's profit margin, reduce products and services differentiation, weaken customer loyalty, and create perceptions of price unfairness. Zhu (2002, 2004) show that cost transparency can reduce the high-cost firms' incentive to participate in the market, hence may reduce the profit of these firms and the total social welfare. On the positive side, Mohan et al. (2016) show that firms disclosing its cost can attract more consumers and raise their willingness-to-buy. On how cost transparency can affect consumers, Simintiras et al. (2015) argue that unit-cost transparency can help consumers make judgement on price fairness and product quality. By contrast, Kuah and Weerakkody (2015) state that unit cost are often hard to define in practice and thus can mislead the consumers. Our paper adds to the discussion above by building an analytical model to investigate how cost transparency affects consumer purchase timing, the firm's innovation and pricing decisions, and the consumer surplus. Specifically, we show that cost transparency has a bright side on firms and consumers: when the firm sells a durable product and can change the price dynamically, cost transparency can foster product innovation and therefore benefit consumers and firms.

We start with why and how cost transparency can affect a durable good producer's dynamic pricing and the consumer's purchase timing decisions. After a firm has sold products to consumers with relatively high valuations, it has an incentive to cut its price to target some low-valuation consumers. This phenomenon, termed as *intertemporal price discrimination,* has been well documented in the literature (e.g., Bridges et al., 1995; Coase, 1972; Conlisk et al., 1984; Narasimhan, 1989; Stokey, 1979, 1981). Strategic consumers, anticipating the firm's incentive to drop future prices, may postpone purchase if they are patient and believe that the price will significantly decrease in the future. The consumers' belief about the future price is affected by the firm's cost. If consumers know or believe that the firm has a high cost (hence a relatively low profit margin), they will expect any dramatic future price drop to be unlikely and thus will be inclined to buy the product in the current period.

Such consumer behaviors are common in reality. For instance, as a technology blog noted, *"While prices for sub-50-inch HDTVs are flat, prices for displays larger than 60 inches are already heading down."* It then explained, "*TV-makers are looking to stimulate sales at the high-end [HDTVs], where profit margins are the greatest, while keeping prices steady for sub-50-inch models that already have razor-thin margins. On the low-end of the market, the margins are too small and pricing will stay flat.*"[25] On another online tech-forum, one user suggested that consumers should buy new computers right away rather than wait because "*... with hardware profit margins already pretty low, I wouldn't expect massive reductions [of computer prices]."*[26]

Without cost transparency, consumers do not know the firm's cost and their belief about the future price will depend on the firm's current price. Intuitively, a high-cost firm tends to charge a high price. When a consumer sees a high price, she may infer that the firm has a high cost and expect that the future price will also be relatively high, so she tends to buy the product immediately. As a result, a low-cost firm may have an incentive to mimic the high price to induce consumers to buy right away. With cost transparency in the market, the firm's ability to manipulate consumers' expectation of future prices will be limited.

We analyze a dynamic model in which a firm first decides whether to make an R&D investment to develop a new product. If the firm develops the product, the firm can sell to consumers in two periods. Without cost transparency, the firm's cost is its private information. In the first period, consumers may infer the firm's cost from its current price. This affects their expectation of the future (second-period) price and thus the current purchase decisions. In this case, the low-cost firm has an incentive to mimic the high-cost firm by charging the same first-period price as the high-cost firm would, and the high-cost firm has an incentive to raise its first-period price, and thus sell to fewer customers to avoid the low-cost firm's mimicry. However, with cost transparency, the firm's cost is common knowledge and the consumer's belief about the future price will be based on the firm's true cost (rather than the inferred cost) and its current profit margin. In this case, because the low-cost firm can no longer pretend to be the high-cost firm, it will be worse off whereas the high-cost firm will be better off.

A firm's R&D investment for innovation is often made long before the product will be manufactured and sold to consumers. So, when making an innovation investment decision, the firm is typically uncertain about the final marginal cost for its product. Thus, the firm's innovation investment decision depends on whether its *expected* profit exceeds the upfront R&D investment. Our analysis reveals that cost transparency will increase the firm's *expected* profit and hence make the firm more likely to invest in innovation.

We also examine the effect of cost transparency on consumers. Conventional wisdom suggests that customers will benefit from having more information. However, we show that this is not always true in the context of cost transparency. When the firm has a high cost, cost transparency can reduce the consumer's surplus. This is because the high-cost firm will charge higher prices since cost transparency prevents a low-cost firm from pooling with the high-cost firm. Although cost transparency can reduce the consumer surplus in case of a high-cost firm, we show that, in expectation, cost transparency will benefit the consumer. Thus, in expectation, cost transparency is a *win-win* situation for *both* the firm *and* the consumers.

We also check the result robustness under different model settings. We show that all the main results remain qualitatively the same when consumers tend to buy the product early either because they value the "newness" of the product or their utility is time-discounted. We also consider the case where the market has a low entry barrier, i.e., the (incumbent) firm faces competition of entrants in the second period. We find that most of our results remain qualitatively unchanged in the low-entry-barrier scenario. Interestingly, when the competition in the second period is perfect, we show that the incumbent firm's profit can be independent of its marginal cost (up to a threshold), when the cost information is transparent to consumers.

3.2 Literature Review

Our research contributes to the literature on intertemporal price discrimination and dynamic pricing. Coase (1972) proposes that if a monopolist selling durable products is able to decrease its price on an infinitely frequent basis or on an infinite time horizon, consumers will not accept any price higher than the product's marginal cost and the firm will thus make zero profit. However, it has been shown that when the firm can pre-commit its future price or it has an increasing cost with respect to time, it can charge prices higher than its marginal cost (Kahn 1986, Stokey 1981). Several other papers also focus on firms' optimal intertemporal price discrimination strategies under different settings (Aviv and Pazgal 2008, Besanko and Winston 1990, Conlisk et al. 1984, Levin et al. 2008, Narasimhan 1989, Stokey 1979).

Our research complements the aforementioned literature on intertemporal price discrimination in that we study cost uncertainty and information asymmetry, which this literature has mostly neglected. Only a few studies investigate the impact of uncertainty and information asymmetry on the firm's intertemporal price discrimination decisions. For example, Png (1991) shows that when the firm has demand uncertainty, high-valuation consumers may gamble on a future price cut. To mitigate this problem, the firm can offer most-favored-customer protection which guarantees early buyers the benefit of subsequent reduction in prices. To the best of our knowledge, our paper is the first to study how the consumer's knowledge about the firm's cost will affect the firm's intertemporal price discrimination and innovation decisions.

This paper also relates to the signaling literature in marketing (Desai and Srinivasan 1995, Jiang et al. 2011, Kuksov 2004, Kuksov and Lin 2017, Moorthy and Srinivasan 1995, Simester 1995, Soberman 2003). One stream of this literature studies why and how a firm signals its cost information in different contexts. Simester (1995) shows that in a duopoly where firms' marginal costs are their private information, the firm with a low marginal cost may advertise low prices for some products to signal that prices of unadvertised products are also low, since costs of different products are positively correlated. Shin (2005) examines how a store's "vague advertisement," which commits only the minimum price of a product, may construct a credible price image if consumers do not know the store's selling cost. Guo and Jiang (2016) consider the case in which a consumer feels that it is unfair when the firm's profit margin is too high relative to her surplus. Hence, a high-cost firm may have an incentive to use its price and product quality to signal its high cost. They find that as the expected cost-efficiency in the market decreases, both product quality and social welfare may increase rather than decrease. In the extant signaling literature, the work most closely related to our paper is Balachander and Srinivasan (1998). They consider a firm selling a durable good whose cost decreases over time due to learning-by-doing—the more products a firm sells in the first period, the lower its unit cost will be in the second period. Consumers know the firm's current cost but do not know *a priori* the firm's efficiency of learning-by-doing. The authors show that a "high-experience" firm tends to charge a lower price to sell more products in the first period in order to greatly reduce its future cost, which will lower the consumers' expectation of the future price. The low-experience firm can charge a high first-period price to signal that it has low learning efficiency and hence its future price will not drop dramatically. Our paper studies a new substantive question of how cost transparency affects firm innovation through investments in product development, which has not been examined in this literature. In our model, the cost signaling game in the case without cost transparency is merely a subgame following the firm's innovation decision.

This paper is also related to the literature on cost transparency, which is typically focused on whether a firm shares its private cost information with competitors or within a supply chain (Fried 1984, Gal-or 1986, Shapiro 1986, Yao et al. 2008). Some recent studies also consider the cost information asymmetry between the firm and consumers. Mohan et al. (2016) show, through experiments, that a firm's voluntary disclosure of its cost information to consumers will increase their trust to the firm and hence their intent to purchase. Several qualitative studies discuss the potential benefits and problems of cost transparency to the consumers and the society (Kuah and Weerakkody 2015, Simintiras et al. 2015). Our paper complements this stream of literature by analytically modeling the effects of cost transparency on firm pricing and innovation.

3.3 Model

We consider a firm deciding whether to invest in R&D to develop a new durable product. If it does not invest, the product will not be developed and the firm's payoff is normalized to zero. If it invests, it incurs a fixed cost $I > 0$ and the product will be developed. Given that the firm invests, it can sell its developed product in two time periods ($t = 1, 2$), and the consumers will buy at most one unit of the product, either in the first period or the second period. We assume that when the firm decides whether to invest, it does not know the marginal cost of product. This accommodates the reality that when making innovation investment decision, the firm typically does not know the exact technology, materials and production techniques that will be used later. Thus, the firm's investment decision will depend on whether its *expected* future profit exceeds its upfront fixed cost I. To capture the uncertainty in the firm's future cost of production, we assume that the firm's marginal cost will be high (c_H) with probability α, or low (c_L) with probability $1-\alpha$. When deciding whether to invest I, the firm knows only the distribution of its future cost. In essence, the firm's cost can be thought of as its type, denoted by $i \in \{H, L\}$; we will use these terms (e.g., high-cost or high-type) interchangeably. We normalize $c_L = 0$ and denote $c_H = c$. Therefore, c represents the cost difference between the two types of firms. The firm's cost is constant across the two selling periods (please see Section 6 for discussion regarding the possibility of cost decreases over time, or learning-by-doing). With cost transparency, the consumers can learn the firm's marginal cost from the third-party infomediaries before their purchase decisions. Without cost transparency, consumers do not observe the firm's marginal cost when making purchase decisions.

Let $p_{i,1}$ and $p_{i,2}$ denote the i-type firm's first-period price and second-period price, respectively. If the consumer does not purchase the product in either period, she gets zero utility (from the outside option). If consumers buy the product in the first period, they can get a total usage value of v. We assume that $v \sim \text{uniform}(0,1)$ in the consumer population. We normalize the total population of consumers to 1.

Given our interest in modeling intertemporal price discrimination, we consider two reasons why a consumer may want to purchase early rather than wait. First, for innovative or fashion products, consumers tend to derive extra satisfaction from being innovators or early adopters. To capture this notion, we assume that if consumers buy the product in the second period, they will derive only a fraction $\mu \in (0,1)$ of the total usage value v, because they no longer enjoy the "newness" of the product or the satisfaction of being early adopters. Second, consumers may have a time discount factor δ on future utility from delaying purchase. Thus, a consumer obtains a net present utility of $u_1 = v - p_{i,1}$ if buying the product in the first period; she gets a net present utility of $u_2 = \delta(\mu v - p_{i,2})$ if buying the product in the second period. In our main analysis, we focus on the "newness" factor μ and abstract away from the effect of time discounting by assuming $\delta = 1$. Section 5 will consider the robustness of the results with the time discount factor.

The game proceeds as follows. First, the firm decides whether to invest I to develop the product. If it does not invest, the firm's payoff is zero. If the firm invests, it can sell the product in two periods. In the first period, the firm chooses its price $p_{i,1}$, and consumers decide whether to purchase the product in the first period based on their expectation about the firm's second-period price. In the second period, the firm chooses $p_{i,2}$ and consumers who did not buy the product decide whether to buy it in the second period.

3.4 Analysis

Subsection 4.1 studies the subgame given the firm invests I to develop the new product. We compare the firm's optimal pricing strategy, profit, and consumer surplus for the cases with and without cost transparency. Subsection 4.2 examines how cost transparency affects the firm's innovation decision and the expected consumer surplus.

3.4.1 Firm Pricing Decisions

Given the firm has invested I, it can produce and sell its product in two periods. We first consider the case with cost transparency, i.e., consumers know the firm's marginal cost (c_i) and can rationally infer the firm's future price based on the firm's current price and its *actual* marginal cost. Then, we analyze the case without cost transparency, i.e., consumers do not know the firm's actual cost but will infer it from the firm's price. We will compare the results to determine the effect of cost transparency on the firm and consumers.

With cost transparency (perfect-information case)

With cost transparency, the firm's cost is common knowledge and the consumer's belief about future prices will be based on the firm's true cost. We use "˜" over a variable to indicate this perfect-information setting. Using backward induction, one can show that type-i firm's optimal second-period price is $\tilde{p}_{i,2}^{*} = \frac{(1-\mu)c+\mu\tilde{p}_{i,1}}{2-\mu}$. One can see that a higher first-period price will lead to a higher second-period price, because fewer consumers will purchase the product in the first period. In addition, a higher c will lead to a higher $\tilde{p}_{i,2}^{*}$, which is also intuitive. Substituting the firm's optimal second-period price into its profit function, we can derive type-i firm's optimal first-period price and its optimal profit, as shown in lemma 1.

LEMMA 1. *When the firm's cost is common knowledge, its optimal first-period and second-period prices are* $\tilde{p}_{i,1}^{*} = \frac{(2-\mu)^2}{2(4-3\mu)} + \frac{c_i}{2}$ *and* $\tilde{p}_{i,2}^{*} = \frac{\mu(2-\mu)}{2(4-3\mu)} + \frac{c_i}{2}$ *, respectively, and its total profit is* $\tilde{\pi}_i^{*} = \frac{(1-\mu)^2}{4-3\mu} + \frac{(\mu-c_i)^2}{4\mu}$, *where* $i \in \{H, L\}$.

Without cost transparency

The consumers' belief about the firm's cost affects their expectations of the firm's future price and will thus influence their current purchase decisions. When consumers do not know the firm's cost, a low-cost firm may have an incentive to mimic a high-cost firm's pricing strategy in the first period to induce consumers to purchase immediately rather than wait. If the firm has a high cost, it would want consumers to know its high cost so that they will be less likely to postpone their purchase.[27] To credibly convince consumers that it has a high cost, the firm needs to sufficiently *raise* its first-period price such that a low-cost firm would not want to mimic. Note that a low-cost firm will not choose a very high price even if consumers believe that it has a *high* cost. Because the low-cost firm's optimal price is lower than that of the high-cost firm, the opportunity cost of choosing a high price is higher for a low-cost firm than for a high-cost firm. Put differently, for a given price, the low-cost firm's profit margin is higher, so it loses more profit when losing a sale (due to the high price) than a high-cost firm.

Since the firm prefers to be believed to have a high cost, one might wonder whether the firm may want to intentionally increase its cost. Our analysis reveals that a low-cost firm's equilibrium profit is always *higher* than that of a high-cost firm, and that even if the firm's cost is directly observable to consumers, the firm will *not* be able to improve its profit by wastefully raising its cost. Thus, although a low-cost firm may want consumers to believe that it has a high cost, it has no incentive to raise its *actual* cost.

Two types of Perfect Bayesian Equilibria (PBE) are possible in our setting. In *separating* equilibria, different types of firms charge different p_1, so consumers can correctly infer the firm's type from p_1. In *pooling* equilibria, both types of firms will choose the same p_1, so consumers will not be able to tell the firm's type. There are infinitely many PBE outcomes depending on consumers' off-equilibrium beliefs. We use the Lexicographical Maximum Sequential Equilibrium (LMSE) concept, proposed by Mailath et al. (1993), to refine multiple equilibria. LMSE and the related Undefeated Equilibrium concepts are widely used in marketing and management research (e.g., Gill and Sgroi 2012; Jiang et al. 2014; Miklós-Thal and Zhang 2013; Nan and Wen 2014; Taylor 1999). In our setting, the LMSE refinement selects among all PBE the outcome that is most profitable for the type of firm that wants its type revealed (i.e., the high-cost firm), and subsequently, if multiple outcomes persist, then LMSE selects among them the outcome that is the most profitable for the low-type firm.[28]

We derive the LMSE of our game in these the following steps: First, we determine the PBE yielding the highest profit for the high-cost firm among all separating equilibria, σ_{sep}^* . Second, we find the PBE giving the highest profit to the high-cost firm among all pooling equilibria, σ_{pool}^*. Finally, we compare σ_{sep}^* and σ_{pool}^* to determine the LMSE outcome. Throughout this section, we assume $c < \frac{(2-\mu)^2}{4-3\mu}\mu$ such that in equilibrium a high-cost firm will serve some consumers in the second period. Otherwise, the model will *de facto* reduce to an uninteresting one-period game. In practice, firms in an industry often use similar production technology, so the cost difference between different firms will not be very dramatic. Besides, the consumer's valuation for the product's newness may be relatively small compared with their overall valuation for the product, so we expect that c is low and μ is high in many realistic situations.

LEMMA 2. *Suppose that consumers do not know the firm's cost. A unique LMSE outcome exists; it is separating if $\alpha < \alpha^*$, and pooling if $\alpha \geq \alpha^*$, where* $\alpha^* =$

$$\frac{\sqrt{4-\frac{8c}{1-\mu}-2\left(\frac{c}{1-\mu}\right)^2+\frac{4c}{1-\mu}\sqrt{\frac{c}{1-\mu}\left(2+\frac{c}{1-\mu}\right)}}-2\left(1-\frac{c}{1-\mu}\right)}{\frac{2c}{1-\mu}}.$$

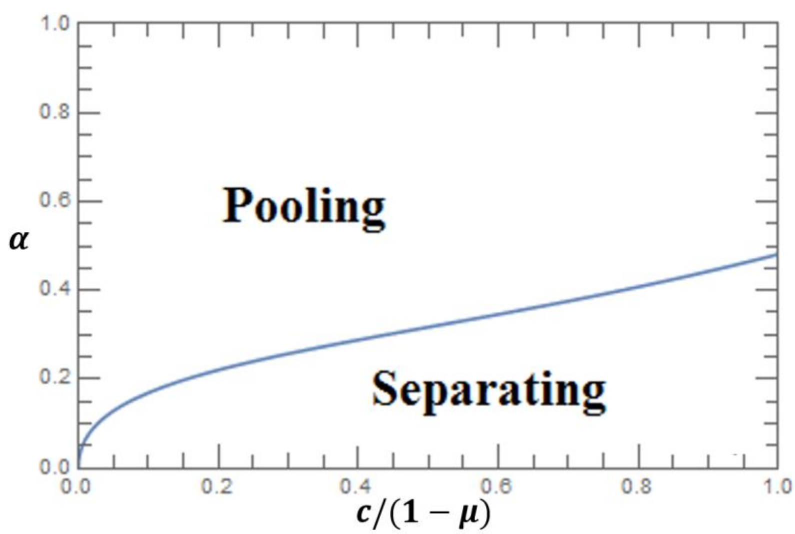

Figure 3.1 Equilibrium Outcome

Figure 3.1 depicts whether the LMSE equilibrium outcome is separating or pooling. Note that when α is low enough, if the high-cost firm pools with the low-cost firm, many consumers may postpone their purchases because the firm will very likely to have a low cost and will significantly reduce its price in the second period. In other words, when α is low, the high-cost firm will find the opportunity cost for pooling very high, so it will prefer the separating outcome, in which it incurs the signaling cost (of raising its first-period price) to separate itself from the low-cost firm.

Lemma 2 can be equivalently stated as that the equilibrium is separating if and only if c is large enough. Recall that the low-cost firm's marginal cost is zero, so the high-cost firm's marginal cost (c) represents the difference between the two types of firms' marginal costs. Hence, Lemma 2 suggests that when the difference in costs between the two types of firms is high, the high-cost firm will prefer separating itself from the low-cost firm.

COROLLARY 1. *The high-cost firm's profit* π_H^* *decreases with* c. *The low-cost firm's profit* π_L^* *increases with c when* $c \leq \frac{2(1-\mu)\alpha}{1-\alpha^2}$, *decreases with c when* $\frac{2(1-\mu)\alpha}{1-\alpha^2} < c \leq c^*$, *and is independent of c when* $c > c^*$, *where* c^* *is implicitly defined by* $1 - \frac{(1-\alpha)c^*}{1-\mu} = \sqrt{1 - \frac{2c^*}{1-\mu} - \frac{1}{2}\left(\frac{c^*}{1-\mu}\right)^2 + \frac{c^*}{1-\mu}\sqrt{\frac{c^*}{1-\mu}\left(2 + \frac{c^*}{1-\mu}\right)}}$.

As a side note, Corollary 1 shows that the high-cost firm's profit strictly decreases with c whereas the low-cost firm's profit changes non-monotonically with c. Note that when $c \leq c^*$, the equilibrium is pooling. Under this condition, a higher c has two opposite effects on the low-cost firm's profit. First, a higher c tends to increase the consumers' expectation of the second-period price, hence consumers will be more likely to purchase the product in the first period. Second, when c increases, the high-cost firm tends to increase its first-period price, which the low-cost firm will mimic under pooling. This higher pooling price will reduce the low-cost firm's first-period demand. When $c \leq \frac{2(1-\mu)\alpha}{1-\alpha^2}$, the first effect dominates so the low-cost firm's profit increases with c. By contrast, when $\frac{2(1-\mu)\alpha}{1-\alpha^2} < c \leq c^*$, the low-cost firm's profit decreases with c. Note that when

$c > c^*$, the equilibrium is separating so the *low-cost* firm's profit does not depend on the high-cost firm's marginal cost c.

Effect of cost transparency

We can determine the effect of cost transparency by comparing the market outcomes with versus without cost transparency.

PROPOSITION 1. *(1) Cost transparency will lower the high-cost firm's first-period and second-period prices when $\alpha < \alpha^*$, and will increase its first-period and second-period prices when $\alpha \geq \alpha^*$; cost transparency will not affect the low-cost firm's prices when $\alpha < \alpha^*$ and will lower its first-period and second-period prices when $\alpha \geq \alpha^*$. (2) Cost transparency will increase the high-cost firm's total profit and (weakly) reduce the low-cost firm's total profit.*

Proposition 1 examines how cost transparency affects the firm's pricing strategies and its total profit. When the firm's cost is not known to consumers, if $\alpha < \alpha^*$, the equilibrium is separating. The high-cost firm has to set a first-period price higher than its perfect-information price to reduce its demand enough to make mimicking unprofitable for a low-cost firm. Note that under the separating equilibrium, the high-cost firm's second-period price is also higher than its second-period price under perfect information (i.e., under cost transparency). This is because in the separating equilibrium the second-period customer base (those consumers who have not purchased in the first period) has higher valuations than the second-period customer base in the case with cost transparency. When $\alpha \geq \alpha^*$, the equilibrium is pooling. Because consumers cannot tell the firm's cost, their expectation of the second-period price is lower than the price that the high-cost firm will actually charge in the second period. Therefore, consumers are less willing to purchase the product in the first period, so the equilibrium prices are lower than the high-cost firm's perfect-information prices. With cost transparency, the high-cost firm can charge its perfect-information prices, making more profits than when its cost is not known to consumers.

