國立臺灣大學管理學院資訊管理學系

碩士論文

Department of Information Management

College of Management

National Taiwan University

Master Thesis

# 零售商或平台商？線上中介商的商業模式選擇

# Merchant or Platform? The Business Model Selection Problem of an Online Intermediary

陳韋志

Wei-Chih Chen

指導教授：孔令傑 博士

Adviser: Ling-Chieh Kung, Ph.D.

中華民國 106 年 6 月

June, 2017

doi:10.6342/NTU201704144

# 國立臺灣大學碩士學位論文
# 口試委員會審定書

零售商或平台商？線上中介商的商業模式選擇

Merchant or Platform? The Business Model Selection Problem of an Online Intermediary

本論文係陳韋志君（學號 R04725004）在國立臺灣大學資訊管理學系、所完成之碩士學位論文，於民國 106 年 6 月 20 日承下列考試委員審查通過及口試及格，特此證明

口試委員： 孔令傑

所　　長： 蔡益坤

doi:10.6342/NTU201704144

## 謝辭

十餘年的就學生涯，於今終於要寫下句點，不禁讓我有些不捨與惆悵。不捨在於，也許以後再也無法繼續擁有學生時期悠閒自在的時光，雖然偶有讓人覺得繁重喘不過氣的作業與報告，但回首一望卻也不過僅僅是如此而已；惆悵在於，即將到來的兵役與職場生活，都是與學生截然不同的身分環境，我又是否能夠保持初心、得償所願呢？

在研究所的日子中，我有幸能夠遇到一位兼具耐心與幽默的指導老師孔令傑教授，在教授的引領之下，我才得以在短短的兩年中，稍稍體會做研究的生活與精神。與教授的緣分要自大學說起，在我的大學時期，教授就已經以大學長的角色提供我經驗避免我走了許多彎路，小到生活瑣事、選課考量，大到生涯規劃，研究所選擇。從碩一上，教授就賦予我們挑戰，在 2016 年年初的決策分析研討會中投稿！在當下，我們連研究是什麼都還很茫然，更別說論文題目了。於是在如此壓力的鞭策下，我們迅速的吸收成長；當其他同儕還在適應研究所生活時，我們已經開始習慣與教授咪聽、與數學為伍的生活。在學習的過程中，教授所給予的細心指導與幫助是不可或缺的，不僅僅是讓我避免在錯誤的地方徘徊過久鑽牛角尖，更重要的是他對研究的熱情與對真相的執著，這樣的精神讓我十分敬佩，教授對論文的要求相當高，甚至會非常細心的為我的論文逐字修改，不厭其煩的為我校正許多錯誤。到了論文口試與 PACIS 研討會的前夕，教授甚至不惜犧牲假日撥出時間陪我們練習，給予指導，讓我不勝感謝。

在此也要感謝我的家人，在我念研究所的期間給予我最大的支持，不僅在經濟上讓我無後顧之憂，也在生活上盡量讓我專注於研究。除此之外研究所期間的同儕也是非常大的力量，感謝偉宏、騏瑋學長在碩一時期的引領，讓我更快熟悉研究的節奏；謝謝冠宇、何禾學長姐在勤業實習時的幫助，也是一段很難忘的時光；謝謝維哲常常陪著我插科打諢；謝謝珮瑜總能即時制止我們過度



doi:10.6342/NTU201704144

的喧鬧；謝謝柏宣總是在研究室，陪著我度過了數不清的夜晚；謝謝千瑜在電子錢包一案所給予的所有幫助與一起趕報告的時光；謝謝怡安如媽媽一樣的關懷與體貼；謝謝宸安讓我明白研究的熱情，也祝你在國外得償所願。最後也要謝謝子翔、敬傑、鑑霖、佩蓉等學弟妹們，雖然我如此的不正經卻仍然願意當作學長尊重，度過了好長一段值得懷念的時光。