By contrast, cost transparency can make the low-cost firm worse off. When $\alpha < \alpha^*$ and consumers do not know the firm's cost, the equilibrium is separating, where consumers can correctly infer the firm's cost. In this case, the low-cost firm will charge its perfect-information price. Therefore, cost transparency will not affect its profit when $\alpha < \alpha^*$. When $\alpha \geq \alpha^*$, the equilibrium is pooling and consumers cannot infer the firm's cost from p_1. Note that in this case a low-cost firm can always deviate to its perfect-information price and earn the perfect-information profit, so its pooling-equilibrium profit must be higher than its profit under cost transparency. Hence, cost transparency will reduce the low-cost firm's profit. Proposition 2 summarizes how cost transparency affects the consumer surplus.

PROPOSITION 2. *When $\alpha < \alpha^*$, cost transparency will increase the consumer surplus if the firm has a high cost, and it will not affect the consumer surplus if the firm has a low cost. When $\alpha \geq \alpha^*$, cost transparency will lower (increase) the consumer surplus if the firm has a high (low) cost.*

Suppose that the firm has a high cost. When consumers do not know the firm's cost, if $\alpha < \alpha^*$, the equilibrium is separating. As discussed earlier, the firm's price will be higher than its perfect-information price. Hence, cost transparency lowers the high-cost firm's price and increases the consumer surplus. When $\alpha \geq \alpha^*$, the equilibrium is pooling and the equilibrium price is lower than the high-cost firm's perfect-information price. Hence, when consumers know the firm's cost, the firm does not need to lower its price anymore, so consumer surplus will decrease. Similarly, in the low-cost firm case, consumer surplus increases when $\alpha < \alpha^*$ and remains unchanged when $\alpha \geq \alpha^*$.

3.4.2 Firm Innovation Decision

We have so far examined how cost transparency affects the consumer and the profits of both types of firms. In the case of a high-cost firm, cost transparency will benefit the firm but may either increase or reduce the consumer surplus. By contrast, if the firm's cost is low, cost transparency makes the firm worse off but the consumers better off. Now we analyze the first stage of the game, in which the firm decides whether to invest in innovation. Since the firm does not know its future cost at the time of the innovation decision, it will be based on whether its *expected* profit exceeds the required fixed-cost investment (I).

LEMMA 3. *Cost transparency will lower the expected price in both the first period* ($\alpha p_{H,1} + (1-\alpha)p_{L,1}$) *and the second period* ($\alpha p_{H,2} + (1-\alpha)p_{L,2}$)*. However, it will increase both the firm's expected profit* ($\alpha \pi_H + (1-\alpha)\pi_L$) *and the expected consumer surplus.*

Lemma 3 examines how cost transparency affects the expected price, the expected profit and the consumer surplus. We find that cost transparency will reduce the expected prices in both periods. One might intuit that lower expected prices will lead to a lower expected profit for the firm. However, our analysis reveals that both the firm and consumers will actually be better off in expectation. In the separating parameter region, without cost transparency, if the firm has a high cost, it will raise its price to signal its cost, but with cost transparency the firm will choose a lower price (i.e., its perfect-information price). Note that in the separating parameter region (when $\alpha < \alpha^*$ as shown in Figure 1), if the firm has a low cost, it will charge its perfect-information price regardless of cost transparency. Thus, overall cost transparency will lower the expected prices in the separating region. In contrast, in the pooling region (when $\alpha \geq \alpha^*$), cost transparency will lower the expected price mainly because with cost transparency a low-cost firm will significantly reduce its price from the high pooling price to its low perfect-information price. Hence, cost transparency will lower the firm's prices in expectation, resulting in a higher expected consumer surplus.

Cost transparency will also increase the firm's expected profit. In the separating region, if the firm has a low cost, cost transparency will have no effect on its profit, but if the firm has a high cost, cost transparency will allow the firm to make a higher profit (i.e., its perfect-information profit) since the firm no longer needs to distort its price to separate from a low-cost firm. Thus, overall, in the separating region, cost transparency will give the firm a higher expected profit. Similarly, in the pooling region ($\alpha \geq \alpha^*$), cost transparency will also increase the firm's *ex ante* expected profit because the firm's benefit from having a high cost revealed will dominate its profit loss from having a low cost revealed. Proposition 3 easily follows. It shows that cost transparency will make the firm more likely to develop a new product. Moreover, because consumers will also benefit from the development of the new product, cost transparency can be a Pareto improvement for the society.

PROPOSITION 3. *There exist $\underline{I}$ and $\bar{I}$ such that (1) if the firm's fixed-cost investment $I \in (\underline{I}, \bar{I})$, the firm will develop the product under cost transparency but not develop it without cost transparency; (2) if $I \in [0, \underline{I}]$, the firm will develop the product regardless of transparency, (3) if $I \in [\bar{I}, \infty)$, the firm will not develop the product regardless of transparency.*

Our results suggest that infomediaries that share cost information with consumers are socially beneficial. In fact, the firm may *a priori* have incentives to commit to sharing its cost information through a credible third-party infomediary that collects and disseminates product-cost information to consumers. The information-sharing platform can potentially earn a profit through service fees. Consumer advocacy groups can also help to promote or facilitate such cost transparency.

Our result may also help to partially explain why in practice a growing number of firms are building a reputation for making their cost more transparent (e.g., Everlane, Honestby, Oliver Cabell). Mohan et al. (2016) show through experimental and field studies that a firm's disclosure of costs can increase its trustworthiness in consumers' mind, making consumers more interested in considering the firm's product. Our paper provides a direct economic rationale why firms can benefit from cost transparency.

3.5 Extension

3.5.1 Time Discount

In our main model, the consumer's "cost" of delaying purchase is the loss of "newness" when consuming the product in a later period; we have assumed no time-discounting (i.e., $\delta = 1$). We now assess the robustness of our results to the alternative assumption that the consumer's "cost" of delaying purchase is due to time discounting of future utility (not newness concerns), by considering the case of $\delta < 1$ and assuming away the consumer's "newness" concern (i.e., $\mu = 1$). That is, the consumer's present value of buying the firm's product in the second period is $u_2 = \delta(v - p_{i,2})$. Other assumptions are the same as in the main model. Result 1 summarizes the firm's optimal prices and profit under cost transparency (i.e., in the perfect-information case), where "˜" over a variable indicates the case of cost transparency. Result 2 describes the LMSE equilibrium outcome when the firm's cost is not known to consumers.

RESULT 1. *When the firm's cost is common knowledge, its first-period and second-period (perfect-information) prices are* $\tilde{p}_{i,1}^* = \frac{(2-\delta)^2+(4-2\delta-\delta^2)c_i}{2(4-3\delta)}$ *and* $\tilde{p}_{i,2}^* = \frac{(2-\delta)+(6-5\delta)c_i}{2(4-3\delta)}$ *respectively, and its total profit is* $\tilde{\pi}_i^* = \frac{(2-\delta)^2(1-c_i)^2}{4(4-3\delta)}$*, where* $i \in \{H, L\}$.

RESULT 2. *Suppose that consumers do not know the firm's cost. When* $c > \delta$*, the equilibrium is costless-separating, i.e., both types of firms will charge their respective perfect-information* *prices. When* $c < \delta$ *, if* $\alpha < \alpha^{**} = \frac{2(1-\delta)-c(2-\delta)+\sqrt{2(1-c)[2-(2-\delta)(2-c)\delta]+2c(2-\delta)\sqrt{c\delta[4-(4-c)\delta]}}}{c\delta}$ *, the equilibrium is costly-separating, i.e., the high-cost firm's first-period price is higher than its perfect-information price and its total profit is lower than its perfect-information profit. When* $c < \delta$ *and* $\alpha > \alpha^{**}$*, the equilibrium is pooling.*

When consumers have time discounting rather than a "newness" preference, if the cost difference between the high-cost firm and the low-cost firm is large (i.e., c is high), the high-cost firm does not need to distort its price to signal its high cost to prevent the low-cost firm's mimicry and can earn a profit as high as its perfect-information profit, even if consumers do not know the firm's cost a priori. This is because when the cost difference between the two types of firms is large, the low-cost firm needs to greatly increase its price from its perfect-information price in order to be believed as having a high cost, which significantly reduces its unit sales. Note that the result is qualitatively similar to that in our main model with consumer "newness" preference, where the separating parameter region is the largest when c is high (illustrated in lemma 2). Also similarly, when $c < \delta$, the equilibrium is separating when the prior probability of the firm's cost being high, α, is low.

PROPOSITION 4. *If* $c > \delta$*, the firm's innovation decision will not be affected by cost transparency. If* $c < \delta$*, there exist* $\underline{I}'$ *and* $\bar{I}'$ *such that (1) if the firm's fixed-cost investment* $I \in (\underline{I}', \bar{I}')$*, the firm will develop the product under cost transparency but not develop it without cost transparency; (2) if* $I \in [0, \underline{I}']$*, the firm will develop the product regardless of transparency, (3) if* $I \in [\bar{I}', \infty)$*, the firm will not develop the product regardless of transparency.*

Proposition 4 examines how cost transparency affect the firm's innovation decision. When $c > \delta$, the equilibrium is costless-separating, so cost transparency will not affect the firm's expected profit, nor its decision of whether to invest the fixed-cost I to develop the product. By contrast, when $c < \delta$, cost transparency will increase the firm's expected profit, so it will increase the firm's incentive to develop the product, i.e., expanding the parameter region in which the firm will develop the product. This is consistent with proposition 3, where consumers have "newness" concerns but no time discounting.

3.5.2 Market with Low Entry-barriers

Our main model has implicitly assumed a very high entry barrier in the market such that the firm is a monopoly in both periods, so the intertemporal price decrease is mainly due to the firm's intertemporal price discrimination rather than increasing future competition. In some markets, firms can maintain their monopoly power for a long time because they are protected by high entry barriers such as patents, government policies, or geographical barriers. In such markets, intertemporal price discrimination may be the main driving force of the over-time price decrease. But some markets may have very low entry barrier, stronger competition can also drive the future price down, and it may be the main factor for the firm's price intertemporal decrease. In this subsection, we check whether the findings from our main model are robust when the market entry barrier is low.

We analyze a limiting case where the entry barrier is very low so that the market becomes perfectly competitive in the second period. This contrasts our assumption in Section 4 that the firm remains a monopoly in the second period, which represents the other limit of prohibitively high entry barrier. In reality, future entry barriers or the level of competition in the market may lie somewhere between these two cases; analyzing these two limits will help better gauge the boundary of our results.

We assume the firm to be a monopoly for its new product in the first period, but in the second period new entrants will enter to produce the product at the same marginal cost (c_i). Thus, the second-period equilibrium price will drop to c_i. Other aspects of the model are the same as in the main model. We focus on the interesting case of $c \leq \frac{\mu}{2}$ such that in equilibrium the high-cost firm will serve some consumers in the second period. Lemma 4 presents the equilibrium results when consumers do not know the firm's cost.

LEMMA 4. *Suppose that the firm's cost is not known to consumers. The unique LMSE outcome is separating if $\alpha < \alpha^*_{comp}$, and pooling if $\alpha \geq \alpha^*_{comp}$, where α^*_{comp} is given in Appendix C.*

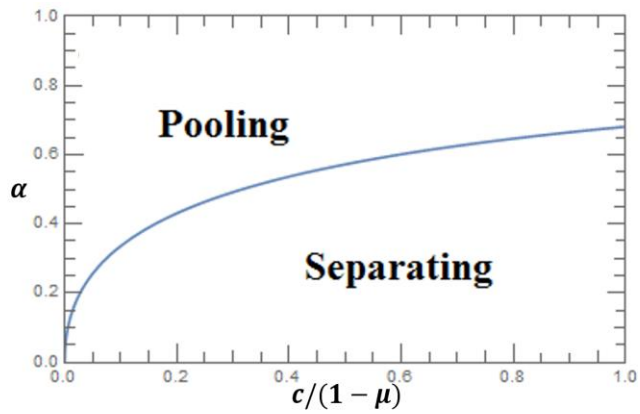

Figure 3.2 Equilibrium Outcome – Market with Low Entry Barriers

When the prior probability of the firm having a high cost is low (i.e., $\alpha < \alpha^*_{comp}$), the LMSE outcome is separating, otherwise it is pooling. Figure 3.2 illustrates the equilibrium outcome in different parameter regions. One can see that the boundary between the pooling and separating parameter regions is qualitatively the same as that in Figure 3.1. Corollary 2 shows that when the market has low entry barriers, the high-cost firm's profit decreases with its marginal cost (c), but interestingly, c has a non-monotonic effect on the low-cost firm's profit. This is qualitatively similar to Corollary 1 in the main model.

COROLLARY 3. *The high-cost firm's total profit* π_H^* *decreases with* c. *The low-cost firm's total profit* π_L^* *increases with* c *if* $c \leq \frac{(1-\mu)\alpha}{1-\alpha^2}$, *decreases with* c *if* $\frac{(1-\mu)\alpha}{1-\alpha^2} < c \leq c_{comp}^*$, *and is independent of* c *if* $c > c_{comp}^*$, *where* c_{comp}^* *is implicitly defined by* $\sqrt{1-\left(\sqrt{\frac{c_{comp}^*}{1-\mu}\left(\frac{c_{comp}^*}{1-\mu}+2\right)}-\frac{c_{comp}^*}{1-\mu}\right)^2} = (1-\alpha)\frac{c_{comp}^*}{1-\mu}$.

RESULT 3. *With cost transparency, the firm's optimal first-period price and profit is* $\tilde{p}_{i,1}^* = c_i + \frac{1-\mu}{2}$, *and its total profit is* $\tilde{\pi}_i^* = \frac{1-\mu}{4}$.

Result 3 summarizes the equilibrium outcome under cost transparency. Interestingly, the firm's profit is independent of its marginal cost. This is because a higher marginal cost has two opposing effects on the firm. On the one hand, it tends to lower the firm's profit margin. On the other hand, it raises the consumers' expected second-period price ($\bar{p}_2$), which tends to make consumers more likely to buy the product in the first period. Note that when consumers know the firm's cost, $\bar{p}_2$ will be equal to the firm's marginal cost c_i (since the market is perfectly competitive in the second period). One can also show that the consumer's first-period purchase decision will remain unchanged if both the first-period price p_1 and the expected second-period price $\bar{p}_2$ increase by the same amount (not too large). So, when c_i increases, the firm can raise its first-period price by the same amount, making the firm's profit margin and its market coverage stay the same in the first period. Since the firm earns zero profit in the second period, the firm's total profit is just its first-period profit, which will not be affected by the change in marginal cost. In other words, when the market has very low entry barriers, the two opposing effects of a cost increase can cancel out when there is cost transparency in the market, so the firm's total profit will be unchanged.

Result 3 shows the invariance of the firm's profit with respect to its marginal cost under cost transparency, assuming perfect competition in the future. In practice, the level of competition in the market is often not perfect, so the two effects of a cost change may not perfectly cancel out, and the firm's profit can decrease with its marginal cost. We cautiously interpret our result as that under cost transparency the negative effect of an increase in a firm's marginal cost may be significantly mitigated because it can reduce the consumer's strategic delay of product purchase.

Our analysis shows that all other results in section 4 remain qualitatively the same in the current case of very low entry barrier. That is, the qualitative effects of cost transparency on the firm's profit and consumer surplus are robust to different levels of entry barriers in the market.

3.6 Conclusion

This paper examines the effects of cost transparency on firm innovation, pricing, profits, and the consumer surplus. Our analysis shows that although cost transparency may *ex post* make the firm or consumers worse off, it *ex ante* makes both the firm and the consumers better off in expectation. This suggests that cost transparency can encourage more innovation by the firm and increase the overall consumer surplus. Moreover, cost transparency reduces the expected first-period and second-period prices in the market.

Our results provide insight on why a high-cost firm may seek to reveal its high cost to consumers on its own or facilitate the sharing of cost information through third-party infomediaries. For example, Xiaomi, a Chinese electronics company, has been actively informing consumers of its low profit margin. Some fashion firms, such as Everlane and Oliver Cabell, disclose the detailed cost breakdown of their products on their own websites. However, a firm's own claim of high costs may sometimes lack credibility. Many consumers question Xiaomi's own claim of its high cost (or low margins),[29] and the third-party's cost estimate of Xiaomi's cellphone can be much lower than Xiaomi's own claim.[30] Moreover, the reach of the firm's own claim of its cost may be narrow. Kuah and Weerakkody (2015) also summarize some other difficulties for the firm to credibly disclose its cost information. In contrast, many third-party infomediaries and news media, such as *Electronics360*, can examine or take apart the new products to provide more credible cost information because they do not have conflict of interests. So, infomediaries can serve an important role in providing credible cost transparency.

Our results around the effect of cost transparency on profit margins are consistent with some anecdotal evidence. For example, Scott Painter, CEO of TrueCar.com, suggested that the "average gross profit [of participating dealerships] has risen $100 per new vehicle to $350 today, from $250 a year and a half ago."[31] This is consistent with our prediction that if the equilibrium is pooling when consumers do not know the firm's cost, then cost transparency will increase the high-cost firm's optimal price because the firm is no longer pooled with the low-cost firm.

Note that we assumed that the product's marginal cost is independent of the firm's innovation cost (I). This is a reasonable assumption when the variance in production cost arises from the uncertainty in *exogenous* factors such as production technology or input prices. We however conjecture that when the firm's investments are focused on reducing its unit cost (e.g., process innovation), cost transparency will tend to lower the firm's incentive in making *cost-reduction* investments, since cost transparency will increase a high-cost firm's profit and reduce a low-cost firm's profit, leading to a smaller profit difference between a high-cost firm and a low-cost firm.

We hope that our paper will inspire empirical work on testing when cost infomediaries arise and their effects on firm pricing and margins. We offer the conjecture that cost infomediaries can lead to greater product innovation and lower process innovation. Similarly, our paper offers hypotheses for empirical testing of the effects of cost intermediaries on prices and margins.

Our analysis can be extended in the following ways: First, throughout the paper we have assumed that all consumers are strategic and anticipate future price change when they make purchase decisions. It will be interesting to investigate what happens if some of the consumers are myopic and do not anticipate future price changes. Previous research shows that the existence of myopic consumers increases the firm's profit when there is no information asymmetry (Aviv and Pazgal 2008). Future research can focus on whether this result will still hold when information asymmetry exists and consumers do not know the firm's cost.

Second, in this paper we have analyzed two-period models, and have not explicitly investigated a multi-period model or a continuous-time model. Previous research shows that as the number of periods increases, firms' incentive to acquire a good reputation (e.g., "being tough" or "being benevolent" as in Kreps and Wilson 1982) becomes stronger. If we apply their arguments to our research setting, a firm will tend to have a stronger incentive to be considered as a high-cost type when the number of periods increases. Hence, a low-cost firm will have stronger incentive to mimic a high-cost firm and the high-cost firm will need to raise its price more to prevent being mimicked. Consequently, we conjecture that if the number of periods increases, the high-cost firm's benefit from cost transparency will tend to increase whereas the low-cost firm will become even worse off.

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Endnotes:

[24] http://electronics360.globalspec.com/article/5474/jawbone-mini-jambox-j2013
[25] http://www.pcworld.com/article/2020284/cracking-the-gadget-pricing-code-buy-now-or-wait.html
[26] http://www.tomshardware.com/forum/305519-28-should-expect-computer-prices-drop-released

[27] The high-cost firm may want to directly reveal its cost to consumers but its own claim may lack credibility. In contrast, third-party infomediaries can provide reliable cost information because they do not have conflict interests. See the Conclusion section for a detailed discussion.

[28] We adopt LMSE as the equilibrium refinement criterion instead of other criteria mainly because, in our model, other refinement criteria, such as the Intuitive Criterion, still leave a continuum of PBE and do not identify a unique equilibrium outcome. By contrast, all PBE surviving LMSE correspond to the same equilibrium outcome.

[29] https://www.zhihu.com/question/52035702?sort=created

[30] http://www.cnbeta.com/articles/166239.htm

[31] http://www.autonews.com/article/20131027000100/RETAIL/310289984?template=print

Appendix A

PROOF OF LEMMA 1. Note that $U_{i,2}$ is defined as type-i consumer's utility if she does not buy tickets in the first period and makes her optimal buying decision (from the primary market, from the resale market, or not buying) in the second period. Hence $E[U_{i,2}] \geq 0$ and a type-i consumer will try to buy tickets in the first period if and only if $E[U_{i,1}] \geq E[U_{i,2}]$.

Because $N \leq \overline{N} < \frac{1+\alpha}{2}$, there will be always some consumers with strictly positive valuation unserved in the second period, so $\widehat{r^*} > 0$. Thus, $\widehat{r^*}$ is either V_A or V_C.

LEMMA A.1 *If there are any casual fans trying to buy tickets in the first period, all avid fans will try to buy tickets in the first period.*

This is true because $E[U_{A,1}] - E[U_{A,2}] \geq E[U_{C,1}] - E[U_{C,2}]$ for all $0 \leq \rho_i \leq 1$.

LEMMA A.2 *If a casual fan with $\rho_i = \rho > 0$ will try to buy tickets in the first period, then all casual fans with $\rho_i \in [\rho, 1]$ will try to buy tickets in the first period.*

We prove by contraposition. Suppose that there exist $\rho \in (0,1)$, such that the casual consumer with $\rho_i = \rho$ will try to buy tickets in the first period and that there exist $\rho_i > \rho$ and the casual consumer with ρ_i will not buy tickets in the first period. Because both $E[U_{C,1}]$ and $E[U_{C,2}]$ are linear in ρ_i and $E[U_{C,2}] \geq 0$, the casual consumer with $\rho_i = 1$ will not try to buy tickets in the first period, and the casual consumer with $\rho_i = 0$ will try to buy tickets in the first period. But $E[U_{C,2}] = 0$ if $\rho_i = 0$, so $E[U_{C,1}] > 0$ when $\rho_i = 0$, which is equivalent to $(1-k)\widehat{r^*} - p > 0$. Therefore, $\widehat{r^*} \neq 0$, so $\widehat{r^*} \geq V_C$.

Note that both $E[U_{C,1}]$ and $E[U_{C,2}]$ are weakly increasing in ρ_i and that $E[U_{C,1}] > 0$ when $\rho_i = 0$, so $E[U_{i,1}] > 0$ for all $\rho_i = 0$. We divide the discussion into the following three cases.

(i) If tickets are expected to sell out in the first period, $E[U_{C,2}] = \rho_i \cdot \widehat{Pr_{2,R}} \cdot \max\{V_C - \widehat{r^*}, 0\} = 0$ for all $\rho_i \geq 0$. So $E[U_{C,1}] > E[U_{C,2}]$ when $\rho_i = 1$.

(ii) If tickets are not expected to sell out and $p > \widehat{r^*}$, $E[U_{C,2}] = 0$ for all $\rho_i \geq 0$. So $E[U_{C,1}] > E[U_{C,2}]$ when $\rho_i = 1$.

(iii) If tickets are not expected to sell out and $p \leq \widehat{r^*}$, for the casual consumer with $\rho_i = 1$, $E[U_{C,1}] = \max\{V_C, (1-k)\widehat{r^*}\} - p = \max\{V_C - p, (1-k)\widehat{r^*} - p\} \geq \max\{V_C - p, 0\} \geq \widehat{Pr_{2,P}} \max\{V_C - p, 0\} = E[U_{C,2}]$.