最後也要謝謝從大學以來陪我至今的蔡伶。謝謝妳，沒有妳的話，我不知道現在的生活會是甚麼樣子；妳也讓我明白了何為負責任，希望我能成為像妳一樣的人。

陳韋志 謹致

于台大資訊管理研究所

民國一百零六年八月



doi:10.6342/NTU201704144

# 中文摘要

時至今日，線上中介商在電子商務中扮演了重要角色。傳統上它以零售商的方式向製造商購買商品再販售給消費者；隨著科技的演進，越來越多的中介商選擇轉型成為平台，將消費者轉介給賣家。由於可能的商業模型不只一種，對中介商而言，如何抉擇一個恰當的商業模型無可厚非地是個必須考慮的議題。

為了探討這個問題，我們建立了一個賽局模型，考慮一個線上中介商與數個製造商，其中製造商們生產異質性的商品並相互競爭。中介商有的選項為：(1) 以零售商自居，向製造商買進商品。(2) 以平台身分讓製造商直接販售商品給終端消費者。兩種商業模型間最關鍵的差異點為零售模式具有設定零售價的權力，但是平台沒有。

我們的研究結果指出隨著商品在生產端或消費者端的異質程度減少，中介商在零售模式與平台模式的抉擇中會比較偏向平台模式。相對地，如果商品們差異甚大，零售模式會是一個較好的選項。除此之外，我們進一步考慮了混合模式，即讓部分製造商以零售模式合作，部分製造商以平台模式合作。結果指出，中介商應與生產成本較低的製造商以平台模式合作，因為先行者優勢應利用在更具商業潛力的商品。另一方面，我們也研究了以收入分成方式合作的平台模式，發現隨著商品相似度提高，其抑制高零售價抑制的特性會侵蝕中介商的利潤。

關鍵字：線上中介商、雙層供應鏈、雙邊平台、賽局理論



doi:10.6342/NTU201704144

## Thesis Abstract

Online intermediary plays an important role in e-commerce nowadays. Traditionally, it serves as a merchant buying goods from manufacturers and reselling them to consumer. With the development of technology, more and more intermediaries choose to become platforms referring consumers to sellers. As there are more than one potential business models exist, it is critical for an intermediary to decide which model to adopt.

To address this question, we establish a game-theoretic model with an intermediary and multiple manufacturers competing in selling heterogeneous products. The intermediary has the options of (1) playing the role of a merchant and buying goods from the manufacturers and (2) being a platform and allowing manufacturers to reach end consumers through it. The key difference between the two models is a merchant has the power to set the retail price, while a platform does not.

Our analysis indicates that as the heterogeneity among products decreases, either at the production or the consumer side, the intermediary prefers the platform model to the merchant model. Nevertheless, if the products are highly distinct, the merchant model will be a better choice. Moreover, we further study the mixed model that combines both the merchant and platform models. Considering the first-mover advantage, the intermediary should adopt the platform model for the cost-effective manufacturer as his product owns greater commercial potential. On the other hand, we investigate the implementation of the platform model with revenue sharing. Restriction of high price hurts the intermediary's profit when the product similarity goes up.

Keywords: Online intermediary, Two-layer supply chain, Two-sided platform, Game theory



doi:10.6342/NTU201704144

# Contents





doi:10.6342/NTU201704144

doi:10.6342/NTU201704144

# List of Figures





doi:10.6342/NTU201704144

doi:10.6342/NTU201704144

# List of Tables





doi:10.6342/NTU201704144

doi:10.6342/NTU201704144

# Chapter 1

# Introduction

## 1.1 Background and motivation

The exponential growth of the Internet is an influential and important issue that brings new thoughts of managerial strategies in commerce. For instance, eBay, as a representative success of the dot-com bubble, is famous for its C2C (customer-to-customer) auction-type sales. Taobao, founded as an online platform that allows people to trade on, is now one of the most influential marketplace in the world. They revolutionize the way businesses happen and give the general public a playing ground for their market.

eBay, Taobao, and many C2C marketplace are well-known as two-sided platforms. Ryan et al. (2012) define the *platform* model as "control of the goods is left to the seller, and the intermediary simply matches buyers with sellers." In other words, a platform does not own the products sold through it. Instead, it provides referrals for the engaged sellers to reach consumers. Consequently, the product prices are set by the sellers. On



doi:10.6342/NTU201704144

the contrary, in the traditional supply chain model, which is called the *merchant* model in this study, a retailer buys products from manufacturers, keeps them as inventories, and resells to consumers. Apparently, by having the ownerships of the products, the retailer set retail prices to maximize its profit.