Therefore, in all three cases, the casual fan with $\rho_i = 1$ will try to buy tickets in the first period, contradictory to the previous conclusion that this consumer will not try to buy tickets in the first period.

Let n_1 be the number of consumers trying to buy tickets in the first period. Lemma A.1 and Lemma A.2 together imply that if there are two rational expectation subgame perfect equilibria with the same n_1, then they are the same group of consumers in these two equilibria. $\widehat{Pr_1} = \min\{1, \frac{N}{n_1}\}$ is also the same in these two equilibria. Further, note that in the second period, the number of consumers who want to sell tickets, the number of avid fans, and the number of casual fans who want to buy tickets are uniquely pinned down by n_1, so r^* is also uniquely determined by n_1, and so is $\widehat{r^*}$. Thus, if there are two rational expectation subgame perfect equilibria with the same n_1, these two equilibria are identical. This directly implies that the buying-spree equilibrium is unique. ■

Derivation of the casual fan's utility function

We first derive the consumer's utility functions. Note that, as described earlier, a consumer who wants to buy a ticket may not be able to get a ticket. Let $U_{i,1}$ denote type-i consumer's utility of *trying to buy* a ticket in the first period, and $u_{i,1}$ denote her utility of *successfully* getting a ticket in the first period. Let $U_{i,2}$ be type-i consumer's utility if she does not buy tickets in the first period and makes her optimal buying decision (from the primary market, from the resale market, or not buying) in the second period. In the buying-spree equilibrium, the rational prediction will be fulfilled. Because the resale price $r \leq V_A$, an avid fan will never resell her ticket in the second period. Thus, an avid fan will attend the concert if she has a ticket, and will always want to buy a ticket from either the primary or the resale market if she does not have a ticket. If tickets are expected to sell out on the primary platform in the first period, an avid fan's expected utility of trying to buy a ticket in the first period is

$$E[U_{A,1}] = \widehat{Pr_1}(V_A - p) + \left(1 - \widehat{Pr_1}\right) \cdot \widehat{Pr_{2,R}}(V_A - \widehat{r^*}), \tag{1}$$

where Pr_1 is the probability of successfully getting a ticket (from the primary market) in the first period and $Pr_{2,R}$ is the probability of successfully getting a ticket from the resale market in the second period. Note that $E\left[U_{A,1}\right]$ consists of two terms. The first term represents the case that the avid fan successfully gets a ticket in the first period, where $\widehat{Pr_1}$ is the rationally expected probability of getting the ticket and $V_A - p$ is the avid fan's utility conditional on getting the ticket in the first period. The second term in (1) represents the case that the avid fan does not get a ticket in the first period (which occurs with a probability of $1 - \widehat{Pr_1}$) but gets a ticket in the second period (which occurs with a probability of $\widehat{Pr_{2,R}}$) and $V_A - \widehat{r^*}$ is her utility conditional on getting the resale ticket.[32] Note that in the second period the consumer cannot get a ticket from the sold-out primary platform. In this case, an avid fan's expected utility from trying to buy a ticket in the second period is $E[U_{A,2}] = \widehat{Pr_{2,R}}(V_A - \widehat{r^*}) \geq 0$.

If tickets are not expected to sell out on the primary platform in the first period, $\widehat{Pr_1} = 1$ and an avid fan's expected utility from buying in the first period is $E[U_{A,1}] = V_A - p$. Her expected utility of trying to buy a ticket in the second period depends on p and the expectation of r. If $p < \widehat{r^*}$, avid fans will first try to buy tickets from the cheaper, primary platform, and if unsuccessful, then from the resale platform. An avid fan's expected utility from trying to buy in the second period is given by

$$E[U_{A,2}] = \widehat{Pr_{2,P}}(V_A - p) + \left(1 - \widehat{Pr_{2,P}}]\right) \cdot \widehat{Pr_{2,R}} \cdot (V_A - \widehat{r^*}), \tag{2}$$

where $Pr_{2,P}$ is the probability of successfully getting a ticket on the primary market in the second period. The first term in (2) corresponds to the situation in which the avid fan can successfully get a ticket from the primary platform in the second period, which occurs with probability $\widehat{Pr_{2,P}}$ and conditional on which the avid fan's utility is $V_A - p$. The second term of (2) represents the situation in which the avid fan does not successfully get a ticket from the primary platform in the second period, which happens with probability $1 - \widehat{Pr_{2,P}}$. In this case, the avid fan will try to buy a ticket from the resale platform, where she can successfully get a ticket with probability $\widehat{Pr_{2,R}}$, in which case her utility is $V_A - \widehat{r^*}$. Similarly, if $p \geq \widehat{r^*}$, an avid fan will try to buy tickets from the resale platform first, and if unsuccessful, then try the primary platform. So, $E[U_{A,2}] = \widehat{Pr_{2,R}}(V_A - \widehat{r^*}) + \left(1 - \widehat{Pr_{2,R}}\right) \cdot \widehat{Pr_{2,P}}(V_A - p) \geq 0$.

A casual fan i has probability $1 - \rho_i$ of having realized valuation $v_i = 0$, in which case she wants to resell the ticket at any positive price. With probability ρ_i, her valuation is $v_i = V_C$. Note that the consumer can earn $(1-k)r$ from reselling a ticket, so when her realized valuation is $v_i = V_C$, a casual fan will resell her ticket if and only if $V_C < (1-k)r$. Therefore, if a causal fan successfully gets a ticket in the first period, her expected utility is $E\left[u_{C,1}\right] = \rho_i \cdot \max\{V_C, (1-k)\widehat{r^*}\} + (1-\rho_i)(1-k)\widehat{r^*} - p$. If tickets are expected to sell out on the primary platform in the first period, a casual fan's expected utilities from trying to buy a ticket in the first period and in the second period are $E\left[U_{C,1}\right] = \widehat{Pr_1} \cdot E\left[u_{C,1}\right] + \rho_i \cdot \left(1 - \widehat{Pr_1}\right) \cdot \widehat{Pr_{2,R}} \cdot \max\{V_C - \widehat{r^*}, 0\}$ and $E\left[U_{C,2}\right] = \rho_i \cdot \widehat{Pr_{2,R}} \cdot \max\{V_C - \widehat{r^*}, 0\}$, respectively. If tickets are not expected to sell out on the primary platform in the first period, $E\left[U_{C,1}\right] = \rho_i \cdot \max\{V_C, (1-k)\widehat{r^*}\} + (1-\rho_i)(1-k)\widehat{r^*} - p$ and

$$E[U_{C,2}] = \begin{cases} \rho_i \cdot \left[\widehat{Pr_{2,P}} \max\{V_C - p, 0\} + \left(1 - \widehat{Pr_{2,P}}\right) \cdot \widehat{Pr_{2,R}} \cdot \max\{V_C - \widehat{r^*}, 0\}\right], if\ p \leq \widehat{r^*} \\ \rho_i \cdot \left[\widehat{Pr_{2,R}} \max\{V_C - \widehat{r^*}, 0\} + \left(1 - \widehat{Pr_{2,R}}\right) \cdot \widehat{Pr_{2,P}} \max\{V_C - p, 0\}\right],\ if\ p > \widehat{r^*} \end{cases}.$$

PROOF OF LEMMA 2.

(a) $E[u_{C,1}] \leq V_C - p = 0$, so $E[U_{C,1}] \leq E[U_{C,2}]$. Therefore, no casual fans will buy tickets in the first period. Tickets will hence not sell out in equilibrium. $E[U_{A,1}] = V_A - p > 0$, so all avid fans will buy tickets in the first period.

(b) If there is an equilibrium where the concert sells out in the first period and $r^* = V_A$, there will be more avid fans, whose valuation is $v_i = V_A$, wanting to buy tickets than the number of consumers wanting to reselling tickets in the second period.

Let $x = v_L - p$ and $y = v_L - (1-k)v_H$. We need to guarantee that (i) there are more than N consumers who want to buy tickets in the first period, (ii) on the resale market, there are at least as many consumers who want to buy tickets as those who want to resell tickets at resale price $r = v_H$.

If tickets sell out, $n_1 \geq N \geq \alpha$, so all avid fans will buy tickets in the first period. For casual fans, $E[U_{C,1}] = \rho_i V_C + (1-\rho_i)(1-k)V_A - p$ and $E[U_{C,2}] = 0$. Casual fans with $\rho_i > \rho^* = \frac{p-(1-k)V_A}{V_C-(1-k)V_A}$ will buy tickets in the first period. Thus condition (i) $n_1 = \alpha + (1-\alpha)(1-\rho^*) > N$ is equivalent to $\rho^* < \frac{1-N}{1-\alpha}$.

There will be $\frac{\alpha}{\alpha+(1-\alpha)(1-\rho^*)}N$ avid fans and $\frac{(1-\alpha)(1-\rho^*)}{\alpha+(1-\alpha)(1-\rho^*)}N$ casual fans with $\rho_i \geq \rho^*$ successfully getting tickets in the first period. In the second period, all avid fans with tickets will attend the concert. Consumers reselling tickets are casual fans with a ticket but unable to attend the concerts. Thus, the supply of resale tickets is $S_R = N\frac{(1-\alpha)x}{\alpha y+(1-\alpha)x} \cdot \int_{\rho^*}^{1}(1-\rho_i)d\rho_i = \frac{N(1-\alpha)(1-\rho^*)}{\alpha+(1-\alpha)(1-\rho^*)} \cdot \frac{1-\rho^*}{2}$. There will be $\alpha[1 - \frac{N}{\alpha+(1-\alpha)(1-\rho^*)}]$ avid fans who did not get tickets in the first period, so the demand in the resale market when $r = V_A$ is $D_R = \alpha[1 - \frac{N}{\alpha+(1-\alpha)(1-\rho^*)}]$. Condition (ii) can be written as $D_R \geq S_R$, which is equivalent to $\rho^* \leq \frac{\sqrt{(1-\alpha)\alpha[\alpha(1+2N)-\alpha^2-2N^2]}}{(1-\alpha)N}$.

Since $\frac{\sqrt{(1-\alpha)\alpha[\alpha(1+2N)-\alpha^2-2N^2]}}{(1-\alpha)N} < \frac{1-N}{1-\alpha}$, condition (ii) implies condition (i). There is an equilibrium where the concert sells out in the first period and $r^* = V_A$ if and only if $\rho^* \leq \frac{\sqrt{(1-\alpha)\alpha[\alpha(1+2N)-\alpha^2-2N^2]}}{(1-\alpha)N}$, i.e., when $(1-k)V_A \leq p \leq \theta V_C + (1-\theta)(1-k)V_A$, where $0 < \theta = \frac{(1-\alpha)(N-\alpha)+\sqrt{(1-\alpha)\alpha[\alpha(1+2N)-\alpha^2-2N^2]}}{(1-\alpha)N} < 1$. ■

PROOF OF LEMMA 3. Lemma 3 summarizes the equilibrium outcome in the independent-platforms case. We first consider the primary platform's optimal strategy given the musician's choices of N and f.

When $N \leq \alpha$, it is optimal for the primary platform to choose $p = V_A$. The primary platform's profit is $\pi_P = \alpha(V_A - f)$.

When $\alpha < N \leq \bar{N} \leq \frac{2\alpha}{1+\alpha}$, it will be optimal for the primary platform to either choose $p = V_A$ or $p = V_C$. If it chooses $p = V_A$, its profit will be $\pi_P(p = V_A) = \alpha(V_A - f)$. If it chooses $p = V_C$, its profit will be $\pi_P(p = V_C) = N(V_C - f)$. The primary platform will choose $p = V_A$ if $f > \frac{NV_C - \alpha V_A}{N-\alpha}$, and will choose $p = V_C$ if $f \leq \frac{NV_C - \alpha V_A}{N-\alpha}$.

Then we consider the musician's optimal strategy:

If $N \leq \alpha$, its profit is $\pi_M = N(f - c)$, so the musician will choose $N = \alpha$ and $f = V_A$.

If $N \geq \alpha$ and $f > \frac{NV_C - \alpha V_A}{N-\alpha}$, the primary platform will choose $p = V_A$, and only avid fans will buy tickets from the primary platform. So the musician's profit is $\pi_M = \alpha f - cN$. The musician will choose $f = V_A$ and $N = \alpha$.

If $N \geq \alpha$ and $f \leq \frac{NV_C - \alpha V_A}{N-\alpha}$, the primary platform will choose $p = V_C$, so avid fans will buy tickets in the first period and casual fans with $v_i = V_C$ will buy in the second period, and tickets sell out. The musician's profit is $\pi_M = N(f - c)$. Because $\frac{NV_C - \alpha V_A}{N-\alpha}$ increases in N, the musician will choose $N = \bar{N}$ and $f = \frac{NV_C - \alpha V_A}{N-\alpha}$.

To conclude, the musician will either choose $(N, f) = (\alpha, V_A)$ or $(N, f) = (\bar{N}, \frac{\bar{N}v_L - \alpha v_H}{\bar{N}-\alpha})$, and the musician's corresponding profits are $\pi_M(N = \alpha, f = V_A) = \alpha(V_A - c)$ and $\pi_M\left(N = \bar{N}, f = \frac{\bar{N}v_L - \alpha v_H}{\bar{N}-\alpha}\right) = \bar{N}(\frac{\bar{N}v_L - \alpha v_H}{\bar{N}-\alpha} - c)$. It will be optimal for the musician to choose $(N, f) = (\alpha, V_A)$ if $\alpha \geq \bar{N}(1 - \sqrt{\frac{V_A - V_C}{V_A - c}})$, and will choose $(N, f) = (\bar{N}, \frac{\bar{N}v_L - \alpha v_H}{\bar{N}-\alpha})$ if $\alpha < \bar{N}(1 - \sqrt{\frac{V_A - V_C}{V_A - c}})$. ■

PROOF OF PROPOSITION 1. Proposition 1 can be directly shown from the integrated platform's optimal choice of p in the integrated-platform case.

When $N \leq \alpha$, the integrated platform will optimally choose $p = V_A$. Its profit is $\pi_P(p = V_A) = \alpha(V_A - f)$.

Next we discuss the case when $\alpha < N \leq \frac{2\alpha}{1+\alpha}$.

(i) If the integrated platform chooses $p > V_C$, its profit is $\pi_I = \alpha(p - f)$, so it is optimal for the integrated platform to choose $p = V_A$.

(ii) If the integrated platform chooses $p = V_C$, its profit is $\pi_I(p = V_C) = N(V_C - f)$

(iii) Suppose that the integrated platform chooses $\theta V_C + (1-\theta)(1-k)V_A < p < V_C$. Suppose that casual consumers with $\rho_i \geq \rho_0$ will try to buy tickets in the first period. Thus $n_1 = \alpha + (1-\alpha)(1-\rho_0)$. If $n_1 \leq N$, i.e., $1 - \rho_0 \leq \frac{N-\alpha}{1-\alpha}$, all consumers trying to buy tickets in the first period will get a ticket successfully, and there will be $S_R = (1-\alpha)(1-\rho_0)\int_{\rho_0}^{1}(1-\rho_i)d\rho_i = \frac{(1-\alpha)(1-\rho_0)^2}{2}$ consumers reselling their tickets in the second period. Note that $\frac{(1-\alpha)(1-\rho_0)^2}{2} \leq \frac{(N-\alpha)^2}{2(1-\alpha)} < \frac{(N-\alpha)(N-N\alpha)}{2(1-\alpha)} < \frac{N(1-\alpha)}{2}$. If $n_1 > N$, i.e., $1 - \rho_0 > \frac{N-\alpha}{1-\alpha}$, all tickets sell out in the first period and consumers get tickets with probability $\frac{N}{n_1}$, thus there will be $S_R = \frac{N}{n_1} \cdot (1-\alpha)(1-\rho_0)\int_{\rho_0}^{1}(1-\rho_i)d\rho_i = \frac{(1-\rho_0)^2}{\alpha+(1-\alpha)(1-\rho_0)} \cdot \frac{N(1-\alpha)}{2}$ consumers reselling their tickets in the second period. Note that $\frac{(1-\rho_0)^2}{\alpha+(1-\alpha)(1-\rho_0)} \cdot \frac{N(1-\alpha)}{2} \leq \frac{N(1-\alpha)}{2}$. Thus $S_R \leq \frac{N(1-\alpha)}{2}$ no matter whether $n_1 > N$ or not.

Lemma 2 indicates that in equilibrium, it is either $r^* \leq V_C$ or tickets do not sell out in the first period. We discuss the following cases.

(a) If tickets do not sell out in the first period and no casual consumers buy tickets in the first period, there will be no consumers reselling tickets in the second period, so the integrated platform's profit is $\pi_I = N(p - f) < N(V_C - f)$.

(b) If tickets do not sell out in the first period and some casual consumers buy tickets in the first period, we claim that $r^* \leq V_C$. If not, $r^* = V_A$, so $E[U_{A,1}] > E[U_{A,2}]$, and all avid fans will buy tickets in the first period and get tickets successfully. In the second period there will be no avid fans wanting tickets and there will be some casual fans reselling the tickets, so $r^* \leq V_C$, which is contradictory to $r^* = V_A$. Therefore $r^* \leq V_C$. For the casual fan with $\rho_i = \rho_0$, $0 \leq E[U_{C,1}] \leq E[u_{C,1}] = \rho_0 V_C + (1-\rho_0)(1-k)r^* - p \leq [\rho_0 + (1-\rho_0)(1-k)]V_C - p$, so $p \leq [\rho_0 + (1-\rho_0)(1-k)]V_C$. The integrated platform's profit is $\pi_I = (p-f)N + S_R k r^* \leq \{[\rho_0 + (1-\rho_0)(1-k)]V_C - f\}N + S_R k V_C = \left[\rho_0 + (1-\rho_0)(1-k) + \frac{(1-\alpha)(1-\rho_0)^2}{2N} k\right] V_C N - Nf$. Note that $1-\rho_0 \leq \frac{N-\alpha}{1-\alpha}$, so $\pi_I \leq \left[\rho_0 + (1-\rho_0)(1-k) + \frac{(1-\alpha)(1-\rho_0)^2}{2N} k\right] V_C N - Nf < N(V_C - f)$.

(c) If tickets sell out in the first period, then $r^* \leq V_C$. For the casual fan with $\rho_i = \rho_0$, $0 \leq E\left[U_{C,1}\right] \leq E\left[u_{C,1}\right] = \rho_0 V_C + (1-\rho_0)(1-k)r^* - p \leq [\rho_0 + (1-\rho_0)(1-k)]V_C - p$, so $p \leq [\rho_0 + (1-\rho_0)(1-k)]V_C$. The integrated platform's profit is $\pi_I = (p-f)N + S_R k r^* \leq \{[\rho_0 + (1-\rho_0)(1-k)]V_C - f\}N + S_R k V_C = \left[\rho_0 + (1-\rho_0)(1-k) + \frac{(1-\rho_0)^2}{\alpha + (1-\alpha)(1-\rho_0)} \cdot \frac{(1-\alpha)}{2} k\right] V_C N - Nf$. Note that $\frac{1-\rho_0}{\alpha+(1-\alpha)(1-\rho_0)} \cdot \frac{1-\alpha}{2} < 1$, so $\rho_0 + (1-\rho_0)(1-k) + \frac{(1-\rho_0)^2}{\alpha+(1-\alpha)(1-\rho_0)} \cdot \frac{(1-\alpha)}{2} k < 1$. Thus $\pi_I < N(V_C - f)$.

The discussion of case (a) to (c) together show that if $\theta V_C + (1-\theta)(1-k)V_A < p < V_C$, the integrated platform will earn strictly less profit than when choosing $p = V_C$. Thus the integrated platform will never choose $p \in (\theta V_C + (1-\theta)(1-k)V_A, V_C)$.

(iv) If the integrated platform chooses $(1-k)V_A \leq p \leq \theta V_C + (1-\theta)(1-k)V_A$, by part (b) of Lemma 2, all tickets sell out in the first period and $r^* = V_A$ in the buying-spree equilibrium. The integrated platform's profit is $\pi_I = (p-f)N + S_R k V_A = Nx \frac{\frac{kV_A}{2}(1-\alpha)x - \{\alpha y + (1-\alpha)x\}y}{\{\alpha y + (1-\alpha)x\}y} + N(V_C - f) = Nx\left[\frac{\frac{kV_A}{2}(1-\alpha)x}{[\alpha y + (1-\alpha)x]y} - 1\right] + N(V_C - f)$, where $x = V_C - p$ and $y = V_C - (1-k)V_A$, so $(1-\theta)y \leq x \leq y$. The integrated platform will thus choose $x \in [(1-\theta)y, y]$ to maximize π_I. Note that $\pi_I < N(V_C - f)$ when $\frac{\frac{kV_A}{2}(1-\alpha)x}{[\alpha y + (1-\alpha)x]y} < 1$, and π_I strictly increases with x when $\frac{\frac{kV_A}{2}(1-\alpha)x}{[\alpha y + (1-\alpha)x]y} \geq 1$. So if $\pi_I \leq N(V_C - f)$ when $x = y$, then it is not optimal for the integrated platform to choose $(1-k)V_A \leq p \leq \theta V_C + (1-\theta)(1-k)V_A$. By contrast, if $\pi_I > N(V_C - f)$, the integrated platform can earn a higher profit by choosing $x = y$ (i.e., $p = (1-k)V_A$) than choosing $p = V_C$. $\frac{\frac{kV_A}{2}(1-\alpha)x}{[\alpha y + (1-\alpha)x]y} \geq 1$ if and only if $\alpha < \alpha_0 \equiv \frac{(2-k)V_A - 2V_C}{kV_A}$. The integrated platform's profit with $p = (1-k)V_A$ is $\pi_I = N\left[V_A\left(1 - \frac{k(1+\alpha)}{2}\right) - f\right]$.

(v) If the integrated platform chooses $p < (1-k)V_A$, the integrated platform's profit is $\pi_I = (p-f)N + S_R k r^* < \left((1-k)V_A - f\right)N + \frac{N(1-\alpha)}{2} k V_A \leq N\left[V_A\left(1 - \frac{k(1+\alpha)}{2}\right) - f\right]$.

From the results in (i) to (v), we know that the integrated platform will choose either $p = V_A, V_C$ or $(1-k)V_A$. In addition, $\pi_I(p = (1-k)V_A) \geq \pi_I(p = V_C)$ if and only if $\alpha < \alpha_0$, and $\pi_I(p = (1-k)V_A) \geq \pi_I(p = V_A)$ if and only if $f < \frac{N\left[1-\frac{k(1+\alpha)}{2}\right]-\alpha}{N-\alpha}V_A$. ■

DERIVATION OF TABLE 2. We know from the proof of Proposition 1 that the integrated platform will choose either $p = V_A$, $p = V_C$ or $p = (1-k)V_A$. $\pi_I(p = (1-k)V_A) \geq \pi_I(p = V_C)$ if and only if $\alpha < \alpha_0$, $\pi_I(p = (1-k)V_A) \geq \pi_I(p = V_A)$ if and only if $f < \frac{N\left[1-\frac{k(1+\alpha)}{2}\right]-\alpha}{N-\alpha}V_A$, and $\pi_I(p = V_C) \geq \pi_I(p = V_A)$ if and only if $f < \frac{NV_C-\alpha V_A}{N-\alpha}$.