As there are more than one feasible business models of the online selling business, an important issue naturally arises: which model to adopt to maximize the online channel owner's profit? In this study, we look for critical factors one should consider when deciding which model to adopt. As the owner of the online channel may be a retailer, a platform, or a mixture, in this study we will follow the economics literature to call it an online *intermediary*. We investigate the strategic impacts of an intermediary on an online market. In particular, we concentrate on the impact of the intermediary's model selection on the industry structure, pricing decisions, and competition intensity.

## 1.2 Research objectives

To address our research question, we construct a stylized model with an online intermediary and several manufacturers producing and selling heterogeneous products. The intermediary has the options of (1) playing the role of a merchant and buying goods from the manufacturers and (2) being a platform and allowing manufacturers to reach end consumers through it. By being a merchant, the intermediary sets product prices with regards to the wholesale prices set by manufactures. In contrast, by adopting the platform model, the intermediary sets up a transaction fee, which will be considered by manufactures when setting their retail prices. By referring consumers to manufacturers,



doi:10.6342/NTU201704144

the intermediary shares a part of sales revenues from manufacturers. The problem is more complicated when we take the heterogeneity of manufacturers and products into consideration. The main research question is the intermediary's model selection problem: Which types of model is more beneficial?

## 1.3 Research plan

The remainder of this study is organized as follows. In the next section, we review some related works with respect to e-tailers, platforms, and referrals. Then we develop a game-theoretic model to describe the interaction among the intermediary and manufacturers. We first analyze the market equilibrium under each of the two business models and then discuss the intermediary's model selection problem. The last section summarizes our findings. All proofs are in the appendix.



doi:10.6342/NTU201704144

doi:10.6342/NTU201704144

# Chapter 2

# Literature review

## 2.1 E-tailers

Direct sales of suppliers through online websites and delivery service to end consumers has been widely discussed in academic research. Tsay and Agrawal (2004) notice that channel conflicts occur due to the fact that a supplier may compete with its consumer in the environment of direct channel. Balasubramanian (1998) models the competition between direct Internet marketers and conventional retailers. Chiang et al. (2003) and Yoo and Lee (2011) compare the traditional channel, direct channel, and dual-channel considering the impact of consumer acceptance and conclude that direct marketing reduces system inefficiency. Wu et al. (2015) examine the condition for exclusive or nonexclusive referrals to retailers.

Balasubramanian (1998) analyzes the competition between direct Internet marketers and conventional retailers. The author considers a model consisting of circularly located



doi:10.6342/NTU201704144

consumers, retailers and a direct marketer. In a setting where consumers have complete knowledge of product availability and prices in all channels, each retailer competes with the direct marketer rather than neighboring retailers. In contrast, in a setting where the direct marketer may control the level of information in the marketplace, it is shown that providing information to all consumers may be suboptimal under some circumstances.

Chiang et al. (2003) look into the supply-chain design considering a dual channel, direct sales and retailer channel, especially focusing on the impact of customer acceptance of the direct channel. They show that direct marketing reduces system inefficiency by alleviating double marginalization in equilibrium. In addition, they conclude that the introduction of the direct channel will be accompanied by a wholesale price reduction, which benefits the retailer.

Tsay and Agrawal (2004) notice a "channel conflict" on a supply chain when a supplier considers establishing a direct channel and therefore competing with her reseller. In order to coordinate the channel, they evaluate three distribution strategies: (1) only reseller sales, (2) only direct sales, and (3) both channel types. They compare the three strategies with a benchmark system which is centrally controlled. It is found that the addition of a direct channel alongside a reseller channel is not necessarily detrimental to the reseller. In fact, it may make both parties better off in some cases.

Yoo and Lee (2011) focus on the competition between direct marketers and their retailers with heterogeneous consumer preference for using the Internet channel. They build a model based on Balasubramanian (1998) to analyze the impact of the mixed channel structures under diverse market conditions. They show that, in equilibrium, the introduction of an Internet outlet leads to ambiguous effects on retail prices depending on



doi:10.6342/NTU201704144

the channel structure. Furthermore, they conclude that under certain market conditions, an independent retailer might become worse off by adding its own Internet channel.

Wu et al. (2015) investigate whether it is an equilibrium for the manufacturer to refer consumers exclusively to a retailer or nonexclusively to both retailers in a market with one manufacturer and two heterogeneous retailers. They suggest that if the referral segment market size is sufficiently high, the nonexclusive referral is the equilibrium because the benefit of a bigger demand surpasses the loss of double marginalization deterioration. Otherwise, the exclusive referral is the equilibrium choice and the manufacturer would refer consumers to the more cost-efficient and smaller retailer.

While this stream of literature focuses on the relation and competition in a supply chain, they do not take the other channel option, the platform model, into consideration. We contribute to this stream by allowing the intermediary to strategically choose between being a e-tailer or a platform.

## 2.2 Platform

There are also numerous studies which investigate the impact of *informediary* which provides informations rather than physical goods. Baye and Morgan (2001) find that building a market that shares price information results to more competitive equilibrium prices. Viswanathan et al. (2007) show that consumers who search for price information online pay lower prices for automobiles than those who do not search. Chen et al. (2002) and Iyer and Pazgal (2003) conclude that the referral infomediary prefers an exclusive strategy. Arnold et al. (2011) study the market with asymmetric customer segments.



doi:10.6342/NTU201704144

Baye and Morgan (2001) consider an information gatekeeper who establishes a platform for sharing price information. The gatekeeper sets up subscription and advertising fees for consumers and retailers, respectively. They find that in order to maximize her profit, the gatekeeper would set a low subscription fee to motivate all consumers to join the platform. In addition, she sets the advertising fee higher than the system optimal one, which is zero. Moreover, the product price on the platform is lower than that outside the platform due to competition. They also show that there exists potential inefficiency.

Chen et al. (2002) analyze the effect of referral informediaries on retail markets and examine the contractual arrangements that they should use in selling their service. Two retailers both have two types of consumers: a segment of loyal consumers and a segment of comparison shopping consumers. Another player is a referral informediary which reaches some proportion of the total consumer population. They find that, in equilibrium, the referral price will be lower than the retail store price offered by the enrolled retailer. Moreover, the profits of the enrolled retailer are in the form of an inverted U with respect to the reach of the referral informediary because of an increasing demand effect, an increasing competitive effect, and a price discrimination effect. Furthermore, the referral infomediary prefers an exclusive strategy of allowing only one of the retailers to enroll.

Iyer and Pazgal (2003) study Internet shopping agents (ISAs) that allow consumers to costlessly look for online retailers. In an environment with intense price competition, homogeneous goods, and no search cost for obtaining price information, one does not expect to find large differences between the prices charged by retailers in an ISA. However, as the empirical data show, the prices charged by different retailers in the ISA can differ substantially. To investigate the conflict, they build a model with an ISA, $n$ retailers,



doi:10.6342/NTU201704144

and consumers consisting of store loyals, ISA loyals, and partial loyals. They find that in equilibrium an inside retailer will use a mixed price strategy. The average prices that consumers pay through the ISA can increase or decrease with the number of inside retailers depending on whether the reach of the ISA is independent of the number of joining retailers.

Viswanathan et al. (2007) focus on a mechanism for market segmentation and price discrimination based on consumers' use of online infomediaries. Initially, they begin with an analytical model that investigates the implications of providing different types of information on the prices consumers paid. They indicate that consumers not only seek different types of information but also pay different prices for the same product. With an empirical study in the automotive retailing market, they reinforce the previous statement and show that different uses of online infomediaries is related to underlying consumer characteristics.

Arnold et al. (2011) state that in previous studies, the analyses related to the information gatekeeper are based on a critical assumption that loyal customers are allocated equally across firms. However, they observe a discrepancy exists between those models and the practice. Therefore, they build their model based on that in Baye and Morgan (2001) to investigate the role of asymmetric loyal customer segments in a market with an information gatekeeper. They show that in equilibrium the firm with the smaller loyal market is more likely to advertise its price through the gatekeeper but adopts a higher advertised price distribution than that of the firm with a larger loyal market. In addition, the existence of the gatekeeper results in a more intense competition on price.