(i) If $\alpha > \alpha_0$, then the integrated platform will choose $p = V_A$ if and only if $f > \frac{NV_C-\alpha V_A}{N-\alpha}$, and will choose $p = V_C$ if and only if $f \leq \frac{NV_C-\alpha V_A}{N-\alpha}$. Lemma 3 has shown that when $\alpha \leq \alpha_{IDP}$, the musician will choose $f = \frac{\bar{N}V_C-\alpha V_A}{\bar{N}-\alpha}$ and $N = \bar{N}$, and the integrated platform will choose $p = V_C$. When $\alpha > \alpha_{IDP}$, the musician will choose $f = V_A$ and $N = \alpha$, and the integrated platform will choose $p = V_A$.

(ii) If $\alpha < \alpha_0$, then the integrated platform will choose $p = V_A$ if and only if $f \geq \frac{N\left[1-\frac{k(1+\alpha)}{2}\right]-\alpha}{N-\alpha}V_A$, and will choose $p = (1-k)V_A$ if and only if $f < \frac{N\left[1-\frac{k(1+\alpha)}{2}\right]-\alpha}{N-\alpha}V_A$.

Now consider the musician's optimal choice of N and f.

If $N \leq \alpha$, the musician's profit is $\pi_M = N(f-c)$, so the musician will choose $N = \alpha$ and $f = V_A$.

If $N \geq \alpha$ and $f > \frac{N\left[1-\frac{k(1+\alpha)}{2}\right]-\alpha}{N-\alpha}V_A$, the primary platform will choose $p = V_A$, and only avid fans will buy tickets from the primary platform. So the musician's profit is $\pi_M = \alpha f - cN$. The musician will choose $f = V_A$ and $N = \alpha$.

If $N \geq \alpha$ and $f \leq \frac{N\left[1-\frac{k(1+\alpha)}{2}\right]-\alpha}{N-\alpha}V_A$, the primary platform will choose $p = V_C$, so avid fans will buy tickets in the first period and casual fans with $v_i = V_C$ will buy in the second period, and tickets sell out. The musician's profit is $\pi_M = N(f - c)$. Because $\frac{N\left[1-\frac{k(1+\alpha)}{2}\right]-\alpha}{N-\alpha}V_A$ increases in N, the musician will choose $N = \bar{N}$ and $f = \frac{N\left[1-\frac{k(1+\alpha)}{2}\right]-\alpha}{N-\alpha}V_A$.

Thus, the musician will choose either $(N, f) = (\alpha, V_A)$ or $(\bar{N}, \frac{\bar{N}\left[1-\frac{k(1+\alpha)}{2}\right]-\alpha}{\bar{N}-\alpha}V_A)$ in equilibrium, and the profits are $\pi_M(N = \alpha, f = V_A) = \alpha(V_A - c)$ and $\pi_M\left(N = \bar{N}, f = \frac{\bar{N}\left[1-\frac{k(1+\alpha)}{2}\right]-\alpha}{\bar{N}-\alpha}V_A\right) = \bar{N}(\frac{\bar{N}\left[1-\frac{k(1+\alpha)}{2}\right]-\alpha}{\bar{N}-\alpha}V_A - c)$ respectively. Define $\alpha_{INT} \equiv \bar{N}\left[1 - \frac{\sqrt{V_A k[V_A k\bar{N}^2+8(1+\bar{N})(V_A-c)]}-V_A k\bar{N}}{4(V_A-c)}\right]$.The musician will choose $(N, f) = (\alpha, V_A)$ if and only if $\alpha > \alpha_{INT}$, and will choose $(N, f) = (\bar{N}, \frac{\bar{N}\left[1-\frac{k(1+\alpha)}{2}\right]-\alpha}{\bar{N}-\alpha}V_A)$ if and only if $\alpha \leq \alpha_{INT}$.

Therefore, in the case of $\alpha_0 < \alpha_{INT}$:

If $\alpha \leq \alpha_0$, the musician will choose $(N^*, f^*) = (\bar{N}, \frac{\bar{N}\left[1-\frac{k(1+\alpha)}{2}\right]-\alpha}{\bar{N}-\alpha}V_A)$, and the integrated platform will choose $p^* = (1 - k)V_A$.

If $\alpha_0 < \alpha \leq \alpha_{IDP}$, the musician will choose $(N^*, f^*) = (\bar{N}, \frac{\bar{N}V_C-\alpha V_A}{\bar{N}-\alpha})$, and the integrated platform will choose $p^* = V_C$.

If $\alpha > \alpha_{IDP}$, the musician will choose $(N^*, f^*) = (\alpha, V_A)$, and the integrated platform will choose $p^* = V_A$.

In the case of $\alpha_0 > \alpha_{INT}$:

If $\alpha < \alpha_{INT}$, the musician will choose $(N^*, f^*) = (\bar{N}, \frac{\bar{N}\left[1-\frac{k(1+\alpha)}{2}\right]-\alpha}{\bar{N}-\alpha}V_A)$, and the integrated platform will choose $p^* = (1 - k)V_A$.

If $\alpha > \alpha_{INT}$, the musician will choose $(N^*, f^*) = (\alpha, V_A)$, and the integrated platform will choose $p^* = V_A$.

One can directly calculate the profits of the musician, the integrated platform, and consumer surplus with the N^*, f^*, and p^* above. ■

PROOF OF PROPOSITION 2. Let $k_1 = \frac{2}{1+\alpha}\left(1 - \frac{V_C}{V_A}\right) + \epsilon_1$, and $k_2 = \frac{2}{1+\alpha}\left(1 - \frac{V_C}{V_A}\right) - \epsilon_2$, where $\epsilon_1, \epsilon_2 > 0$ and they are sufficiently small. So $k_1 > k_2$. Since $\frac{(2-k)V_A - 2V_C}{kV_A}$ decreases with k, and $\frac{(2-k)V_A-2V_C}{kV_A} < \frac{(3-k)V_A-3V_C}{(1+k)V_A-V_C}$, so there exist α such that $\frac{(2-k_1)V_A-2V_C}{k_1V_A} < \alpha < \min\{\bar{N}\left[1 - \frac{\sqrt{V_Ak_1[V_Ak_1\bar{N}^2+8(1+\bar{N})(V_A-c)]}-V_Ak_1\bar{N}}{4(V_A-c)}\right], \frac{(3-k_1)V_A-3V_C}{(1+k_1)V_A-V_C}\}$, and $\alpha < \frac{(2-k_2)V_A-2V_C}{k_2V_A} < \min\{\bar{N}\left[1 - \frac{\sqrt{V_Ak_2[V_Ak_2\bar{N}^2+8(1+\bar{N})(V_A-c)]}-V_Ak_2\bar{N}}{4(V_A-c)}\right], \frac{(3-k_2)V_A-3V_C}{(1+k_2)V_A-V_C}\}$.

When k_1 and k_2 satisfy the conditions above, if $k = k_1$, $\alpha_0 < \alpha < \alpha_{INT}$, in equilibrium the musician will choose $(N^*, f^*) = (\bar{N}, \frac{\bar{N}V_C-\alpha V_A}{\bar{N}-\alpha})$ and the integrated platform will choose $p^* = V_C$, and the consumer surplus is $\bar{N}(V_A - V_C)$; if $k = k_2$, $\alpha < \alpha_0 < \alpha_{INT}$, in equilibrium the musician will choose $(N^*, f^*) = (\bar{N}, \frac{\bar{N}\left[1-\frac{k_2(1+\alpha)}{2}\right]-\alpha}{\bar{N}-\alpha}V_A)$ and the integrated platform will choose $p^* = (1-k_2)V_A$, and the consumer surplus is $\bar{N}[\alpha V_A k_2 + \frac{(1-\alpha)[V_C-(1-k_2)V_A]}{2}]$. Since $\alpha < \frac{(3-k_2)V_A-3V_C}{(1+k_2)V_A-V_C}$, $\bar{N}\left[\alpha V_A k_2 + \frac{(1-\alpha)[V_C-(1-k_2)V_A]}{2}\right] < \bar{N}(V_A - V_C)$. So, p^* is smaller when $k = k_2$ than when $k = k_1$, but the consumer surplus is lower when $k = k_2$ than when $k = k_1$. ■

PROOF OF PROPOSITION 3 AND PROPOSITION 4. One can derive the results by directly comparing the outcomes of Lemma 3 and Table 2.

PROOF OF LEMMA 4. We prove Lemma 4 by contradiction. Suppose that in equilibrium $r^* > V_C$. As we discussed earlier, there are three possible equilibrium resale prices in our setting: V_A, V_C, and zero, so $r^* = V_A$. If $p \geq (1-k)V_A$, no casual fans will buy tickets from the primary market in the first period, so no one will resell tickets in equilibrium (since avid fans can always attend the concert). If $p < (1-k)V_A$, all casual fans will try to buy tickets in the first period and resell them at the high resale price $r^* = V_A$ regardless of whether they can attend the concert. Because all casual fans and avid fans will try to buy tickets in the first period, the concert will sell out in the first period. Because in equilibrium all ticket resellers successfully resell their tickets, the casual fans will not possess any tickets after all resale transactions have completed. This implies that the number of consumers attending the concert cannot exceed the population of avid fans, α. This contradicts the fact that $N > \alpha$ and the concert sells out in the primary market. This completes the proof. ■

PROOF OF LEMMA 5. Lemma 4 shows that $r^* \leq V_C$. Suppose that the retail price is $p < V_C$. A casual fan's expected utility of successfully buying a ticket in the first period is $E\left[u_{C,1}\right] = \rho_i V_C + (1-\rho_i)(1-k)V_C - p$. A necessary condition for the casual fan to try to buy tickets in the first period is $E\left[u_{C,1}\right] \geq 0$, i.e., $\rho_i \geq 1 - \frac{V_C - p}{kV_C}$. The number of casual fans who will resell tickets in the second period will not exceed $(1-\alpha)N\frac{V_C-p}{kV_C}$. The integrated platform's profit is $\pi_I \leq \pi_P + \pi_R = (p-f)N + (1-\alpha)N\frac{V_C-p}{kV_C} \cdot kV_C < (V_C - p)N$, which is strictly lower than the integrated platform's profit if it chooses $p = V_C$. Thus the integrated platform will never choose $p < V_C$. The equilibrium outcome will be the same in the independent-platforms case and in the integrated-platform case. ■

PROOF OF LEMMA 6. We consider the parameter region with $\beta \leq \frac{2\alpha-(1+\alpha)\bar{N}}{1-\alpha}$ and $k \geq 1 - \frac{V_C}{V_A}$.

If $p > V_C$, it is optimal for the integrated platform to choose $p = V_A$. Only avid fans will buy tickets in the first period. No casual fans or scalpers will buy tickets in either period. The integrated platform's profit is $\pi_I = \alpha(V_A - f)$.

If $V_C \geq p > (1-k)V_A$, no scalpers will buy tickets in the first period. Similar to the proof of Proposition 1, the integrated platform will optimally choose $p = V_C$.

If $p = (1-k)V_A$ and $r^* = V_A$, all consumers and scalpers will buy in the first period. β scalpers, $\alpha(N-\beta)$ avid fans and $(1-\alpha)(N-\beta)$ casual fans will successfully receive the ticket. All scalpers and $\frac{(1-\alpha)(N-\beta)}{2}$ casual fans will resell the tickets, so the supply in the resale market is $S_R = \beta + \frac{(1-\alpha)(N-\beta)}{2}$. $\alpha(1 - N + \beta)$ avid fans will buy resale tickets in the resale market, so $D_R = \alpha(1 - N + \beta)$. Because $\beta \leq \frac{2\alpha-(1+\alpha)\bar{N}}{1-\alpha} \leq \frac{2\alpha-(1+\alpha)N}{1-\alpha}$, $S_R < D_R$, so $r^* = V_A$. The number of tickets resold on the resale platform is $\beta + \frac{(1-\alpha)(N-\beta)}{2}$. The integrated platform's total profit is $\pi_I = \frac{1+\alpha}{2}\beta k V_A + N\left[V_A\left(1 - \frac{k(1+\alpha)}{2}\right) - f\right]$. ■

PROOF OF PROPOSITION 4. $\alpha_{SCP} = \bar{N}[1 - \frac{\sqrt{1-\frac{\beta}{\bar{N}}}\sqrt{V_A k[V_A k\bar{N}(\bar{N}-\beta)+8(1+\bar{N})(V_A-c)]}-V_A k(\bar{N}-\beta)}{4(V_A-c)}]$. We will next prove that $\frac{\partial\alpha_{SCP}}{\partial\beta} > 0$, which is equivalent to $\sqrt{[V_A k(\bar{N}-\beta)]^2 + \frac{8(1+\bar{N})(V_A-c)}{\bar{N}}V_A k(\bar{N}-\beta)} - V_A k(\bar{N}-\beta)$ decreases with β. Let $a = V_A k(\bar{N} - \beta) > 0$ and $b = \frac{8(1+\bar{N})(V_A-c)}{\bar{N}} > 0$. So $\sqrt{[V_A k(\bar{N}-\beta)]^2 + \frac{8(1+\bar{N})(V_A-c)}{\bar{N}}V_A k(\bar{N}-\beta)} - V_A k(\bar{N} - \beta) = \sqrt{a^2+ab} - a$. $\frac{\partial(\sqrt{a^2+ab}-a)}{\partial\beta} = \frac{\partial(\sqrt{a^2+ab}-a)}{\partial a}\cdot\frac{\partial a}{\partial\beta} = \left[\frac{\sqrt{a^2+ba+\frac{b^2}{4}}}{\sqrt{a^2+ab}} - 1\right]\cdot(-V_A k) < 0$. When $\beta < \frac{2\alpha-(1+\alpha)\bar{N}}{1-\alpha}$, one can show that $\frac{\partial\alpha_{SCP}}{\partial\beta} > 0$. Also note that if $\beta = 0$, $\alpha_{SCP} = \alpha_{INT}$, so $\alpha_{SCP} > \alpha_{INT}$ when $\beta > 0$.

$\alpha_1 = \frac{2\bar{N}(V_A-V_C)}{(\bar{N}-\beta)V_A k} - 1$ is increasing in β, and if $\beta = 0$, $\alpha_1 = \alpha_0$. So $\alpha_1 > \alpha_0$ when $\beta > 0$.

When $\beta = 0$ and $\alpha > \min\{\alpha_0, \alpha_{INT}\}$, Table 2 has shown that if $\beta = 0$, the integrated platform will set $p^* \geq V_C$. But if $\beta > 0$ and $\alpha < \min\{\alpha_1, \alpha_{INT}\}$, in equilibrium the musician will choose $N^* = \bar{N}$ and $f^* = V_A[1 - \frac{k(1+\alpha)(\bar{N}-\beta)}{2(\bar{N}-\alpha)}]$, and the integrated platform will choose $p^* = (1-k)V_C$. ■

PROOF OF PROPOSITION 5. We consider the case when $\delta \to 0^+$. From the previous analysis, we know that in the independent-platforms case, the primary platform will choose p such that no casual fans will buy tickets in the first period. This is still true when $\delta \to 0^+$. The only consumers reselling tickets in the first period are avid fans who find themselves not being able to attend the concert, whose population is $\delta\alpha$. The resale platform's profit is $\pi_R = \delta\alpha k r^*$. Because $\delta \to 0^+$, changing k will not affect the resale ticket demand, so r^* will not change with k. Hence the resale platform will always choose $k^*_{IDP} = 1$.

Next we consider the integrated-platform case. If $k < 1 - \frac{V_C}{V_A}$, as is shown in Lemma 5, the integrated platform will never set $p^* < V_C$, and its profit is less than when it sets $p = V_C$ and $k = 1$. If $k \geq 1 - \frac{V_C}{V_A}$ and $N \leq \alpha$, in equilibrium the musician will choose $f^* = V_A$, and the integrated platform will choose $p^* = V_A$, so the integrated platform will receive zero profit. When $k \geq 1 - \frac{V_C}{V_A}$ and $\alpha < N \leq \frac{2\alpha}{1+\alpha}$, it could either set $p = (1-k)V_A$, $p = V_C$, or $p = V_A$. If $p = (1-k)V_A$, the integrated platform's profit is $N\left[V_A\left(1 - \frac{k(1+\alpha)}{2}\right) - f\right]$, which strictly decreases with k. So it will set $k = 1 - \frac{V_C}{V_A}$ and set $p = V_C$. $\pi_I = N\{(V_C - f) + \frac{1-\alpha}{2}(V_A - V_C)\}$. If the integrated platform sets $p = V_A$, its profit is $\pi_I = \alpha(V_H - f)$, and in this case the integrated platform will optimally choose $k = 1$. The platform will choose $(p,k) = (V_C, 1 - \frac{V_C}{V_A})$ instead of $(V_A, 1)$ if and only if $f > \frac{N[(1-\alpha)V_A + (1+\alpha)V_C] - 2\alpha V_A}{2(N-\alpha)}$.

For the musician, it will either choose (N, f) to be (α, V_A) or $\left(\bar{N}, \frac{N[(1-\alpha)V_A + (1+\alpha)V_C] - 2\alpha V_A}{2V_A(N-\alpha)}\right)$. The musician's profits are $\pi_P(f = V_A) = \alpha(V_A - c)$ and $\pi_P\left(f = \frac{N[(1-\alpha)V_A + (1+\alpha)V_C] - 2\alpha V_A}{2V_A(N-\alpha)}\right) = \bar{N}\left[\left(1 - \frac{\bar{N}(1+\alpha)\left(1 - \frac{V_A}{V_C}\right)}{2(\bar{N}-\alpha)}\right)V_A - c\right]$, respectively. The performer will choose $f = V_A$ if and only if $\alpha > \bar{N}\left[1 - \frac{\sqrt{(V_A - V_C)[(V_A - V_C)\bar{N}^2 + 8(1+\bar{N})(V_A - c)]} - (V_A - V_C)\bar{N}}{4(V_A - c)}\right] \equiv \alpha_2$. If $\alpha > \alpha_2$, the musician will choose $N^* = \alpha$ and $f^* = V_A$, and the integrated platform will choose $p^* = V_A$ and $k^* = 1$. If $\alpha \leq \alpha_2$, the musician will choose $N^* = \bar{N}$ and $f^* = \frac{N[(1-\alpha)V_A + (1+\alpha)V_C] - 2\alpha V_A}{2V_A(N-\alpha)}$, and the integrated platform will choose $p^* = V_C$ and $k^*_{INT} = 1 - \frac{V_C}{V_A}$. ■

PROOF OF PROPOSITION 6. Suppose that $\alpha < N < \frac{2\alpha}{1+\alpha}$ and $k_C \geq 1 - \frac{V_C}{V_A}$. In the competitive platform case, suppose the musician has chosen $\frac{2\alpha}{1+\alpha} > N > \alpha$ and f, the integrated platform's total profit is $\pi_I(p=(1-k_{COMP})V_A) = N\left[V_A\left(1-\frac{k_{COMP}[2-(1-\alpha)\phi]}{2}\right)-f\right]$ if it sets $p=(1-k_{COMP})V_A$, its profit is $\pi_I(p=V_C)=N(V_C-f)$ if $p=V_C$, and its profit is $\pi_I(p=V_A)=\alpha(V_A-f)$ if $p=V_A$.

$\pi_I(p=(1-k)V_A) = N\left[V_A\left(1-\frac{k_{COMP}[2-(1-\alpha)\phi]}{2}\right)-f\right] > \pi_I(p=V_C)=N(V_C-f)$ if and only if $\alpha < 1-\frac{2[V_C-(1-k_{COMP})V_A]}{k_{COMP}\phi V_A}$. If $\alpha < 1-\frac{2[V_C-(1-k_{COMP})V_A]}{k_{COMP}\phi V_A}$, the integrated platform will choose $p=(1-k_{COMP})V_A$ when $f<\frac{N\left[1-\frac{k_{COMP}[2-(1-\alpha)\phi]}{2}\right]-\alpha}{N-\alpha}V_A$, and will charge $p=V_A$ when $f\geq\frac{N\left[1-\frac{k_{COMP}[2-(1-\alpha)\phi]}{2}\right]-\alpha}{N-\alpha}V_A$.

Next we consider the musician's decision. The musician will either choose $(N,f)=(\alpha,V_A)$ or $(\bar{N},\frac{\bar{N}\left[1-k_{COMP}(1-\frac{1-\alpha}{2}\phi)\right]-\alpha}{\bar{N}-\alpha}V_A)$, and its corresponding profits are $\pi_M(N=\alpha,f=V_A)=\alpha(V_A-c)$ and $\pi_M\left(N=\bar{N},f=\frac{N\left[1-k_{COMP}(1-\frac{1-\alpha}{2}\phi)\right]-\alpha}{N-\alpha}V_A\right)=\bar{N}[\frac{\bar{N}\left[1-k_{COMP}(1-\frac{1-\alpha}{2}\phi)\right]-\alpha}{\bar{N}-\alpha}V_A-c]$. The musician will choose $N=\bar{N},f=\frac{N\left[1-k_{COMP}(1-\frac{1-\alpha}{2}\phi)\right]-\alpha}{N-\alpha}V_A$ if and only if $\alpha<\alpha_{COMP}\equiv\bar{N}[1-\frac{\sqrt{(\phi k_{COMP}\bar{N}V_A)^2+8V_A(V_A-c)k_{COMP}[2-(1-\bar{N})\phi]}-\phi k_{COMP}\bar{N}V_A}{4(V_A-c)}]$. Note that $\alpha_{COMP}<\alpha_{INT}$ and $1-\frac{2[V_C-(1-k_{COMP})V_A]}{k_{COMP}\phi V_A}<\alpha_0$ if and only if $\phi<1-\frac{k-k_{COMP}}{k_{COMP}}\cdot\frac{1+\alpha}{1-\alpha}$. So if $\min\{\alpha_{COMP},1-\frac{2[V_C-(1-k_{COMP})V_A]}{k_{COMP}\phi V_A}\}<\alpha<\min\{\alpha_0,\alpha_{INT}\}$, in the competing-platform case, the musician will choose $f=V_A$ and $N=\alpha$, and the integrated platform will choose $p=V_A$, and in the integrated-platform case, the musician will choose $f=[1-\frac{\bar{N}k(1+\alpha)}{2(\bar{N}-\alpha)}]V_A$ and $N=\bar{N}$, and the integrated platform will choose $p=(1-k)V_A$. ■

Endnotes:

[32] In our setting, in the buying-spree equilibrium, $\widehat{Pr_1}$, $\widehat{Pr_{2,R}}$, and $\widehat{r^*}$ can be uniquely calculated, and they will be *exactly* equal to their realized values. Hence $E\left[(1-Pr_1)Pr_{2,R}(V_A-r^*)\right]=\left(1-\widehat{Pr_1}\right)\cdot\widehat{Pr_{2,R}}(V_A-\widehat{r^*})$ in equilibrium. The similar reasoning applies to all the equations in this section.