In contrast with the aforementioned papers, our study includes both types of business



doi:10.6342/NTU201704144

models, e-tailer and platform, and consider the optimal strategy for the intermediary. The endogeneity of the strategic choice is our main focus.

## 2.3 Referrals

The literature about a marketer's decision to provide referrals to competitors is of a small body. Cai and Chen (2011) state that competing retailers may use the referrals to align their incentives. Ryan et al. (2012) study a marketplace and a retailer with higher consumer preference on purchasing from the marketplace.

Cai and Chen (2011) adopt a game-theoretic model to study referrals among competing online retailers. The customers possess heterogeneous preferences, which is captured by a Hotelling line. They show that although retailers have to share profit with its competitors, one-way and mutual referrals may both be beneficial under certain market conditions. Because of the fact that referrals help retailers expand the aggregate market, these competing retailers may use the referrals to align the retailer's incentives and facilitate implicit collusion.

Ryan et al. (2012) study a retailer facing a marketplace selling similar and competing products about whether to sell through the marketplace and at what price. At the same time, the marketplace firm also considers whether she should sell products and compete with his merchant as well as design the optimal contract with his participating retailer. In conclusion, they find that the "three channel system" does not exist in the equilibrium. Moreover, the pure competition equilibrium is more likely to arise when the retailer is much weaker than the marketplace firm. In contrast, the pure coordination equilibrium



doi:10.6342/NTU201704144

takes place with higher likelihood when consumers do not have a strong preference for purchasing from the marketplace system relative to purchasing from the retailer.

Motivated by these two studies, we also consider an online intermediary which can serve as a merchant and a platform at the same time. As an extension of this stream of literature, we concentrate on the optimal alternative in business.



doi:10.6342/NTU201704144

doi:10.6342/NTU201704144

# Chapter 3

# Model

**Intermediary and manufacturers.** We consider a market with an intermediary (she) and two manufacturers (for each of them, he) producing substituting products. Manufacturers are heterogeneous at the production side. More precisely, manufacturer $i \in \{1, 2\}$ has an exogenous unit production cost $c_i$, where $c_1 \geq c_2$. That is, manufacturer 2 is more cost-effective than manufacturer 1. We call product $i$ as the product manufactured by manufacturer $i$, $i \in \{1, 2\}$.

Each manufacturer may establish one of two relationships with the intermediary. If the intermediary serves as a merchant for manufacturer $i$, she will purchase product $i$ from manufacturer $i$ at a wholesale price $w_i$. She then decides the retail price $p_i$ for product $i$. As manufacturer $i$ needs to choose his wholesale price, we say the two players are in mode W. On the contrary, if the intermediary serves as a platform for manufacturer $i$, the manufacturer will set the retail price $p_i$. This is therefore called mode R. By referring consumers to manufacturer $i$, the intermediary shares revenues for product $i$ sold through her by setting a transaction fee $r_i$.



doi:10.6342/NTU201704144

| | $W$ | $R$ |
|---|---|---|
| $W$ | $\pi_1^{WW}, \pi_2^{WW}, \pi_I^{WW}$ | $\pi_1^{WR}, \pi_2^{WR}, \pi_I^{WR}$ |
| $R$ | $\pi_1^{RW}, \pi_2^{RW}, \pi_I^{RW}$ | $\pi_1^{RR}, \pi_2^{RR}, \pi_I^{RR}$ |

Table 3.1: Profits of players

**Industry structures.** In the most general situation, the platform may be flexible to serve the two manufacturers in different modes. There will then be four possible industry structures: RR (the intermediary is a pure platform), WW (the intermediary is a pure merchant), WR (the intermediary is a merchant for manufacturer 1 but a platform for manufacturer 2), and RW (the opposite of WR). The profit of manufacturer $i \in \{1, 2\}$ in structure $k \in \{RR, WR, RW, WW\}$ is denoted by $\pi_i^k$, and that of the intermediary is $\pi_i^k$. We denote the demand of product $i$, which naturally depends on the prices of both products, by $D_i(p_1, p_2)$ or simply $D_i$. For manufacturer $i$, his profit is $(w_i - c_i)D_i$ under the W mode or $(p_i - c_i - r_i)D_i$ under the R mode. For the intermediary, her profit from product $i$ is $(p_i - w_i)D_i$ under the W mode or $r_i D_i$ under the R model. Her total profit is then the sum of the profits from the two products. The complete list of profit notations is in Table 3.1.

In this study, we restrict the intermediary to set a single transaction fee $r$ for both manufacturers under the RR structure, that is, $r_1 = r_2 = r$. This can be a reasonable restriction, as applying applying suitable transaction fees for each products brings more challenges and costs at management sides. In practice, platforms usually set a single fee for one category of products.

**Product demands.** To capture the heterogeneity of products and the impact of



doi:10.6342/NTU201704144

prices, we adopt the model of Bertrand competition of heterogeneous products (Gibbons, 1992). More precisely, we assume that the demand of product $i$ is

$$D_i(p_1, p_2) = 1 - p_i + bp_{3-i},$$

where $i \in \{1, 2\}$ and $b \in [0, 1)$. In this setting, a product's demand is negatively affected by its own price but positively affected by the price of the competing product. The exogenous parameter $b$ measures the degree of similarity of the two products or intensity of competition. The larger $b$ is, the more similar the two products are. The competition then becomes more intense, as one's price affects the other's demand more significantly. Note that $b$ is restricted to be strictly less than 1, as the direct impact of one's price should be higher than the indirect impact of the competitor's price.

The sequence of events is depicted in Figure 3.1. First, the intermediary chooses a model, platform, merchant or mixed. Second, if the platform model is chosen, the intermediary sets a transaction fee for manufacturers. For the merchant model, the two manufacturers set their wholesale prices simultaneously. In the mixed model, the intermediary sets a transaction fee for one manufacturer and the other manufacturer set his wholesale price afterwards. Third, the retail prices of the two products are either set by the intermediary under the platform model or the two manufacturers simultaneously under the merchant model. Finally, products are sold and all players gain their profits.

Table 3.2 lists the parameters and decision variables.



doi:10.6342/NTU201704144

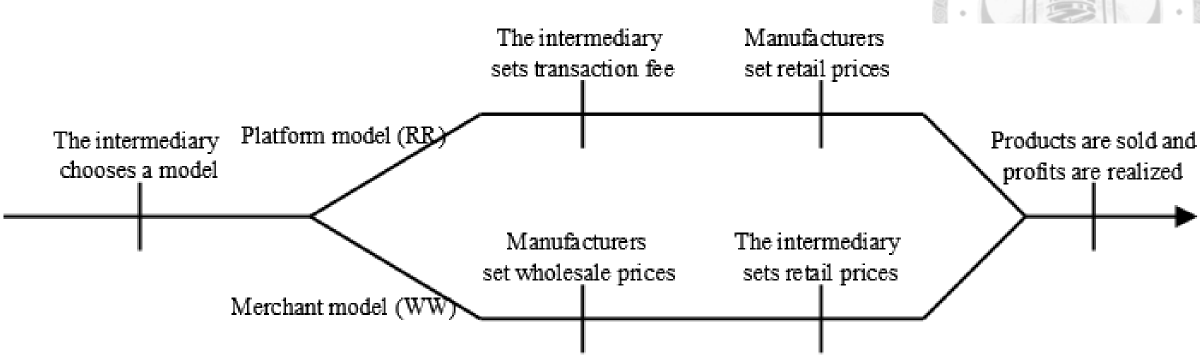


Figure 3.1: Time sequence

| | |
|---|---|
| **Parameters** | |
| $b$ | The degree of similarity of the two products |
| $c_i$ | The unit production cost of product $i$ |
| **Decision variables** | |
| $D_i$ | The demand of product $i$ |
| $p_i$ | The retail price of product $i$ |
| $w_i$ | The wholesale price of product $i$ |
| $r$ | Transaction fee |

Table 3.2: List of notations



doi:10.6342/NTU201704144

# Chapter 4

# Analysis

In this chapter, we first characterize the best strategy for each player in different scenarios. We focus on pure strategy: the pure merchant model (WW) and the pure platform model (RR). As a result, the intermediary has the information of which business model can maximize its own profit. We then discuss how the intermediary's optimal business model changes in response to the heterogeneity of manufacturers/products at the supply and demand sides. It is investigated which parameters affect the decision of the firms and the equilibrium industry structure. Based on our findings, we connect our results to real world suggestions.