Appendix B

PROOF OF LEMMA 1. Suppose that the referral fee is r and all sellers' retailing prices are $p^*(r)$. In equilibrium, seller i will not change its retail price p_i away from $p^*(r)$. Seller i's profit is

$$\pi_i^S(p_i;r) = \frac{F_0(\bar{m}+\mu_K-p^*(r))}{n(1-F(\bar{m}))}\cdot[1-F(\bar{m}-p^*(r)+p_i)]\cdot[(1-r)p_i-c].$$

The first-order condition is: $\frac{d\pi_i^S(p_i;r)}{dp_i} = \frac{F_0(\bar{m}+\mu_K-p^*(r))}{n(1-F(\bar{m}))}\cdot\{[1-F(\bar{m}-p^*(r)+p_i)](1-r)-f(\bar{m}-p^*(r)+p_i)\cdot[(1-r)p_i-c]\}=0$, i.e., $p_i=\frac{c}{1-r}+h(\bar{m}-p^*(r)+p_i)$. In a symmetric equilibrium, $p_i=p^*(r)$, therefore, $p^*(r)=\frac{c}{1-r}+h(\bar{m})$. We also need to check the second-order condition, i.e., $\frac{d^2\pi_i^S(p_i;r)}{dp_i^2}|_{p_i=p^*(r)}<0$. This is equivalent to $-2f(\bar{m})-f'(\bar{m})h(\bar{m})<0$. This is true because $h'(\bar{m})<0$ implies that $-\frac{f(\bar{m})+h(\bar{m})f'(\bar{m})}{f(\bar{m})}<0$, which implies that $-2f(\bar{m})-f'(\bar{m})h(\bar{m})<0$.

Substituting $p^*(r)=\frac{c}{1-r}+h(\bar{m})$ into expressions of $\tilde{\pi}_i^S$ and $\widetilde{D}$, we have $\tilde{\pi}_i^{S*}=\frac{F_0\left(\bar{m}+\mu_K-\frac{c}{1-r}-h(\bar{m})\right)}{n}(1-r)h(\bar{m})$ and $\widetilde{D}=F_0\left(\bar{m}+\mu_K-\frac{c}{1-r}-h(\bar{m})\right)$. ■

PROOF OF PROPOSITION 1. These results are straightforward because $\frac{\partial\tilde{p}^*}{\partial\tau}=h'(\bar{m})\cdot\frac{\partial\bar{m}}{\partial\tau}>0$ and $\frac{\partial\widetilde{D}}{\partial\tau}=f_0\left(\bar{m}+q-\frac{c}{1-r}-h(\bar{m})\right)\left(1-h'(\bar{m})\right)\cdot\frac{\partial\bar{m}}{\partial\tau}<0$. ■

PROOF OF PROPOSITION 2. Since $\frac{\partial\bar{m}}{\partial\tau}<0$, it is sufficient to show that , $\frac{d\pi^{P*}(\bar{m})}{d\bar{m}}>0$.

$\pi^{P*}(\bar{m})=\pi^P\left(r^*(\bar{m})\right)=F_0\left(\bar{m}+\mu_K-\frac{c}{1-r^*(\bar{m})}-h(\bar{m})\right)\cdot r^*(\bar{m})\cdot\left(\frac{c}{1-r^*(\bar{m})}+h(\bar{m})\right)$. Because $r^*(\bar{m})$ maximizes the platform's profit π^P, it must follow the FOC that $\frac{\partial\pi^{P*}}{\partial r}|_{r=r^*}=F_0\left(\bar{m}+\mu_K-\frac{c}{1-r}-h(\bar{m})\right)\left[\frac{c}{(1-r)^2}+h(\bar{m})\right]-\frac{rc}{(1-r)^2}\left(\frac{c}{1-r}+h(\bar{m})\right)f_0\left(\bar{m}+\mu_K-\frac{c}{1-r}-h(\bar{m})\right)=0$.

When consumer search becomes easier, $\bar{m}$ increases. By envelope theorem, $\frac{d\pi^{P*}(\bar{m})}{d\bar{m}} = \frac{\partial \pi^P}{\partial \bar{m}}|_{r=r^*(\bar{m})} = F_0\left(\bar{m}+\mu_K-\frac{c}{1-r^*(\bar{m})}-h(\bar{m})\right)r^*(\bar{m})h'(\bar{m}) + f_0\left(\bar{m}+\mu_K-\frac{c}{1-r^*(\bar{m})}-h(\bar{m})\right)(1-h'(\bar{m}))\cdot r^*(\bar{m})\cdot\left(\frac{c}{1-r^*(\bar{m})}+h(\bar{m})\right) = F_0\left(\bar{m}+\mu_K-\frac{c}{1-r^*(\bar{m})}-h(\bar{m})\right)r^*(\bar{m})h'(\bar{m}) + F_0\left(\bar{m}+\mu_K-\frac{c}{1-r^*(\bar{m})}-h(\bar{m})\right)(1-h'(\bar{m}))\cdot\frac{\frac{c}{(1-r^*(\bar{m}))^2}+h(\bar{m})}{\frac{c}{(1-r^*(\bar{m}))^2}} = F_0\left(\bar{m}+\mu_K-\frac{c}{1-r^*(\bar{m})}-h(\bar{m})\right)\cdot\left[\left(1+\frac{h(\bar{m})(1-r^*(\bar{m}))^2}{c}\right)-h'(\bar{m})\left(1-r^*(\bar{m})+\frac{h(\bar{m})(1-r^*(\bar{m}))^2}{c}\right)\right] > 0.$ ■

PROOF OF PROPOSITION 3. The platform's profit is $\pi^P = D(r,\bar{m})\cdot(\frac{cr}{1-r}+rh(\bar{m}))$. The FOC is $\frac{\partial\pi^{P*}}{\partial r}|_{r=r^*(\bar{m})} = 0$ for all $\bar{m}$, thus $0 = \frac{d\frac{\partial\pi^P}{\partial r}|_{r=r^*(\bar{m})}}{d\bar{m}} = \frac{\partial^2\pi^P}{\partial r^2}|_{r=r^*(\bar{m})}\cdot\frac{\partial r^*(\bar{m})}{\partial\bar{m}} + \frac{\partial^2\pi^P}{\partial r\partial\bar{m}}|_{r=r^*(\bar{m})}$. Because the second-order condition guarantees $\frac{\partial^2\pi^P|_{r=r^*(\bar{m})}}{\partial r^2} < 0$, therefore, $\frac{\partial r^*(\bar{m})}{\partial\bar{m}} > 0$ if and only if $\frac{\partial^2\pi^P}{\partial r\partial\bar{m}}|_{r=r^*(\bar{m})} > 0$. Moreover $\frac{d\frac{\partial ln\pi^P}{\partial lnr}}{d\bar{m}} = \frac{d\left(\frac{\partial\pi^P}{\partial r}\cdot\frac{r}{\pi^P}\right)}{d\bar{m}} = \frac{\partial^2\pi^P}{\partial r\partial\bar{m}}\cdot\frac{r}{\pi^P}+\frac{\partial\pi^P}{\partial r}\cdot\frac{-r\cdot\frac{\partial\pi^P}{\partial\bar{m}}}{(\pi^P)^2}$. Thus $\frac{d\frac{\partial ln\pi^P}{\partial lnr}|_{r=r^*(\bar{m})}}{d\bar{m}} = \frac{\partial^2\pi^P}{\partial r\partial\bar{m}}|_{r=r^*(\bar{m})}\cdot\frac{r^*(\bar{m})}{\pi^P(r^*(\bar{m}))}+0 = \frac{\partial^2\pi^P}{\partial r\partial\bar{m}}|_{r=r^*(\bar{m})}\cdot\frac{r^*(\bar{m})}{\pi^P(r^*(\bar{m}))}$. Hence $\frac{\partial r^*(\bar{m})}{\partial\bar{m}} > 0$ if and only if $\frac{d\frac{\partial ln\pi^P}{\partial lnr}|_{r=r^*(\bar{m})}}{d\bar{m}} > 0$.

Note that $\frac{\partial ln\pi^P}{\partial lnr} = \epsilon_{D,r}(r,\bar{m}) + \frac{\partial\left(\frac{cr}{1-r}+rh(\bar{m})\right)}{\partial r}\cdot\frac{r}{\frac{cr}{1-r}+rh(\bar{m})} = \epsilon_{D,r}(r,\bar{m}) + \frac{c+h(\bar{m})(1-r)^2}{c+h(\bar{m})(1-r)}$. Thus $\frac{d\frac{\partial ln\pi^P}{\partial lnr}|_{r=r^*(\bar{m})}}{d\bar{m}} > 0$ if and only if $\frac{\partial\epsilon_{D,r}(r^*,\bar{m})}{\partial\bar{m}} > \frac{ch'(\bar{m})r^*(\bar{m})}{(c+h(\bar{m})(1-r^*(\bar{m})))^2}$. Because $\epsilon_{D,r}(r^*,\bar{m}) < 0$, $\frac{d\frac{\partial ln\pi^P}{\partial lnr}|_{r=r^*(\bar{m})}}{d\bar{m}} > 0$ if and only if $\frac{\partial|\epsilon_{D,r}(r^*,\bar{m})|}{\partial\bar{m}} < \frac{-ch'(\bar{m})r^*(\bar{m})}{(c+h(\bar{m})(1-r^*(\bar{m})))^2}$. ■

PROOF OF PROPOSITION 4. Let $G(x) = \int_x^{m_{\max}}(m-x)f(m)dm$. One can show that $G'(x) = F(x)-1 < 0$ and $G''(x) = f(x) > 0$. When filtering is not available, the consumer's acceptance aggregate match level threshold, $\bar{M}$, satisfies $\int_{\bar{M}}^{M_{\max}}(M-\bar{M})f_M(M)dM=\tau$, where $M_{\max}=m_{\max}+\mu_K$. Note that $f(m)=0$ when $m>m_{\max}$. The left-hand-side can be written as:

$$\tau=\int_{\bar{M}}^{m_{\max}+\mu_K}(M-\bar{M})f_M(M)dM=\sum_{k=1}^{K}\phi_k\int_{\bar{M}-\mu_k}^{m_{\max}+(\mu_K-\mu_k)}(m-(\bar{M}-\mu_k))f(m)dm=$$
$$\sum_{k=1}^{K}\phi_k\int_{\bar{M}-\mu_k}^{m_{\max}}(m-(\bar{M}-\mu_k))f(m)dm=\sum_{k=1}^{K}\phi_k G(\bar{M}-\mu_k).$$

Because $G''(x)>0$ and $\sum_{k=1}^{K}\phi_k\mu_k=0$, $G(\bar{M})=G(\sum_{k=1}^{K}\phi_k(\bar{M}-\mu_k))<\sum_{k=1}^{K}\phi_k G(\bar{M}-\mu_k)=\tau$.

When filtering is available, the consumers will search products with $m_{ij}=\mu_K$ and will buy a product only if $m_{ij}>\bar{m}$. $\bar{m}$ is determined by $G(\bar{m})=\int_{\bar{m}}^{m_{\max}}(m-\bar{m})f(m)dm=\tau>G(\bar{M})$. Because $G(x)$ is a strictly decreasing function, $\bar{M}>\bar{m}$. Thus $\bar{M}_N-\bar{M}=\mu_K+\bar{m}-\bar{M}<\mu_K$. Moreover, $G(\bar{m})=\tau=\sum_{k=1}^{K}\phi_k G(\bar{M}-\mu_k)<\sum_{k=1}^{K}\phi_k G(\bar{M}-\mu_K)=G(\bar{M}-\mu_K)$, so $\bar{M}-\mu_K<\bar{m}$, i.e., $\bar{M}_N-\bar{M}>0$. ■

PROOF OF PROPOSITION 5. Consider the marginal impact of filtering on the sellers' equilibrium price. Let $\max_k|\mu_k|\to 0$. Let $\sigma_\mu^2=Var(\mu)$.

First we determine the relationship between $\bar{M}$ and $\bar{m}$. Observe that:

$$\tau=G(\bar{m})=E_\mu G(\bar{M}-\mu)=E_\mu G\big(\bar{m}+(\bar{M}-\bar{m}-\mu)\big)$$
$$=E_\mu\left[G(\bar{m})+G'(\bar{m})(\bar{M}-\bar{m}-\mu)+\frac{G''(\bar{m})}{2}(\bar{M}-\bar{m}-\mu)^2+o((\bar{M}-\bar{m}-\mu)^2)\right]$$
$$=G(\bar{m})+G'(\bar{m})(\bar{M}-\bar{m})+\frac{G''(\bar{m})}{2}\left[(\bar{M}-\bar{m})^2+\sigma_\mu^2\right]+o((\bar{M}-\bar{m})^2)+o\big(\sigma_\mu^2\big)$$
$$=G(\bar{m})+G'(\bar{m})(\bar{M}-\bar{m})+\frac{G''(\bar{m})}{2}\sigma_\mu^2+o(\bar{M}-\bar{m})+o\big(\sigma_\mu^2\big)\,.$$

Thus $\bar{M}-\bar{m}\cong-\frac{G''(\bar{m})}{G'(\bar{m})}\cdot\frac{\sigma_\mu^2}{2}=\frac{\sigma_\mu^2}{2}\cdot\frac{f(\bar{m})}{1-F(\bar{m})}=\frac{\sigma_\mu^2}{2}\cdot\frac{1}{h(\bar{m})}$

$$\frac{h(\bar{m})}{h_N(\bar{M})}=h(\bar{m})\cdot\frac{E_\mu f(\bar{M}-\mu)}{E_\mu[1-F(\bar{M}-\mu)]}=h(\bar{m})\cdot\frac{E_\mu f\big(\bar{m}+(\bar{M}-\bar{m}-\mu)\big)}{E_\mu\big[1-F\big(\bar{m}+(\bar{M}-\bar{m}-\mu)\big)\big]}$$
$$=h(\bar{m})\cdot\frac{E_\mu\left[f(\bar{m})+f'(\bar{m})(\bar{M}-\bar{m}-\mu)+\frac{f''(\bar{m})}{2}(\bar{M}-\bar{m}-\mu)^2+o(\bar{M}-\bar{m})+o\big(\sigma_\mu^2\big)\right]}{E_\mu\left[(1-F(\bar{m}))-f(\bar{m})(\bar{M}-\bar{m}-\mu)-\frac{f'(\bar{m})}{2}(\bar{M}-\bar{m}-\mu)^2+o(\bar{M}-\bar{m})+o\big(\sigma_\mu^2\big)\right]}$$

$$\cong \frac{1-F(\bar{m})}{f(\bar{m})} \cdot \frac{f(\bar{m})+f'(\bar{m})(\bar{M}-\bar{m})+\frac{f''(\bar{m})}{2}\sigma_{\mu}^2}{(1-F(\bar{m}))-f(\bar{m})(\bar{M}-\bar{m})-\frac{f'(\bar{m})}{2}\sigma_{\mu}^2}$$

$$= \frac{1+\frac{f'(\bar{m})}{f(\bar{m})}\cdot\frac{\sigma_{\mu}^2}{2}\cdot\frac{f(\bar{m})}{1-F(\bar{m})}+\frac{f''(\bar{m})}{f(\bar{m})}\cdot\frac{\sigma_{\mu}^2}{2}}{1-\frac{f(\bar{m})}{1-F(\bar{m})}\cdot\frac{\sigma_{\mu}^2}{2}\cdot\frac{f(\bar{m})}{1-F(\bar{m})}-\frac{f'(\bar{m})}{1-F(\bar{m})}\cdot\frac{\sigma_{\mu}^2}{2}} \cong 1+\frac{\sigma_{\mu}^2}{2}\left[\frac{f''(\bar{m})}{f(\bar{m})}+\frac{f(\bar{m})}{1-F(\bar{m})}\cdot\frac{f(\bar{m})}{1-F(\bar{m})}+\frac{2f'(\bar{m})}{1-F(\bar{m})}\right]$$

The above expression is greater than 1 if and only if $f''(\bar{m})\cdot h^2(\bar{m})+2f'(\bar{m})\cdot h(\bar{m})+f(\bar{m})>0$. ■

PROOF OF RESULT 3. According to Lemma 4, the consumers will search the non-premium products if and only if $u_0<-p^*(r)+\bar{m}$ and $m_{1j}<p_1-p^*(r)-\Delta q+\bar{m}$. Following Wolinsky (1986), the profit of a non-premium seller's profit is $\pi_i^S(p_i)=F_0\left(\overline{m-p^*(r)}\right)\cdot F(p_1-p^*(r)-\Delta q+\bar{m})\cdot\frac{[1-F(\bar{m}-p^*(r)+p_i)]\cdot[(1-r)p_i-c]}{n-1}$. Note that the first two terms is positive and independent of p_i, so the optimal p_i should satisfy $\frac{\partial[1-F(\bar{m}-p^*(r)+p_i)]\cdot[(1-r)p_i-c]}{\partial p_i}=0$. The FOC implies that $p^*(r)=\frac{c}{1-r}+h(\bar{m})$. ■

PROOF OF PROPOSITION 6. A seller's profit as a function of its price p_i is $\pi_i=\mathbf{E}_\tau\left[\frac{F_0(\bar{m}(\tau)+\mu_K-p^*(r))}{n(1-F(\bar{m}(\tau)))}[1-F(\bar{m}(\tau)-p^*+p_i)][(1-r)p_i-c]\right]$.

The seller's optimal price $\tilde{p}^*$ satisfies the FOC, i.e., $\frac{\partial\mathbf{E}_\tau\left[\frac{F_0(\bar{m}(\tau)+\mu_K-\tilde{p}^*)}{n\left(1-F(\bar{m}(\tau))\right)}[1-F(\bar{m}(\tau)-\tilde{p}^*+p_i)][(1-r)p_i-c]\right]}{\partial p}=0$ when $p_i=\tilde{p}^*$. Rearranging terms, we get $0=\mathbf{E}_\tau\left[\frac{F_0(\bar{m}(\tau)+\mu_K-\tilde{p}^*)}{\frac{\left(1-F(\bar{m}(\tau))\right)}{f(\bar{m}(\tau))}}(\tilde{p}^*-\tilde{p}_\tau^*)\right]=\mathbf{E}_\tau\left[\frac{F_0(\bar{m}(\tau)+\mu_K-\tilde{p}^*)}{h(\bar{m}(\tau))}(\tilde{p}^*-\tilde{p}_\tau^*)\right]$. Let $a(\tau)=\frac{\frac{F_0(\bar{m}(\tau)+\mu_K-\tilde{p}^*)}{h(\bar{m}(\tau))}}{\mathbf{E}_\tau\left[\frac{F_0(\bar{m}(\tau)+\mu_K-\tilde{p}^*)}{h(\bar{m}(\tau))}\right]}$, which is a strict decreasing function of τ, because $F_0\left(\bar{m}+\mu_K-p^*(r)\right)$ increases with $\bar{m}$, $h(\bar{m})$ decreases with $\bar{m}$, and $\bar{m}$ decreases with τ. Note that $\mathbf{E}_\tau[a(\tau)]=1$, so $\tilde{p}^*=\mathbf{E}_\tau[a(\tau)\tilde{p}_\tau^*]$. Note that $\tilde{p}_\tau^*$ strictly increases with τ, so $\tilde{p}^*=\mathbf{E}_\tau[a(\tau)\tilde{p}_\tau^*]=\mathbf{E}_\tau[a(\tau)]\mathbf{E}_\tau[\tilde{p}_\tau^*]+\mathbf{Cov}_\tau(a(\tau),\tilde{p}_\tau^*)<\mathbf{E}_\tau[\tilde{p}_\tau^*]$. ■

HETEROGENEOUS SEARCH COST: SPECIAL CASE. Consider the case with $\tau \sim \text{Uniform}(0, \tau_{\max})$, where $\tau_{\max} < \frac{1}{8}\left(1 - \frac{c}{1-r}\right)^2$. The FOC can be simplified as $\int_0^{\tau_{\max}} \frac{1}{\tau_{\max}} \cdot \frac{1-\sqrt{2\tau}-\tilde{p}^*}{\sqrt{2\tau}}\left(\tilde{p}^* - \frac{c}{1-r} - \sqrt{2\tau}\right) d\tau = 0$. Let $s = \sqrt{2\tau}$, so $\int_0^{\sqrt{2\tau_{\max}}}(1 - s - \tilde{p}^*)\left(\tilde{p}^* - \frac{c}{1-r} - s\right) ds = 0$. One can derive that $\tilde{p}^* = \frac{1-\frac{c}{1-r}}{2} - \sqrt{\frac{1}{3}\left(\sqrt{2\tau_{\max}} - \frac{3}{2}\frac{1-\frac{c}{1-r}}{2}\right)^2 + \left(\frac{1-\frac{c}{1-r}}{2}\right)^2}$, which decreases with $\tau_{\max}$. ■

FIXED REFERRAL FEE. Seller i's profit is $\pi_i^S(p_i; d) = \frac{F_0(\overline{m}+\mu_K-p^*(d))}{n(1-F(\overline{m}))} \cdot [1 - F(\overline{m} - p^*(d) + p_i)] \cdot [p_i - d - c]$.

The equilibrium price is $\tilde{p}^*(d) = d + c + h(\overline{m})$, the equilibrium profit is $\tilde{\pi}_i^{S*} = \frac{F_0(\overline{m}+\mu_K-d-c-h(\overline{m}))}{n} h(\overline{m})$. Total market demand is $\widetilde{D} = F_0\big(\overline{m} + \mu_K - d - c - h(\overline{m})\big)$. The platform's profit is $\tilde{\pi}^{P*} = F_0\big(\overline{m} + \mu_K - d - c - h(\overline{m})\big) \cdot d$.

Appendix C

PROOF OF LEMMA 1. Suppose that the firm is high-type. Let $\bar{\tilde{p}}_{i,2}$ be a consumer's the expectation of type-i firm's second-period price after seeing the first-period price. The marginal consumer who purchases in the first period has a valuation $\tilde{v}^*_{H,1} = \frac{\tilde{p}_{H,1}-\bar{\tilde{p}}_{H,2}}{1-\mu}$, and the marginal consumer who purchase the product in the second period has a valuation $\tilde{v}^*_{H,2} = \frac{\tilde{p}_{H,2}}{\mu}$. In the second period, the firm maximizes its second period profit $\pi^0_{H,2} = (\frac{\tilde{p}_{H,1}-\bar{\tilde{p}}_{H,2}}{1-\mu} - \frac{\tilde{p}_{H,2}}{\mu})(\tilde{p}_{H,2} - c)$, which leads to the optimal p_2 of $\tilde{p}^*_{H,2} = \frac{\mu(\tilde{p}_{H,1}-\bar{\tilde{p}}_{H,2})+(1-\mu)c}{2(1-\mu)}$. Because consumers have rational expectations, i.e., $\tilde{p}^*_{H,2} = \bar{\tilde{p}}_{H,2}$, one can show that $\tilde{p}^*_{H,2} = \frac{(1-\mu)c+\mu\tilde{p}_{H,1}}{2-\mu}$. In the first period, the firm maximizes its total profit $\tilde{\pi}_H = \left(1 - \frac{\tilde{p}_{H,1}-\frac{(1-\mu)c+\mu\tilde{p}_{H,1}}{2-\mu}}{1-\mu}\right)(\tilde{p}_{H,1} - c) + \left(\frac{\tilde{p}_{H,1}-\frac{(1-\mu)c+\mu\tilde{p}_{H,1}}{2-\mu}}{1-\mu} - \frac{\frac{(1-\mu)c+\mu\tilde{p}_{H,1}}{2-\mu}}{\mu}\right)\left(\frac{(1-\mu)c+\mu\tilde{p}_{H,1}}{2-\mu} - c\right)$, which yields $\tilde{p}^*_{H,1} = \frac{(2-\mu)^2}{2(4-3\mu)} + \frac{c}{2}$, $\tilde{p}^*_{H,2} = \frac{\mu(2-\mu)}{2(4-3\mu)} + \frac{c}{2}$ and $\tilde{p}^*_H = \frac{(1-\mu)^2}{4-3\mu} + \frac{(\mu-c)^2}{4\mu}$. Finally, since we focus on the situation where in equilibrium some consumers buy the product in the second period, so, $\tilde{v}^*_{H,1} > \tilde{v}^*_{H,2}$ and $\tilde{p}^*_{H,2} > c$, which yields $c < \frac{(2-\mu)^2}{4-3\mu}\mu$.