## 4.1 Equilibrium analysis

In this section, we investigate on the Nash equilibrium resulting from the impact of the contract between firms under different business structures. For each business model, the contract structure influences the degree of various exogenous impact on the profits



doi:10.6342/NTU201704144

and products' prices of firms. Therefore, we analytically derive the equilibrium of each structures as basis to be compared afterwards.

### 4.1.1 Pure merchant model (WW)

When the merchant model is adopted by the firms, the intermediary becomes a retailer that purchases products from the manufactures and resells to consumers. In this case, the retailer owns the products and has more sovereignty over its pricing decision. Therefore, she may set prices to maximize her profit, i.e., she solves

$$\begin{aligned}\pi_I^{WW} &= \max_{p_1,p_2}(p_1 - w_1)D_1 + (p_2 - w_2)D_2 \\ &= \max_{p_1,p_2}(p_1 - w_1)(1 - p_1 + bp_2) + (p_2 - w_2)(1 - p_2 + bp_1)\end{aligned}$$

subject to $D_1 \geq 0$ and $D_2 \geq 0$. By predicting how the wholesale prices will affect the retail prices and demands, the two manufacturers' play a simultaneous game, in which each of them solves

$$\pi_i^{WW} = \max_{w_i}(w_i - c_i)D_i, i = 1, 2.$$

The equilibrium prices and profits are summarized in Lemma 1.

**Lemma 1.** *Under the merchant model, the equilibrium wholesale prices are* $w_1^{WW} = \frac{(2+b)+2c_1+bc_2}{4-b^2}$ *and* $w_2^{WW} = \frac{(2+b)+2c_2+bc_1}{4-b^2}$ *, retail prices are* $p_1^{WW} = \frac{\left(6-b-2b^2\right)+2(1-b)c_1+b(1-b)c_2}{2(4-b^2)(1-b)}$ *and* $p_2^{WW} = \frac{((6-b-2b^2)+b(1-b)c_1+2(1-b)c_2)}{2(4-b^2)(1-b)}$*, and the manufacturer's profits are* $\pi_1^{WW} = \frac{((2+b)+(b^2-2)c_1+bc_2)^2}{(2(4-b^2)^2)}$ *and* $\pi_2^{WW} = \frac{((2+b)+bc_1+(b^2-2)c_2)^2}{2(4-b^2)^2}$*. Moreover, we have* $w_1^* \geq w_2^*$*,* $p_1^* \geq p_2^*$*, and* $\pi_1^{WW} \leq \pi_2^{WW}$*. The intermediary earns the profit*

$$\pi_I^{WW} = \frac{(2(2+b)^2 - 2(2+b)^2(1-b)(c_1+c_2) - (3b^2-4)(1-b)(c_1^2+c_2^2) - 2b^3(1-b)c_1c_2)}{4(4-b^2)^2(1-b)}.$$



doi:10.6342/NTU201704144

Since manufacturer 2 is more cost-effective in the market, he sets a lower wholesale price and induces a lower retail price compared to manufacturer 1. By utilizing his advantage, he captures a larger market share and earns a higher profit. It is also observed that the intermediary's profit decreases as manufacturer 1's cost goes up.

Lemma 1 also shows that, in equilibrium, the two products will both appear on the market. In other words, the intermediary's optimal strategy is always to sell both products regardless how high the cost difference is. With the control of both product prices, the intermediary maximizes his profit by properly dividing the market into two segments. The existence of the intermediary alleviates the competition between the two manufacturers.