The derivation of the low-type's optimal price and profit is similar. The low-type firm's optimal first-period price and profit are $\tilde{p}^*_{L,1} = \frac{(2-\mu)^2}{2(4-3\mu)}$, $\tilde{p}^*_{L,2} = \frac{\mu(2-\mu)}{2(4-3\mu)}$ and $\tilde{\pi}^*_L = \frac{(1-\mu)^2}{4-3\mu} + \frac{\mu}{4}$.

PROOF OF LEMMA 2. We follow three steps to find the LMSE. First, we analyze all separating equilibria and find σ^*_{sep}, the separating equilibrium which gives the high-type firm the highest payoff. Next we examine all pooling equilibria and find σ^*_{pool}, the pooling equilibrium which gives the high-type firm the highest payoff. Finally we compare the high-type firm's profit in σ^*_{sep} and σ^*_{pool} to determine the PBE giving the high-type firm the highest payoff.

Step 1: finding σ^*_{sep}

Consider separating equilibria. Denote a separating equilibrium $\sigma_{sep} = (\{p_{H,sep,t}\}_{t=1,2}, \{p_{L,sep,t}\}_{t=1,2}, G(v), \phi)$, where $p_{i,sep,t}$ is the i-type firm's price in period t, $G: [0,1] \to \{buy, not\ buy\}$ describes whether consumer v purchase the product in the first period, and $\phi = \phi(i|p)$ is consumers' belief of the probability that the firm is i-type conditional seeing the first-period price p. We assume that ϕ is consistent wherever Bayes rule can be applied. One can see that for all PBE that are sequential, $G(v)$ maximizes consumer v's expected utility, so the value of $G(v)$ can be pinned down given $\{p_{H,sep,t}\}_{t=1,2}$, $\{p_{L,sep,t}\}_{t=1,2}$ and ϕ except for the marginal consumer who has zero mass on interval [0,1]. Moreover, because in the second period, both the high-type firm and the low-type firm will charge their perfect-information price conditional on $p_{H,sep,1}$, $p_{L,sep,1}$ and ϕ, the values of $p_{H,sep,2}$ and $p_{L,sep,2}$ are functions of $p_{H,sep,1}$, $p_{L,sep,1}$ and ϕ. Therefore, it is convenient to denote a separating equilibrium $\sigma_{sep} = (p_{H,sep,1}, p_{L,sep,1}, \phi)$ without loss of generality.

Note that in a separating equilibrium the high-type firm has no incentive to mimic the low-type firm and consumers can correctly infer the firm's type. Thus, the low-type firm will set its prices the same as in the perfect information case, i.e. $p^*_{L,sep,1} = \frac{(2-\mu)^2}{2(4-3\mu)}$ and $p^*_{L,sep,2} = \frac{(2-\mu)\mu}{2(4-3\mu)}$. Low-type firm's profit is $\pi^*_{L,sep} = \frac{(2-\mu)^2}{4(4-3\mu)}$.

The high-type firm's profit is $\pi_{H,sep} = \left(1 - \frac{p_1 - \frac{(1-\mu)c+\mu p_1}{2-\mu}}{1-\mu}\right)(p_1 - c) + \left(\frac{p_1 - \frac{(1-\mu)c+\mu p_1}{2-\mu}}{1-\mu} - \frac{\frac{(1-\mu)c+\mu p_1}{2-\mu}}{\mu}\right)\left(\frac{(1-\mu)c+\mu p_1}{2-\mu} - c\right)$. In a separating equilibrium, we need to guarantee the low-type firm has no incentive to mimic the high-type firm. If the low-type firm mimics the high-type firm, its profit is $\pi_L\left(p_{H,sep,1} \middle| \phi(H|p_{H,sep,1}) = 1\right)$ and $\bar{p}_2 = \frac{(1-\mu)c+\mu p_{H,sep,1}}{2-\mu}$. Therefore, $\pi_L\left(p_{H,sep,1}, p_{L,2} \middle| \phi(H|p_{H,sep,1}) = 1\right) = \left(1 - \frac{p_{H,sep,1} - \frac{(1-\mu)c+\mu p_{H,sep,1}}{2-\mu}}{1-\mu}\right)p_{H,sep,1} + \left(\frac{p_{H,sep,1} - \frac{(1-\mu)c+\mu p_{H,sep,1}}{2-\mu}}{1-\mu} - \frac{p_{L,2}}{\mu}\right)p_{L,2}$. The FOC gives $p^*_{L,2} = \frac{\mu\left(p_{H,sep,1} - \frac{(1-\mu)c+\mu p_{H,sep,1}}{2-\mu}\right)}{2(1-\mu)}$, so $\pi_L\left(p_{H,sep,1}, p_{L,2} \middle| \phi(H|p_{H,sep,1}) = 1\right) = \left(1 - \frac{p_{H,sep,1} - \frac{(1-\mu)c+\mu p_{H,sep,1}}{2-\mu}}{1-\mu}\right)p_{H,sep,1} + \frac{\mu\left(p_{H,sep,1} - \frac{(1-\mu)c+\mu p_{H,sep,1}}{2-\mu}\right)^2}{4(1-\mu)^2}$. Therefore, to guarantee the low-type firm has no incentive to mimic the high-type firm, we need to have $\pi^*_{L,sep} \geq \pi_L\left(p_{H,sep,1}, p_{L,2} \middle| \phi(H|p_{H,sep,1}) = 1\right)$. This is equivalent to $p_{H,sep,1} \in \left(0, \frac{(2-\mu)^2+2c(1-\mu)-(2-\mu)\sqrt{c(4+c-4\mu)}}{2(4-3\mu)}\right] \cup \left[\frac{(2-\mu)^2+2c(1-\mu)+(2-\mu)\sqrt{c(c+4(1-\mu))}}{2(4-3\mu)}, 1-\mu+c\right)$. One can show that under this condition, $\pi_{H,sep}$ is maximized at $p^*_{H,sep,1} = \frac{(2-\mu)^2+2c(1-\mu)+(2-\mu)\sqrt{c(c+4(1-\mu))}}{2(4-3\mu)}$. Thus, in the separating equilibrium which gives the high-type firm the highest profit, $p^*_{H,sep,1} = \frac{(2-\mu)^2+2c(1-\mu)+(2-\mu)\sqrt{c(c+4(1-\mu))}}{2(4-3\mu)}$, $p^*_{H,sep,2} =$

$\frac{c^2(4-5\mu)+(2-\mu)^2\mu+2c\left(8+\mu\left(11\mu-20+\sqrt{c\left(c+4(1-\mu)\right)}\right)\right)}{4(2-\mu)(4-3\mu)}$, $\pi^*_{H,sep} = \frac{(2-\mu)^2\mu+c^2(4-5\mu)+2c\mu\left(5\mu+\sqrt{c\left(c+4(1-\mu)\right)}-6\right)}{4\mu(4-3\mu)}$, $p^*_{L,sep,1} = \frac{(2-\mu)^2}{2(4-3\mu)}$, $p^*_{L,sep,2} = \frac{(2-\mu)\mu}{2(4-3\mu)}$, $\pi^*_{L,sep} = \frac{(2-\mu)^2}{4(4-3\mu)}$.

Step 2: finding $\boldsymbol{\sigma^*_{pool}}$

Consider pooling equilibria. Let $\sigma_{pool} = (p_{pool,1}, \phi)$ be a pooling equilibrium, where $p_{pool,1}$ is the price charged by both the high-type firm and the low-type firm in the first period, and $\phi = \phi(i|p)$ is consumers' belief of the probability that the firm is i-type conditional on the first-period price p. In equilibrium, consumers believe that the firm is high-type with probability α, and that the firm is low-type with probability $1-\alpha$. If a consumer v purchases the product in the first period, her utility is $u_{pool,1} = v - p_{pool,1}$. If she purchases the product in the second period, her utility is $u_{pool,2} = \alpha \cdot \max\{\mu v - p_{H,pool,2}, 0\} + (1-\alpha) \cdot \max\{\mu v - p_{L,pool,2}, 0\}$.

For more interesting analysis, we assume that in the second period there are some consumers who purchase the product even if the firm turns out to be high-type in the second period, which requires that the marginal consumer in the first period v_1^* satisfies $\mu > \mu v_1^* > p_{H,pool,2}$. Therefore, $v_1^* - p_{pool,1} = \alpha\left(\mu v_1^* - \bar{p}_{H,pool,2}\right) + (1-\alpha)\left(\mu v_1^* - \bar{p}_{L,pool,2}\right)$, where $\bar{p}_{i,pool,2}$ is the belief of the second-period price in the pooling equilibrium if the firm is type-i. Simple algebra yields $v_1^* = \frac{p_{pool,1} - \alpha\bar{p}_{H,pool,2} - (1-\alpha)\bar{p}_{L,pool,2}}{1-\mu}$. The high-type firm's second period profit is $\pi_{H,pool,2} = (v_1^* - \frac{p_{H,pool,2}}{\mu})(p_{H,pool,2} - c)$, and the low-type firm's second period profit is $\pi_{L,pool,2} = \left(v_1^* - \frac{p_{L,pool,2}}{\mu}\right)p_{L,pool,2}$. First order condition yields $p^*_{H,pool,2} = \frac{\mu\left(p_{pool,1} - \alpha\bar{p}_{H,pool,2} - (1-\alpha)\bar{p}_{L,pool,2}\right) + (1-\mu)c}{2(1-\mu)}$ and $p^*_{L,pool,2} = \frac{\mu\left(p_{pool,1} - \alpha\bar{p}_{H,pool,2} - (1-\alpha)\bar{p}_{L,pool,2}\right)}{2(1-\mu)}$. Because the consumer has rational belief, $\bar{p}_{H,pool,2} = p^*_{H,pool,2}$ and $\bar{p}_{L,pool,2} = p^*_{L,pool,2}$, which yields $p^*_{H,pool,2} = \frac{\mu(2p_{pool,1} - \alpha c)}{2(2-\mu)} + \frac{c}{2}$, $p^*_{L,pool,2} = \frac{\mu(2p_{pool,1} - \alpha c)}{2(2-\mu)}$, and $v_1^* = \frac{2p_{pool,1} - \alpha c}{2-\mu}$. Therefore the high-type firm's profit in a pooling equilibrium is $\pi_{H,pool} = (1 - v_1^*)\left(p_{pool,1} - c\right) + \left(v_1^* - \frac{p^*_{H,pool,2}}{\mu}\right)\left(p^*_{H,pool,2} - c\right) = \frac{-4\mu(4-3\mu)p^2_{pool,1} + 4\mu\left((2-\mu)^2 + c(2+2\alpha(1-\mu)-\mu)\right)p_{pool,1} + c(c(2-(1+\alpha)\mu)^2 - 4(2-\mu)^2\mu)}{4\mu(2-\mu)^2}$, and the low-type firm's profit in a pooling equilibrium is $\pi_{L,pool} = (1 - v_1^*)p_{pool,1} + \left(v_1^* - \frac{p^*_{L,pool,2}}{\mu}\right)p^*_{L,pool,2} = \frac{-4(4-3\mu)p^2_{pool,1} + 4\left((2-\mu)^2 + 2\alpha c(1-\mu)\right)p_{pool,1} + \alpha^2c^2\mu}{4(2-\mu)^2}$.

Let $M(p_{pool,1}) = \{\phi|\phi(H|p_{pool,1}) = \alpha\}$ be the set of beliefs which are consistent with the pooling equilibrium (i.e., $\phi(H|p_1 = p_{pool,1}) = \alpha$). We proceed to show that $(p_{pool,1}, \phi)$ is a PBE for some $\phi \in M(p_{pool})$ if and only if neither the high-type nor low-type firm has an incentive to deviate to another price p' when consumers have a belief $\phi \in M(p_{pool})$ with $\phi(H|p_1 = p') = 0, \forall p' \neq p_{pool,1}$ (i.e., consumers believe that the firm is low-type with probability 1 when $p' \neq p_{pool,1}$). This is because on the one hand, if this condition is satisfied, then $(p_{pool,1}, \phi)$ is a PBE. On the other hand, if this condition is violated, then for any other $\phi \in M(p_{pool,1})$, $(p_{pool,1}, \phi)$ cannot be a PBE since deviating to p' will give the firm even higher profit. Consequently, this condition is a necessary and sufficient condition for $(p_{pool,1}, \phi)$ to be a PBE for some $\phi \in M(p_{pool,1})$. Hence hereafter we only consider the belief ϕ such that $\phi(H|p_1 = p_{pool,1}) = \alpha$ and $\phi(H|p_1 \neq p_{pool,1}) = 0$.

The highest possible profit a low-type firm can get by deviating is its perfect-information profit $\pi^*_{L,pool,dev} = \pi_{L,sep} = \frac{(2-\mu)^2}{4(4-3\mu)}$. For the high-type firm, suppose it deviates by charging $p_{H,pool,dev,1} \neq p_{pool,1}$ in the first period. In the second period, its profit is $\pi_{H,pool,dev,2} = \left(\frac{p_{H,pool,dev,1}-\bar{p}_2}{1-\mu} - \frac{p_{H,pool,dev,2}}{\mu}\right)(p_{H,pool,dev,2} - c)$,where $\bar{p}_2 = \frac{\mu p_{H,pool,dev,1}}{2-\mu}$ because $\phi(H|p_1 = p_{H,pool,dev,1}) = 0$. When $p_{H,pool,dev,1} < \frac{(2-\mu)c}{2\mu}$, $\pi_{H,pool,dev,2} < 0$. When $p_{H,pool,dev,1} \geq \frac{(2-\mu)c}{2\mu}$, the high-type firm's optimal second-period price and profit are $p^*_{H,pool,dev,2} = \frac{\mu}{2-\mu} p_{H,pool,dev,1} + \frac{c}{2}$ and $\pi^*_{H,pool,dev,2} = \frac{\left(2\mu p_{H,pool,dev,1} - c(2-\mu)\right)^2}{4\mu(2-\mu)^2}$.

The high-type firm's total profit by deviating is:

$$\pi_{H,pool,dev} = \begin{cases} \left(1 - \frac{p_{H,pool,dev,1}-\bar{p}_2}{1-\mu}\right)(p_{H,pool,dev,1} - c) + \left(\frac{p_{H,pool,dev,1}-\bar{p}_2}{1-\mu} - \frac{p_{H,pool,dev,2}}{\mu}\right)(p_{H,pool,dev,2} - c), \\ \qquad if\ p_{H,pool,dev,1} > \frac{(2-\mu)c}{2\mu} \\ (1 - p_{H,pool,dev,1})(p_{H,pool,dev,1} - c), if\ p_{H,pool,dev,1} \leq \frac{(2-\mu)c}{2\mu} \end{cases}.$$

Next we will find the $p_{H,pool,dev,1}$ which maximizes $\pi_{H,pool,dev}$. (1) When $p_{H,pool,dev,1} \leq \frac{(2-\mu)c}{2\mu}$, $\pi_{H,pool,dev}$ increases with $p_{H,pool,dev,1}$ if $p_{H,pool,dev,1} \leq \frac{1+c}{2}$ and decreases if $p_{H,pool,dev,1} > \frac{1+c}{2}$. Because we have assumed $c \leq \frac{(2-\mu)^2}{(4-3\mu)}\mu$, $\frac{1+c}{2} \geq \frac{(2-\mu)c}{2\mu}$ is always true. Therefore, when $p_{H,pool,dev,1} \leq \frac{(2-\mu)c}{2\mu}$,$\pi_{H,pool,dev}$ is maximized when $p_{H,pool,dev,1} = \frac{(2-\mu)c}{2\mu}$ with $\pi_{H,pool,dev} = \frac{(2\mu-(2-\mu)c)(2-3\mu)c}{4\mu^2}$. (2) When $p_{H,pool,dev,1} > \frac{(2-\mu)c}{2\mu}$, $\pi_{H,pool,dev}$ increases with

$p_{H,pool,dev,1}$ when $p_{H,pool,dev,1} \leq \frac{(2+c-\mu)(2-\mu)}{2(4-3\mu)}$, and decreases when $p_{H,pool,dev,1} \geq \frac{(2+c-\mu)(2-\mu)}{2(4-3\mu)}$. When $c \leq \frac{(2-\mu)^2}{(2+\mu)(4-3\mu)}\mu$, $\frac{(2+c-\mu)(2-\mu)}{2(4-3\mu)} \geq \frac{(2-\mu)c}{2\mu}$ is always true. Therefore, when $p_{H,pool,dev,1} > \frac{(2-\mu)c}{2\mu}$, $\pi_{H,pool,dev}$ is maximized when $p_{H,pool,dev,1} = \frac{(2+c-\mu)(2-\mu)}{2(4-3\mu)}$ with $\pi_{H,pool,dev} = \frac{2(2-\mu)c^2+\mu(2-\mu)^2-2c\mu(6-5\mu)}{4\mu(4-3\mu)}$. One can show that when $c \leq \frac{(2-\mu)^2}{(2+\mu)(4-3\mu)}\mu$, $\frac{2(2-\mu)c^2+\mu(2-\mu)^2-2c\mu(6-5\mu)}{4\mu(4-3\mu)} > \frac{(2\mu-(2-\mu)c)(2-3\mu)c}{4\mu^2}$. As a result, $\pi_{H,pool,dev}$ is maximized at $p^*_{H,pool,dev,1} = \frac{(2+c-\mu)(2-\mu)}{2(4-3\mu)}$ with $\pi^*_{H,pool,dev} = \frac{2(2-\mu)c^2+\mu(2-\mu)^2-2c\mu(6-5\mu)}{4\mu(4-3\mu)}$.

In a pooling equilibrium with the first-period price $p_{pool,1}$, neither the high-type nor the low-type firm has an incentive to deviate, which requires $\pi_{H,pool} \geq \pi^*_{H,pool,dev}$ and $\pi_{L,pool} \geq \pi^*_{L,pool,dev}$. Condition $\pi_{H,pool} \geq \pi^*_{H,pool,dev}$ is equivalent to $\frac{-4\mu(4-3\mu)p^2_{pool,1}+4\mu\left((2-\mu)^2+c(2+2\alpha(1-\mu)-\mu)\right)p_{pool,1}+c(c(2-(1+\alpha)\mu)^2-4(2-\mu)^2\mu)}{4\mu(2-\mu)^2} \geq \frac{2(2-\mu)c^2+\mu(2-\mu)^2-2c\mu(6-5\mu)}{4\mu(4-3\mu)}$, which can be equivalently expressed as $p_{pool,1} \in [\frac{(2-\mu)^2+c\left(2-\mu+2\alpha(1-\mu)\right)}{2(4-3\mu)} - \frac{(2-\mu)\sqrt{4c(4+\alpha-(3-\alpha)\mu)-4(4-3\mu)-(2-\alpha)\alpha c^2}}{2(4-3\mu)}, \frac{(2-\mu)^2+c\left(2-\mu+2\alpha(1-\mu)\right)}{2(4-3\mu)} + \frac{(2-\mu)\sqrt{4c(4+\alpha-(3-\alpha)\mu)-4(4-3\mu)-(2-\alpha)\alpha c^2}}{2(4-3\mu)}]$. We define $\mathcal{P}_1 = [\frac{(2-\mu)^2+c\left(2-\mu+2\alpha(1-\mu)\right)}{2(4-3\mu)} - \frac{(2-\mu)\sqrt{4c(4+\alpha-(3-\alpha)\mu)-4(4-3\mu)-(2-\alpha)\alpha c^2}}{2(4-3\mu)}, \frac{(2-\mu)^2+c\left(2-\mu+2\alpha(1-\mu)\right)}{2(4-3\mu)} + \frac{(2-\mu)\sqrt{4c(4+\alpha-(3-\alpha)\mu)-4(4-3\mu)-(2-\alpha)\alpha c^2}}{2(4-3\mu)}]$. The condition $\pi_{L,pool} \geq \pi_{L,pool,dev}$ implies that $\frac{-4(4-3\mu)p^2_{pool,1}+4\left((2-\mu)^2+2\alpha c(1-\mu)\right)p_{pool,1}+\alpha^2c^2\mu}{4(2-\mu)^2} \geq \frac{(2-\mu)^2}{4(4-3\mu)}$, which is equivalent to $p_{pool,1} \in [\frac{(2-\mu)^2+2\alpha c(1-\mu)}{2(4-3\mu)} - \frac{(2-\mu)\sqrt{\alpha c(4(1-\mu)+\alpha c)}}{2(4-3\mu)}, \frac{(2-\mu)^2+2\alpha c(1-\mu)}{2(4-3\mu)} + \frac{(2-\mu)\sqrt{\alpha c(4(1-\mu)+\alpha c)}}{2(4-3\mu)}]$. We define $\mathcal{P}_2 = [\frac{(2-\mu)^2+2\alpha c(1-\mu)}{2(4-3\mu)} - \frac{(2-\mu)\sqrt{\alpha c(4(1-\mu)+\alpha c)}}{2(4-3\mu)}, \frac{(2-\mu)^2+2\alpha c(1-\mu)}{2(4-3\mu)} + \frac{(2-\mu)\sqrt{\alpha c(4(1-\mu)+\alpha c)}}{2(4-3\mu)}]$. Therefore, there exists a belief $\phi \in M(p_{pool,1})$ such that $(p_{pool,1}, \phi)$ is a PBE if and only if $p_{pool,1} \in \mathcal{P}_1 \cap \mathcal{P}_2$.

The LMSE gives the high-type firm the highest profit among all PBE. One can show that without the restriction of $p_{pool,1} \in \mathcal{P}_1 \cap \mathcal{P}_2$, $\pi_{H,pool}$ is maximized when $p_{pool,1} = \frac{(2-\mu)^2+c\left(2-\mu+2\alpha(1-\mu)\right)}{2(4-3\mu)}$. It is obvious that $\frac{(2-\mu)^2+c\left(2-\mu+2\alpha(1-\mu)\right)}{2(4-3\mu)} \in \mathcal{P}_1$. When $\alpha \geq \frac{\sqrt{4(1-\mu)^2+c^2}-2(1-\mu)}{c}$, $\frac{(2-\mu)^2+c\left(2-\mu+2\alpha(1-\mu)\right)}{2(4-3\mu)} \in \mathcal{P}_2$, so the pooling PBE outcome which gives the high-type firm the highest profit are $p^*_{pool,1} = \frac{(2-\mu)^2+c\left(2-\mu+2\alpha(1-\mu)\right)}{2(4-3\mu)}$ and $\pi^*_{H,pool} = \frac{\mu(2-\mu)^2+c^2(4-(2+(2-\alpha)\alpha)\mu)-2c\mu\left(6-5\mu-2\alpha(1-\mu)\right)}{4\mu(4-3\mu)}$. When $\alpha < \frac{\sqrt{4(1-\mu)^2+c^2}-2(1-\mu)}{c}$,

$\frac{(2-\mu)^2+c(2-\mu+2\alpha(1-\mu))}{2(4-3\mu)}$ is higher than the upper bound of $\mathcal{P}_2$, $\frac{(2-\mu)^2+2\alpha c(1-\mu)}{2(4-3\mu)}+\frac{(2-\mu)\sqrt{\alpha c(4(1-\mu)+\alpha c)}}{2(4-3\mu)}$. Therefore, $\pi_{H,pool}$ is an increasing function of $p_{1,pool}$ on $\mathcal{P}_1 \cap \mathcal{P}_2$. As a result, the pooling PBE outcome which gives the high-type firm the highest profit are $p^*_{pool,1}=\frac{(2-\mu)^2+2\alpha c(1-\mu)}{2(4-3\mu)}+\frac{(2-\mu)\sqrt{\alpha c(4(1-\mu)+\alpha c)}}{2(4-3\mu)}$ and $\pi^*_{H,pool}=\frac{\mu(2-\mu)^2+c^2(4-(3+2\alpha)\mu)-2c\mu\left(6-5\mu-\sqrt{\alpha c(4(1-\mu)+\alpha c)}\right)}{4\mu(4-3\mu)}$.

Step 3: comparing σ^*_{sep} and σ^*_{pool}

We compare $\pi^*_{H,pool}$ and $\pi^*_{sep,H}$ to choose the LMSE. One can see that $\pi^*_{H,sep}=\frac{(2-\mu)^2\mu+c^2(4-5\mu)+2c\mu\left(5\mu+\sqrt{c(c+4(1-\mu))}-6\right)}{4\mu(4-3\mu)}$ is independent of α. When $\alpha \geq \frac{\sqrt{4(1-\mu)^2+c^2}-2(1-\mu)}{c}$, $\pi^*_{H,pool}=\frac{\mu(2-\mu)^2+c^2(4-(2+(2-\alpha)\alpha)\mu)-2c\mu(6-5\mu-2\alpha(1-\mu))}{4\mu(4-3\mu)}$. When $\alpha<\frac{\sqrt{4(1-\mu)^2+c^2}-2(1-\mu)}{c}$, $\pi^*_{H,pool}=\frac{\mu(2-\mu)^2+c^2(4-(3+2\alpha)\mu)-2c\mu\left(6-5\mu-\sqrt{\alpha c(4(1-\mu)+\alpha c)}\right)}{4\mu(4-3\mu)}$. Next we show that $\pi^*_{H,pool}$ is an increasing function of α. When $\alpha<\frac{\sqrt{4(1-\mu)^2+c^2}-2(1-\mu)}{c}$, it is obvious that $\frac{\mu(2-\mu)^2+c^2(4-(3+2\alpha)\mu)-2c\mu\left(6-5\mu-\sqrt{\alpha c(4(1-\mu)+\alpha c)}\right)}{4\mu(4-3\mu)}$ increases with α. When $\alpha \geq \frac{\sqrt{4(1-\mu)^2+c^2}-2(1-\mu)}{c}$, $\pi^*_{H,pool}=\frac{\mu(2-\mu)^2+c^2(4-(2+(2-\alpha)\alpha)\mu)-2c\mu(6-5\mu-2\alpha(1-\mu))}{4\mu(4-3\mu)}$. Because $v^*_1=\frac{2p^*_{pool,1}-\alpha c}{2-\mu}<1$, $2(1-\mu)-c(1-\alpha)>0$. As a result, $\frac{\partial \pi^*_{H,pool}}{\partial \alpha}=\frac{c[2(1-\mu)-c(1-\alpha)]}{2(4-3\mu)}>0$. Moreover, one can show that $\pi^*_{H,pool}$ is a continuous function of α. Therefore, $\pi^*_{H,pool}$ is a strictly increasing function of α when $\alpha \in (0,1)$.

When $\alpha \geq \frac{\sqrt{4(1-\mu)^2+c^2}-2(1-\mu)}{c}$, $\pi^*_{H,pool} \geq \pi^*_{H,sep}$, implies that $\frac{\mu(2-\mu)^2+c^2(4-(2+(2-\alpha)\alpha)\mu)-2c\mu(6-5\mu-2\alpha(1-\mu))}{4\mu(4-3\mu)} \geq \frac{(2-\mu)^2\mu+c^2(4-5\mu)+2c\mu\left(5\mu+\sqrt{c(c+4(1-\mu))}-6\right)}{4\mu(4-3\mu)}$, i.e., $\alpha \geq \frac{\sqrt{4-\frac{8c}{1-\mu}-2\left(\frac{c}{1-\mu}\right)^2+\frac{4c}{1-\mu}\sqrt{\frac{c}{1-\mu}\left(2+\frac{c}{1-\mu}\right)}}-2\left(1-\frac{c}{1-\mu}\right)}{\frac{2c}{1-\mu}}$. One can show that $\frac{\sqrt{4-\frac{8c}{1-\mu}-2\left(\frac{c}{1-\mu}\right)^2+\frac{4c}{1-\mu}\sqrt{\frac{c}{1-\mu}\left(2+\frac{c}{1-\mu}\right)}}-2\left(1-\frac{c}{1-\mu}\right)}{\frac{2c}{1-\mu}}>\frac{\sqrt{4(1-\mu)^2+c^2}-2(1-\mu)}{c}$. This result, together with the fact that $\pi^*_{H,sep}=\frac{(2-\mu)^2\mu+c^2(4-5\mu)+2c\mu\left(5\mu+\sqrt{c(c+4(1-\mu))}-6\right)}{4\mu(4-3\mu)}$ is independent of α and $\pi^*_{H,pool}$ is a strictly increasing function of α when $\alpha \in (0,1)$, implies that $\pi^*_{H,pool} \geq \pi^*_{H,sep}$ if and only if $\alpha \geq \frac{\sqrt{4-\frac{8c}{1-\mu}-2\left(\frac{c}{1-\mu}\right)^2+\frac{4c}{1-\mu}\sqrt{\frac{c}{1-\mu}\left(2+\frac{c}{1-\mu}\right)}}-2\left(1-\frac{c}{1-\mu}\right)}{\frac{2c}{1-\mu}} \equiv \alpha^*$.

In conclusion, when consumers do not know the firm's cost, when $\alpha < \alpha^*$, the equilibrium is separating, $\pi^*_{H,sep} = \frac{(2-\mu)^2\mu+c^2(4-5\mu)+2c\mu\left(5\mu+\sqrt{c(c+4(1-\mu))}-6\right)}{4\mu(4-3\mu)}$ and $\pi^*_{L,sep} = \frac{(2-\mu)^2}{4(4-3\mu)}$. When $\alpha \geq \alpha^*$, the equilibrium is pooling, $\pi^*_{H,pool} = \frac{\mu(2-\mu)^2+c^2(4-(2+(2-\alpha)\alpha)\mu)-2c\mu(6-5\mu-2\alpha(1-\mu))}{4\mu(4-3\mu)}$ and $\pi^*_{L,pool} = \frac{(2-\mu)^2+4(1-\mu)\alpha c-(1-\alpha^2)c^2}{4(4-3\mu)}$. When consumers know the firm's cost, $\hat{\pi}^*_H = \frac{(1-\mu)^2}{4-3\mu} + \frac{(\mu-c)^2}{4\mu}$, and $\hat{\pi}^*_L = \frac{(1-\mu)^2}{4-3\mu} + \frac{\mu}{4}$. ■

PROOF OF PROPOSITION 1. We compare the firm's optimal price and profit when its cost is not known to consumers with that when the cost is known.

$$\tilde{p}^*_{H,1} - p^*_{H,Sep,1} = \frac{(2-\mu)^2}{2(4-3\mu)} + \frac{c}{2} - \frac{(2-\mu)^2+2c(1-\mu)+(2-\mu)\sqrt{c(c+4(1-\mu))}}{2(4-3\mu)} = \frac{(2-\mu)\left(c-\sqrt{c(c+4(1-\mu))}\right)}{2(4-3\mu)} < 0.$$

$$\tilde{p}^*_{H,2} - p^*_{H,sep,2} = \frac{\mu}{2-\mu}\left(\tilde{p}^*_{H,1} - p^*_{H,Sep,1}\right) < 0.$$

$$\tilde{p}^*_{H,1} - p^*_{pool,1} = \frac{(2-\mu)^2}{2(4-3\mu)} + \frac{c}{2} - \frac{(2-\mu)^2+c(2-\mu+2\alpha(1-\mu))}{2(4-3\mu)} = \frac{2c(1-\mu)(1-\alpha)}{2(4-3\mu)} > 0.$$

$$\tilde{p}^*_{H,2} - p^*_{pool,2} = \frac{\mu}{2-\mu}\left(\tilde{p}^*_{H,1} - p^*_{pool,1}\right) > 0.$$

$$\tilde{p}^*_{L,1} = p^*_{L,sep,1}, \tilde{p}^*_{L,2} = p^*_{L,sep,2}.$$

$$\tilde{p}^*_{L,1} - p^*_{pool,1} = \frac{(2-\mu)^2}{2(4-3\mu)} - \frac{(2-\mu)^2+c(2-\mu+2\alpha(1-\mu))}{2(4-3\mu)} = -\frac{c(2-\mu+2\alpha(1-\mu))}{2(4-3\mu)} < 0.$$

$$\tilde{p}^*_{L,2} - p^*_{pool,2} = \frac{\mu}{2-\mu}\left(\tilde{p}^*_{L,1} - p^*_{pool,1}\right) > 0.$$

$$\tilde{\pi}^*_H - \pi^*_{H,sep} = \frac{c\left(-\sqrt{c+4(1-\mu)}+c+2(1-\mu)\right)}{2(4-3\mu)} = \frac{(1-\mu)^2\cdot\frac{c}{1-\mu}\left(\frac{c}{1-\mu}+2-\sqrt{\frac{c}{1-\mu}+4}\right)}{2(4-3\mu)} > 0.$$

$\tilde{\pi}^*_H - \pi^*_{H,pool} = \frac{(1-\alpha)c(4-4\mu-(1-\alpha)c)}{4(4-3\mu)}$. Because $c < \frac{(1-\mu)^2\mu}{(2-\mu)(4-3\mu)}$, $\tilde{\pi}^*_H - \pi^*_{H,pool} > 0$.

$\tilde{\pi}^*_L = \pi^*_{L,sep}$.

$\tilde{\pi}^*_L - \pi^*_{L,pool} < 0$ because $\tilde{\pi}^*_L = \pi^*_{L,pool,dev} \leq \pi^*_{L,pool}$.

PROOF OF PROPOSITION 2.

Cost transparency strictly increases the firm's expected first-period and second-period prices:

$\left(\alpha\tilde{p}^*_{H,1} + (1-\alpha)\tilde{p}^*_{L,1}\right) - \left(\alpha p^*_{H,sep,1} + (1-\alpha)p^*_{L,sep,1}\right) = \alpha\left(\tilde{p}^*_{H,1} - p^*_{H,sep,1}\right) + (1-\alpha)\left(\tilde{p}^*_{L,1} - p^*_{L,sep,1}\right) < 0.$

$\left(\alpha\tilde{p}^*_{H,1} + (1-\alpha)\tilde{p}^*_{L,1}\right) - \left(\alpha p^*_{pool,1} + (1-\alpha)p^*_{pool,1}\right) = \alpha\left(\tilde{p}^*_{H,1} - p^*_{pool,1}\right) + (1-\alpha)\left(\tilde{p}^*_{L,1} - p^*_{pool,1}\right) = \alpha\frac{2c(1-\mu)(1-\alpha)}{2(4-3\mu)} - (1-\alpha)\frac{c\left(2-\mu+2\alpha(1-\mu)\right)}{2(4-3\mu)} = -\frac{2-\mu}{2(4-3\mu)} < 0.$ ■

Cost transparency strictly increases the expected consumer surplus:

We define $CS_{i,t}$ as consumer surplus in period t if the firm's cost is c_i, and $CS_i = CS_{i,1} + CS_{i,2}$ is the total consumer surplus. $\widetilde{CS}^*_i = \widetilde{CS}^*_{i,1} + \widetilde{CS}^*_{i,2} = \int_{\tilde{v}^*_{1,H}}^{1}(s-\tilde{p}^*_{i,1})ds + \int_{\tilde{v}^*_{2,i}}^{\tilde{v}^*_{1,i}}(\mu s-\tilde{p}^*_{i,2})ds$, $CS^*_{i,sep} = CS^*_{i,sep,1} + CS^*_{i,sep,2} = \int_{v^*_{i,sep,1}}^{1}(s-p^*_{i,sep,1})ds + \int_{v^*_{i,sep,2}}^{v^*_{i,sep,1}}(\mu s-p^*_{i,sep,2})ds$ and $CS^*_{i,pool} = CS^*_{i,pool,1} + CS^*_{i,pool,2} = \int_{v^*_{pool,1}}^{1}(s-p^*_{pool,1})ds + \int_{v^*_{i,pool,2}}^{v^*_{i,pool,1}}(\mu s-p^*_{i,pool,2})ds$, where $i \in \{H, L\}$. The expected consumer surplus is $E[\widetilde{CS}] = \alpha \cdot \widetilde{CS}^*_H + (1-\alpha)\widetilde{CS}^*_L$ when the cost is known to consumers, is $E[CS_{sep}] = \alpha \cdot CS^*_{H,sep} + (1-\alpha)CS^*_{L,sep}$ when the cost is not known to consumers and σ^* is separating, and is $E[CS_{pool}] = \alpha \cdot CS^*_{H,pool} + (1-\alpha)CS^*_{L,pool}$ when the cost is not known to consumers and σ^* is pooling.

First, we will show that when σ^* is separating, cost transparency strictly increases consumer surplus. $\widetilde{CS}^*_H > CS^*_{H,sep}$ since $\tilde{p}^*_{H,1} < p^*_{H,sep,1}$, $\tilde{p}^*_{H,2} < p^*_{H,sep,2}$, $\tilde{v}^*_{H,1} < v^*_{H,sep,1}$ and $\tilde{v}^*_{H,2} < v^*_{H,sep,2}$. Intuitively, when consumers know the firm's cost, consumer surplus is higher because prices in both periods are lower and the amount of first-period consumers and the amount of total consumers both increase. Moreover $\widetilde{CS}^*_L = CS^*_{L,sep}$ since $\tilde{p}^*_{L,1} = p^*_{L,sep,1}$, $\tilde{p}^*_{L,2} = p^*_{L,sep,2}$. Therefore, $E[\widetilde{CS}] - E[CS_{sep}] > 0$.

Next we show that when σ^* is pooling, cost transparency strictly increases expected consumer surplus. Let $\hat{p}_1 = \alpha\tilde{p}^*_{H,1} + (1-\alpha)\tilde{p}^*_{L,1}$. One can see that $\hat{p}_1 < p_1$ from section (2) of the proof of proposition 1. Now suppose both the high-cost firm and the low-cost firm have to charge a price $\hat{p}_1$ in the first period. Given this first period price $\hat{p}_1$, type-i firm charges $\hat{p}^*_{2,i}$ to maximize its second period profit $\tilde{\pi}_{2,i}$.Since both types of firms charge the same first period price, at the end of the first period consumers still cannot tell the firm's cost type. One can show that $\hat{p}^*_{2,H} = \frac{\mu(2\tilde{p}_1-\alpha c)}{2(2-\mu)} + \frac{c}{2}$ and $\hat{p}^*_{2,L} = \frac{\mu(2\tilde{p}_1-\alpha c)}{2(2-\mu)}$. The marginal consumer in the first period is $\hat{v}_1 = \frac{2\hat{p}_1-\alpha c}{2-\mu}$, the marginal consumer in the second period if the firm has high cost is $\hat{v}_{2,H} = \frac{2\hat{p}_1-\alpha c}{2(2-\mu)} + \frac{c}{2\mu}$, and the marginal consumer in the second period if the firm has low cost is $\hat{v}_{2,L} = \frac{2\hat{p}_1-\alpha c}{2(2-\mu)}$. Therefore, when both types of firms have to charge $\hat{p}_1$ in the first period, consumer surplus is

$\widehat{CS}_i = \int_{\hat{v}_1}^{1}(s - \hat{p}_1)ds + \int_{\hat{v}_{2,i}}^{\hat{v}_1}(\mu s - \hat{p}_{2,i}^*)ds$ if the firm has cost c_i. Since $\hat{p}_1 < p_{pool,1}^*$, $\hat{p}_{2,H} < p_{H,pool,2}^*$, $\hat{p}_{2,L} < p_{L,pool,2}^*$, $\hat{v}_1 < v_{pool,1}^*$, $\hat{v}_{H,2} < v_{H,pool,2}^*$, and $\hat{v}_{L,2} < v_{L,pool,2}^*$, $\widehat{CS}_i > CS_{i,pool}^*$, $\forall i \in \{H, L\}$, therefore $E[\widehat{CS}] > E[CS_{pool}^*]$.

The value of $E[\widehat{CS}]$ bridges the comparison of $E[\widetilde{CS}]$ and $E[CS_{pool}^*]$. One can show that $E[\widehat{CS}] = E[\widetilde{CS}] = \frac{48-\alpha c(4-3\mu)[20-(30-11\mu)\mu]-\mu[88-\mu(32+\mu(20-11\mu))]}{2(4-3\mu)^3}$. Therefore, $E[\widetilde{CS}] > E[CS_{pool}^*]$. Thus, when σ^* is pooling, cost transparency increases the expected consumer surplus. ■

PROOF OF LEMMA 3.

$(\alpha\tilde{\pi}_H^* + (1-\alpha)\tilde{\pi}_L^*) - \left(\alpha\pi_{H,sep}^* + (1-\alpha)\pi_{L,sep}^*\right) = \alpha\left(\tilde{\pi}_H^* - \pi_{H,sep}^*\right) + (1-\alpha)\left(\tilde{\pi}_L^* - \pi_{L,sep}^*\right) > 0.$

$(\alpha\tilde{\pi}_H^* + (1-\alpha)\tilde{\pi}_L^*) - \left(\alpha\pi_{H,pool}^* + (1-\alpha)\pi_{L,pool}^*\right) = \alpha\left(\tilde{\pi}_H^* - \pi_{H,pool}^*\right) + (1-\alpha)\left(\tilde{\pi}_L^* - \pi_{L,pool}^*\right) = \alpha\frac{(1-\alpha)c(4-4\mu-(1-\alpha)c)}{4(4-3\mu)} + (1-\alpha)\frac{c\left(c-\alpha\left(\alpha c+4(1-\mu)\right)\right)}{4(4-3\mu)} = \frac{(1-\alpha)^2c^2}{4(4-3\mu)} > 0.$

PROOF OF RESULT 1. In the first period, a consumer's utility of purchasing the product in period 1 is $u_{1,1} = v - p_1$ and utility of purchasing in period 2 is $u_{1,2} = \delta(v - \bar{p}_2)$. In the second period, the utility of purchasing in period 2 is $u_{2,2} = v - p_2$.

Consider the high-cost firm. The first period marginal consumer is $v_{1,H}^* = \frac{\tilde{p}_{1,H}-\delta\bar{\tilde{p}}_{2,H}}{1-\delta}$, the second period marginal consumer is $v_{2,H} = \tilde{p}_{2,H}$. Solve the game by backward induction. The second-period profit is $\pi_{2,H} = \delta(\frac{\tilde{p}_{1,H}-\delta\bar{\tilde{p}}_{2,H}}{1-\delta} - \tilde{p}_{2,H})(\tilde{p}_{2,H} - c)$. The optimal $\tilde{p}_{2,H}$ is $\tilde{p}_{2,H}^* = \frac{1}{2}\left(c + \frac{p-\delta\bar{\tilde{p}}_{2,H}}{1-\delta}\right)$. Consumers have rational expectation: $\tilde{p}_{2,H} = \bar{\tilde{p}}_{2,H} = \frac{(1-\delta)c+\tilde{p}_{1,H}}{2-\delta}$. The total profit in both periods is $\pi_H = \left(1 - \frac{\tilde{p}_{1,H}-\delta\frac{(1-\delta)c+\tilde{p}_{1,H}}{2-\delta}}{1-\delta}\right)\left(\tilde{p}_{1,H} - c\right) + \delta\left(\frac{\tilde{p}_{1,H}-\delta\frac{(1-\delta)c+\tilde{p}_{1,H}}{2-\delta}}{1-\delta} - \frac{(1-\delta)c+\tilde{p}_{1,H}}{2-\delta}\right)\left(\frac{(1-\delta)c+\tilde{p}_{1,H}}{2-\delta} - c\right) = \frac{1}{(2-\delta)^2}\left(\tilde{p}_{1,H} - c\right)[(2-\delta)^2 + \delta(1-\delta)c - (4-3\delta)\tilde{p}_{1,H}]$. The optimal prices are $\tilde{p}_{1,H}^* = \frac{(2-\delta)^2+(4-2\delta-\delta^2)c}{2(4-3\delta)}$, $\tilde{p}_{2,H}^* = \frac{(2-\delta)+(6-5\delta)c}{2(4-3\delta)}$, $\tilde{\pi}_H^* = \frac{(2-\delta)^2(1-c)^2}{4(4-3\delta)}$.

Similarly, for the low-cost firm, $\tilde{p}_{1,L}^* = \frac{(2-\delta)^2}{2(4-3\delta)}$, $\tilde{p}_{2,L}^* = \frac{(2-\delta)}{2(4-3\delta)}$, $\tilde{\pi}_L^* = \frac{(2-\delta)^2}{4(4-3\delta)}$.

PROOF OF RESULT 2. Similar to the proof of lemma 2, we follow three steps to find the LMSE. First, we focus on all separating equilibria and find σ_{sep}^*, the separating equilibrium which gives the high-type firm the highest payoff. Next we focus on all pooling equilibria and find σ_{pool}^*, the pooling equilibrium which gives the high-type firm the highest payoff. Finally we compare the high-type firm's profit in σ^*_{sep} and σ^*_{pool} to find the PBE giving the high-type firm the highest payoff.

Step 1: finding $\boldsymbol{\sigma^*_{sep}}$

In a separating equilibrium, the low-cost firm's equilibrium prices and profit are $p^*_{sep,1,L} = \frac{(2-\delta)^2}{2(4-3\delta)}$, $p^*_{sep,2,L} = \frac{(2-\delta)}{2(4-3\delta)}$, and $\pi^*_{sep,L} = \frac{(2-\delta)^2}{4(4-3\delta)}$.

If the low-cost firm mimics the high-cost firm's price in the first period, its profit is $\pi_{L,mimic} = \left(1 - \frac{p_{1,H} - \delta\frac{(1-\delta)c+p_{1,H}}{2-\delta}}{1-\delta}\right)p_{1,H} + \delta\left(\frac{p_{1,H} - \delta\frac{(1-\delta)c+p_{1,H}}{2-\delta}}{2(1-\delta)}\right)^2 = \frac{1}{(2-\delta)^2}p_{1,H}[(2-\delta)^2 + 2\delta(1-\delta)c - (4-3\delta)p_{1,H}]$. The low-cost firm will not mimic iff $\pi_{L,mimic} < \frac{(2-\delta)^2}{4(4-3\delta)}$.

When $c > \delta$, the high-cost firm can charge its first-best price $p^*_{sep,1,H} = \frac{(2-\delta)^2+(4-2\delta-\delta^2)c}{2(4-3\delta)}$ and the low-cost firm will not mimic the high-cost firm. The high-cost firm's profit is $\pi^*_H = \frac{(2-\delta)^2(1-c)^2}{4(4-3\delta)}$ and the low-cost firm's profit is $\pi^*_{L,sep} = \frac{(2-\delta)^2}{4(4-3\delta)}$. When $c < \delta$, in a separating equilibrium, the high-cost firm has to charge a price higher than its first-best price to $p^*_{sep,1,H} = \frac{(2-\delta)^2+2\delta(1-\delta)c+(2-\delta)\sqrt{c\delta[4(1-\delta)+c\delta]}}{2(4-3\delta)}$. The high-cost firm's profit is $\pi^*_{H,sep} = \frac{(1-c)\left[(2-\delta)^2+c\delta^2\right]+2c(2-\delta)\sqrt{c\delta[4(1-\delta)+c\delta]}}{4(4-3\delta)}$.

Step 2: finding $\boldsymbol{\sigma^*_{pool}}$

Next consider pooling equilibrium. In a pooling equilibrium, the high-cost firm and the low-cost firm charge the same first-period price $p_{1,pool}$. The first-period marginal consumer is $v^*_{1,pool} = \frac{p_{pool,1}-\alpha\delta\bar{p}_{2,H}-(1-\alpha)\delta\bar{p}_{2,L}}{1-\delta}$. The high-cost firm's second period profit is $\pi_{H,pool,2} = \delta(p_{2,H}-c)(\frac{p_{pool,1}-\alpha\delta\bar{p}_{2,H}-(1-\alpha)\delta\bar{p}_{2,L}}{1-\delta} - p_{2,H})$ and the low-cost firm's second period profit is $\pi_{L,pool,2} = \delta p_{2,L}(\frac{p_{pool,1}-\alpha\delta\bar{p}_{2,H}-(1-\alpha)\delta\bar{p}_{2,L}}{1-\delta} - p_{2,L})$. Consumers have rational expectation, so $p^*_{2,H} = \frac{2p_{pool,1}+2(1-\delta)c+(1-\alpha)\delta c}{2(2-\delta)}$, $p^*_{2,L} = \frac{2p_{pool,1}-\alpha\delta c}{2(2-\delta)}$. Therefore $v^*_{1,pool} = \frac{2p_{pool,1}-\alpha\delta c}{2-\delta}$ The total profit of the high-cost firm is $\pi_{pool,H} = \left(1 - \frac{2p_{pool,1}-\alpha\delta c}{2-\delta}\right)\left(p_{pool,1} - c\right) + \delta\left(\frac{2p_{pool,1}-\alpha\delta c}{2-\delta} - \frac{2p_{pool,1}+2(1-\delta)c+(1-\alpha)\delta c}{2(2-\delta)}\right)\left(\frac{2p_{pool,1}+2(1-\delta)c+(1-\alpha)\delta c}{2(2-\delta)} - c\right)$, the total profit of the low-cost firm is $\pi_{pool,L} = \left(1 - \frac{2p_{pool,1}-\alpha\delta c}{2-\delta}\right)\left(p_{pool,1}\right) + \delta\left(\frac{2p_{pool,1}-\alpha\delta c}{2(2-\delta)}\right)^2$.

Now consider deviation from the pooling equilibrium. It is sufficient to check the belief such that $\Pr(c = c_L) = 1$ whenever $p \neq p_{pool,1}$. If deviate, the high-cost firm's profit is $\pi_{H,pool,deviate} = \left(1 - \frac{2p_{H,dev,1}}{2-\delta}\right)\left(p_{H,dev,1} - c\right) + \delta\left(\frac{2p_{H,dev,1}-(2-\delta)c}{2(2-\delta)}\right)^2$, $p^*_{H,dev,1} = \frac{(1+c)(2-\delta)^2}{2(4-3\delta)}$,

$\pi_{H,dev}^{*} = \frac{(2-\delta)^2+2c^2(2-\delta^2)-2c(4-2\delta-\delta^2)}{4(4-3\delta)}$. The high-cost firm will not deviate if $\pi_{pool,H}^{*} \geq \pi_{H,dev}^{*}$, i.e., $p_{pool,1} \in [\frac{(2-\delta)^2+c[(2-\delta)^2+2\alpha\delta(1-\delta)]-(2-\delta)\sqrt{\alpha c\delta[4(1-\delta)-(4-(2+\alpha)\delta)c]}}{2(4-3\delta)}, \frac{(2-\delta)^2+c[(2-\delta)^2+2\alpha\delta(1-\delta)]+(2-\delta)\sqrt{\alpha c\delta[4(1-\delta)-(4-(2+\alpha)\delta)c]}}{2(4-3\delta)}]$. Similarly, for low-cost firm, if it deviates, its profit is $\pi_{L,dev}^{*} = \frac{(2-\delta)^2}{4(4-3\delta)}$. The low-cost firm doesn't deviate if $\pi_{pool,L}^{*} \geq \pi_{L,dev}^{*}$, i.e., $p_{pool,1} \in [\frac{(2-\delta)^2+2\alpha c(1-\delta)\delta-(2-\delta)\sqrt{\alpha c\delta[4-(4-\alpha c)\delta]}}{2(4-3\delta)}, \frac{(2-\delta)^2+2\alpha c(1-\delta)\delta+(2-\delta)\sqrt{\alpha c\delta[4-(4-\alpha c)\delta]}}{2(4-3\delta)}]$. When $\alpha > \frac{2(1-\delta)+\sqrt{2(1-\delta)^2+c^2(2-\delta)^2}}{c\delta}$, the pooling equilibrium giving the high-cost firm the highest profit is : $p_{pool,1}^{*} = \frac{(2-\delta)^2+c[(2-\delta)^2+2\alpha\delta(1-\delta)]}{2(4-3\delta)}$, $\pi_{pool,H}^{*} = \frac{[2(1-c)-(1-\alpha c)\delta]^2+2(1-\alpha)(1-c)c\delta^2}{4(4-3\delta)}$, $\pi_{pool,L}^{*} = \frac{(2-\delta)^2+4\alpha c(1-\delta)\delta-c^2[(2-\delta)^2-\alpha^2\delta^2]}{4(4-3\delta)}$. When $\alpha < \frac{2(1-\delta)+\sqrt{2(1-\delta)^2+c^2(2-\delta)^2}}{c\delta}$, $p_{pool,1}^{*} = \frac{(2-\delta)^2+2\alpha c(1-\delta)\delta+(2-\delta)\sqrt{\alpha c\delta[4-(4-\alpha c)\delta]}}{2(4-3\delta)}$.

Step 3: comparing σ_{sep}^{*} and σ_{pool}^{*}.

Finally we compare $\pi_{H,sep}^{*}$ and $\pi_{H,pool}^{*}$. One can show that $\pi_{H,pool}^{*} > \pi_{H,sep}^{*}$ if and only if $\alpha > \frac{2(1-\delta)-c(2-\delta)+\sqrt{2(1-c)(2-(2-\delta)(2-c)\delta)+2c(2-\delta)\sqrt{c\delta(4-(4-c)\delta)}}}{c\delta}$ and $c < \delta$, i.e., the equilibrium is pooling. The profits are $\pi_{pool,H}^{*} = \frac{[2(1-c)-(1-\alpha c)\delta]^2+2(1-\alpha)(1-c)c\delta^2}{4(4-3\delta)}$ and $\pi_{pool,L}^{*} = \frac{(2-\delta)^2+4\alpha c(1-\delta)\delta-c^2[(2-\delta)^2-\alpha^2\delta^2]}{4(4-3\delta)}$. If $c < \delta$ and $\alpha < \frac{2(1-\delta)-c(2-\delta)+\sqrt{2(1-c)(2-(2-\delta)(2-c)\delta)+2c(2-\delta)\sqrt{c\delta(4-(4-c)\delta)}}}{c\delta}$, the equilibrium is (costly) separating. The profits are $\pi_{H,sep}^{*} = \frac{(1-c)[(2-\delta)^2+c\delta^2]+2c(2-\delta)\sqrt{c\delta[4(1-\delta)+c\delta]}}{4(4-3\delta)}$ and $\pi_{L,sep}^{*} = \frac{(2-\delta)^2}{4(4-3\delta)}$. When $c > \delta$, the equilibrium is costless separating. ■

PROOF OF PROPOSITION 4.

$(\alpha\tilde{\pi}_H^{*} + (1-\alpha)\tilde{\pi}_L^{*}) - (\alpha\pi_{H,sep}^{*} + (1-\alpha)\pi_{L,sep}^{*}) = \alpha(\tilde{\pi}_H^{*} - \pi_{H,sep}^{*}) + (1-\alpha)(\tilde{\pi}_L^{*} - \pi_{L,sep}^{*}) \geq 0$. The equality holds if and only if $c > \delta$.

$(\alpha\tilde{\pi}_H^{*} + (1-\alpha)\tilde{\pi}_L^{*}) - (\alpha\pi_{H,pool}^{*} + (1-\alpha)\pi_{L,pool}^{*}) = \alpha(\tilde{\pi}_H^{*} - \pi_{H,pool}^{*}) + (1-\alpha)(\tilde{\pi}_L^{*} - \pi_{L,pool}^{*}) = (1-\alpha)c^2[(2-\delta)^2 - \delta(4-3\delta)\alpha] > 0$.

PROOF OF LEMMA 4 AND RESULT 3. We start by solving the sub-game perfect equilibrium of the game with cost transparency. Suppose the firm has high cost. Because the second-period price will be c, the marginal consumer who purchases in the first period is $\hat{v}_{H,1}^* = \frac{\hat{p}_{H,1}-c}{1-\mu}$, and the marginal consumer who purchase the product in the second period is $\hat{v}_{H,2}^* = \frac{c}{\mu}$. Because the market becomes perfectly competitive in the second period, the firm earns all its profit from the first period. Hence $\hat{\pi}_H = \left(1-\frac{\hat{p}_{H,1}-c}{1-\mu}\right)(\hat{p}_{H,1}-c)$. The optimal $\hat{p}_{H,1}$ is $\hat{p}_{H,1}^* = \frac{1-\mu}{2}+c$, and the maximum profit is $\hat{\pi}_H^* = \frac{1-\mu}{4}$. Finally we have to guarantee that $\hat{v}_{H,1}^* > \hat{v}_{H,2}^*$, which yields $c < \frac{\mu}{2}$. Similarly, for the low-cost firm, $\hat{p}_{L,1}^* = \frac{1-\mu}{2}$ and $\hat{\pi}_L^* = \frac{1-\mu}{4}$.

Next we solve the game when cost transparency is absent. To find the LMSE, we follow the same 3 steps as in the proof of lemma 2 and lemma 5. First, we analyze all separating equilibria and find σ_{sep}^*, the separating equilibrium which gives the high-type firm the highest payoff. Next we analyze all pooling equilibria and find σ_{pool}^*, the pooling equilibrium which gives the high-type firm the highest payoff. Finally we compare the high-type firm's profit in σ_{sep}^* and σ_{pool}^* to find the PBE giving the high-type firm the highest payoff.

Step 1: finding $\boldsymbol{\sigma_{sep}^*}$

Consider separating equilibria. Note that in a separating equilibrium the high-cost firm has no incentive to mimic the low-cost firm and that consumers can correctly infer the firm's cost type. Thus, the low-cost firm will set its price the same as the perfect information case, i.e. $p_{L,sep,1}^* = \frac{1-\mu}{2}$ and its profit is $\pi_{L,sep}^* = \frac{1-\mu}{4}$.

The high-cost firm's profit is $\pi_{H,sep} = \left(1-\frac{p_1-c}{1-\mu}\right)(p_1-c)$. In a separating equilibrium, the low-cost firm has no incentive to mimic the high-cost firm by charging the high-cost firm's price in the first period. If the low-cost firm mimics the high-cost firm by charging $p_1 = p_{H,sep,1}$, its profit is $\pi_L\big(p_{H,sep,1}|\phi(H|p_{H,sep,1})=1\big) = (1-\frac{p_{H,sep,1}-c}{1-\mu})p_{H,sep,1}$. $\pi_{L,sep}^* \geq \pi_L\big(p_{H,sep,1}|\phi(H|p_{H,sep,1})=1\big)$ yields $p_{H,sep,1} \in (0,\frac{1-\mu+c-\sqrt{c(c+2(1-\mu))}}{2}]\cup[\frac{1-\mu+c+\sqrt{c(c+2(1-\mu))}}{2},1-\mu)$. Moreover, any $p_{H,sep,1}$ in this region can form a PBE $(p_{H,sep,1},\frac{1-\mu}{2},\phi)$, where $\phi(H|p)=1$ if $p=p_{H,sep}$ and $\phi(H|p)=0$ if otherwise. One can show that under the condition $p_{H,sep,1} \in (0,\frac{1-\mu+c-\sqrt{c(c+2(1-\mu))}}{2}]\cup[\frac{1-\mu+c+\sqrt{c(c+2(1-\mu))}}{2},1-\mu)$, $\pi_{H,sep}$ is maximized at $p_{H,sep,1}^* = \frac{1-\mu+c+\sqrt{c(c+2(1-\mu))}}{2}$, and $\pi_{H,sep}^* = \frac{(1-\mu)^2-2c\left(c+1-\mu-\sqrt{c(c+2(1-\mu))}\right)}{4(1-\mu)}$.

Step 2: Consider pooling equilibria. In such equilibria, consumers believe that the firm is high-type with probability α, and that the firm is low-type with probability $1-\alpha$. If a consumer v purchases the product in the first period, her utility is $u_{pool,1} = v - p_{pool,1}$. If she purchases the product in the second period, her utility is $u_{pool,2} = \alpha \cdot \max\{\mu v - c, 0\} + (1-\alpha) \cdot \mu v$.

To make the analysis interesting, we assume that in the second period there are some consumers who purchase the product even if the firm turns out to be high-type in the second period, which requires that the marginal consumer in the first period v_1^* satisfies $\mu > \mu v_1^* > c$. Therefore, $v_1^* - p_{pool,1} = \alpha(\mu v_1^* - c) + (1-\alpha)\mu v_1^*$. Simple algebra yields $v_1^* = \frac{p_{pool,1} - \alpha c}{1-\mu}$. Therefore, the high-cost firm's profit is $\pi_{H,pool} = (1 - \frac{p_{pool,1}-\alpha c}{1-\mu})(p_{pool,1} - c)$, and the low-cost firm's profit is $\pi_{L,pool} = \left(1 - \frac{p_{pool,1}-\alpha c}{1-\mu}\right) p_{pool,1}$.

Analogous to the proof of Lemma 1 and 2, it is without loss of generality for us to only consider the belief ϕ such that $\phi\left(H \middle| p_1 = p_{pool,1}\right) = \alpha$ and $\phi\left(H \middle| p_1 \neq p_{pool,1}\right) = 0$. The highest possible profit a low-cost firm can get by deviating is its perfect-information profit $\pi_{L,pool,dev}^* = \hat{\pi}_L = \frac{1-\mu}{4}$. For the high-cost firm, if it deviates by charging $p_{H,pool,dev,1} \neq p_{pool,1}$, its profit will be $\pi_{H,pool,dev} = (1 - \frac{p_{H,pool,dev,1}}{1-\mu})(p_{H,pool,dev,1} - c)$. Therefore $\pi_{H,pool,dev}^* = \frac{(1-\mu-c)^2}{4(1-\mu)}$.

In a pooling equilibrium, neither the high-cost firm nor the low-cost firm has incentive to deviate. This requires $\pi_{H,pool} = \left(1 - \frac{p_{pool,1}-\alpha c}{1-\mu}\right)\left(p_{pool,1} - c\right) \geq \pi_{H,pool,dev}^* = \frac{(1-\mu-c)^2}{4(1-\mu)}$ and $\pi_{L,pool} = \left(1 - \frac{p_{pool,1}-\alpha c}{1-\mu}\right) p_{pool,1} \geq \pi_{L,pool,dev}^* = \frac{1-\mu}{4}$. The first condition is equivalent to $p_{pool,1} \in [\frac{1-\mu+(1+\alpha)c-\sqrt{\alpha c(\alpha c-2c-2\mu+2)}}{2}, \frac{1-\mu+(1+\alpha)c+\sqrt{\alpha c(\alpha c-2c-2\mu+2)}}{2}]$.

Let $\mathcal{P}_1 = [\frac{1-\mu+(1+\alpha)c-\sqrt{\alpha c(\alpha c-2c-2\mu+2)}}{2}, \frac{1-\mu+(1+\alpha)c+\sqrt{\alpha c(\alpha c-2c-2\mu+2)}}{2}]$. The second condition is equivalent to $p_{pool,1} \in [\frac{1-\mu+\alpha c-\sqrt{\alpha c(\alpha c+2(1-\mu))}}{2}, \frac{1-\mu+\alpha c+\sqrt{\alpha c(\alpha c+2(1-\mu))}}{2}]$. Let $\mathcal{P}_2 = [\frac{1-\mu+\alpha c-\sqrt{\alpha c(\alpha c+2(1-\mu))}}{2}, \frac{1-\mu+\alpha c+\sqrt{\alpha c(\alpha c+2(1-\mu))}}{2}]$. Therefore, there exists a belief $\phi \in M(p_{pool,1})$ such that $(p_{pool,1}, \phi)$ is a PBE if and only if $p_{pool,1} \in \mathcal{P}_1 \cap \mathcal{P}_2$.

The LMSE gives the high-type firm the highest profit among all PBE. One can show that without the restriction of $p_{pool,1} \in \mathcal{P}_1 \cap \mathcal{P}_2$, $\pi_{H,pool}$ is maximized when $p_{pool,1} = \frac{1-\mu+(\alpha+1)c}{2}$. It is obvious that $\frac{1-\mu+(\alpha+1)c}{2} \in \mathcal{P}_1$. When $\alpha \geq \frac{\sqrt{(1-\mu)^2+c^2}-(1-\mu)}{c}$, $\frac{1-\mu+(\alpha+1)c}{2} \in \mathcal{P}_2$, so the pooling PBE outcome which gives the high-type firm the highest profit is $p_{pool,1}^* = \frac{1-\mu+(\alpha+1)c}{2}$, and $\pi_{H,pool}^* = \frac{[1-\mu-(1-\alpha)c]^2}{4(1-\mu)}$. When $\alpha < \frac{\sqrt{(1-\mu)^2+c^2}-(1-\mu)}{c}$, $\frac{1-\mu+(\alpha+1)c}{2}$ is higher than the upper bound of $\mathcal{P}_2$,

$\frac{1-\mu+\alpha c+\sqrt{\alpha c(\alpha c+2(1-\mu))}}{2}$. Therefore, $\pi_{H,pool}$ is an increasing function of $p_{1,pool}$ on $\mathcal{P}_1 \cap \mathcal{P}_2$. As a result, the pooling PBE outcome which gives the high-cost firm the highest profit is $p_{pool,1} = \frac{1-\mu+\alpha c+\sqrt{\alpha c(\alpha c+2(1-\mu))}}{2}$ and $\pi_{H,pool}^* = \frac{(1-\mu)^2-2\alpha c^2-2c\left(1-\mu-\sqrt{\alpha c(\alpha c+2(1-\mu))}\right)}{4(1-\mu)}$.

Step 3: We compare $\pi_{H,pool}^*$ and $\pi_{sep,H}^*$ to choose the LMSE. One can see that $\pi_{H,sep}^* = \frac{(1-\mu)^2-2c\left(c+1-\mu-\sqrt{c(c+2(1-\mu))}\right)}{4(1-\mu)}$ is independent of α. When $\alpha \geq \frac{\sqrt{(1-\mu)^2+c^2}-(1-\mu)}{c}$, $\pi_{H,pool}^* = \frac{[1-\mu-(1-\alpha)c]^2}{4(1-\mu)}$. When $\alpha < \frac{\sqrt{(1-\mu)^2+c^2}-(1-\mu)}{c}$, $\pi_{H,pool}^* = \frac{(1-\mu)^2-2\alpha c^2-2c\left(1-\mu-\sqrt{\alpha c(\alpha c+2(1-\mu))}\right)}{4(1-\mu)}$. Next we show that $\pi_{H,pool}^*$ is an increasing function of α. When $\alpha < \frac{\sqrt{(1-\mu)^2+c^2}-(1-\mu)}{c}$, rearranging $\pi_{H,pool}^*$ yields $\pi_{H,pool}^* = C + \frac{c}{2(1-\mu)}[\sqrt{\left(\alpha c+(1-\mu)\right)^2-(1-\mu)^2}-\alpha c]$, where C is independent of α. It is easy to see that $\pi_{H,pool}^*$ strictly increases with α when $\alpha < \frac{\sqrt{(1-\mu)^2+c^2}-(1-\mu)}{c}$. When $\alpha \geq \frac{\sqrt{(1-\mu)^2+c^2}-(1-\mu)}{c}$, $\pi_{H,pool}^* = \frac{[1-\mu-(1-\alpha)c]^2}{4(1-\mu)}$ also increases with α. Moreover, one can show that $\pi_{H,pool}^*$ is a continuous function of α. Therefore, $\pi_{H,pool}^*$ is a strictly increasing function of α when $\alpha \in (0,1)$.

When $\alpha \geq \frac{\sqrt{(1-\mu)^2+c^2}-(1-\mu)}{c}$, $\pi_{H,pool}^* \geq \pi_{H,sep}^*$, implies that $\frac{[1-\mu-(1-\alpha)c]^2}{4(1-\mu)} > \frac{(1-\mu)^2-2c\left(c+1-\mu-\sqrt{c(c+2(1-\mu))}\right)}{4(1-\mu)}$, i.e. $\alpha > 1 - \frac{1-\sqrt{1-\left(\sqrt{\frac{c}{1-\mu}\left(\frac{c}{1-\mu}+2\right)}-\frac{c}{1-\mu}\right)^2}}{\frac{c}{1-\mu}}$. One can also show that $1 - \frac{1-\sqrt{1-\left(\sqrt{\frac{c}{1-\mu}\left(\frac{c}{1-\mu}+2\right)}-\frac{c}{1-\mu}\right)^2}}{\frac{c}{1-\mu}} > \frac{\sqrt{(1-\mu)^2+c^2}-(1-\mu)}{c}$. This result, together with the fact that $\pi_{H,sep}^* = \frac{(1-\mu)^2-2c\left(c+1-\mu-\sqrt{c(c+2(1-\mu))}\right)}{4(1-\mu)}$ is independent of α and $\pi_{H,pool}^*$ is a strictly increasing function of α when $\alpha \in (0,1)$, implies that $\pi_{H,pool}^* \geq \pi_{H,sep}^*$ if and only if $\alpha \geq 1 - \frac{1-\sqrt{1-\left(\sqrt{\frac{c}{1-\mu}\left(\frac{c}{1-\mu}+2\right)}-\frac{c}{1-\mu}\right)^2}}{\frac{c}{1-\mu}} \equiv \alpha_{comp}^*$.

In conclusion, when consumers do not know the firm's cost, when $\alpha < \alpha_{comp}^*$, the equilibrium is separating, $\pi_{H,sep}^* = \frac{1-\mu-2c\left(c+1-\mu-\sqrt{c(c+2(1-\mu))}\right)}{4(1-\mu)}$ and $\pi_{L,sep}^* = \frac{1-\mu}{4}$. When $\alpha \geq \alpha_{comp}^*$, the equilibrium is pooling, $\pi_{H,pool}^* = \frac{(1-\mu-(1-\alpha)c)^2}{4(1-\mu)}$ and $\pi_{L,pool}^* = \frac{(\alpha c+1-\mu)^2-c^2}{4(1-\mu)}$. When consumers know the firm's cost, $\hat{\pi}_H^* = \hat{\pi}_L^* = \frac{1-\mu}{4}$. ■