### 4.1.2 Pure platform model (RR)

In the platform model, the intermediary acts as a two-sided platform that matches buyers and sellers. A transaction fee is set by the intermediary. Manufacturers own the products; therefore, the retail prices of products are set by the manufacturers. The intermediary has no direct control of the products' pricing strategies. All she may do is to use the transaction fee to indirectly affect the equilibrium retail prices. The intermediary sets the transaction fee $r$ to maximize her profit

$$\pi_I^{RR}(r) = r(D_1 + D_2).$$

Then the two manufacturers simultaneously set their retail prices by solving

$$\pi_i^{RR} = \max_{p_i}(p_i - c_i - r)D_i, \quad i = 1, 2.$$



doi:10.6342/NTU201704144

All these optimization problems are subject to the demand non-negativity constraints $D_1 \geq 0$ and $D_2 \geq 0$. In Lemma 2, we first characterize the manufacturers' equilibrium decisions given the transaction fee $r$.

**Lemma 2.** *Given the transaction fee $r$, the equilibrium retail prices in the platform model are $p_1^{RR} = \frac{(2+b)(1+r)+2c_1+bc_2}{(4-b^2)}$ and $p_2^{RR} = \frac{(2+b)(1+r)+bc_1+2c_2}{(4-b^2)}$ , where $p_1^{RR} \geq p_2^{RR}$. The intermediary's profit is $\pi_I^{RR}(r) = \frac{r(2-2(1-b)r-(1-b)(c_1+c_2))}{2-b}$.*

Lemma 2 summarizes the equilibrium prices of products in response to the transaction fee $r$ from the manufactures' perspective. Both products' prices increase in the transaction fee since the transaction fee acts as sales cost for manufacturers. Furthermore, similar to the merchant model, manufacturer 2 benefits from his lower production cost. With the cost advantage, he sets a lower price and attracts more consumers. With the manufacturers' responses in mind, the intermediary looks for $r$ to maximize $\pi_I^{RR}(r)$ derived in Lemma 2. In the next lemma we present some analytical properties regarding the intermediary's problem.

**Lemma 3.** *The function $\pi_I^{RR}(r)$ is concave in $r$. Therefore, there exists a unique $\tilde{r}$ that satisfies $\frac{d\pi_I^{RR}(r)}{dr}|_{r=\tilde{r}} = 0$. The intermediary's optimal transaction fee $r^{RR}$ satisfies*

$$r^{RR} = \begin{cases} \tilde{r} = \frac{2-(1-b)(c_1+c_2)}{4(1-b)} & \text{if } \tilde{r} \leq \hat{r} = \frac{(2+b)-(2-b^2)c_1+bc_2}{(2+b)(1-b)} \\ \hat{r} & \text{otherwise} \end{cases},$$

*where $\hat{r}$ is the boundary point to satisfy $D_1 \geq 0$ and $D_2 \geq 0$. The intermediary earns the profit*

$$\pi_I^{RR}(r^{RR}) = \begin{cases} \frac{(2-(1-b)(c_1+c_2))^2}{8(1-b)(2-b)} & \text{if } r^{RR} = \tilde{r} \\ \frac{(1+b)c_1}{(2+b)(1-b)} + \frac{(-2+3b+b^2)c_2}{(2+b)(2-b)(1-b)} + \frac{(1-b)c_1c_2}{2-b} - \frac{(2-b^2)(1+b)c_1^2}{(2+b)^2(1-b)} + \frac{b(-2+3b+b^2)c_2^2}{(2+b)^2(2-b)(1-b)} & \text{otherwise} \end{cases},$$



doi:10.6342/NTU201704144

Lemma 3 states the existence and uniqueness of the optimal transaction fee $r^*$ to maximize the profit of the intermediary in the platform model. There are two special values of $r$ mentioned in Lemma 3. On the one hand, $\tilde{r}$ is the ideal optimal $r$ which satisfies the first-order condition of the concave profit function. $\hat{r}$, on the other hand, is the cap of the feasible region of $r$ derived from the demand constraints. Therefore, the first-order point $\tilde{r}$ is the optimal feasible transaction fee for the intermediary when it does not reach the cap $\hat{r}$. Once $\tilde{r}$ violates the cap, $\hat{r}$ is the optimal transaction fee.

As aforementioned, the product prices increase in the transaction fee. While the transaction fee represents a tool for the intermediary to extract revenue from manufacturers, once it goes beyond the cap, manufacturer 1 earns nothing and stops raising its product price. As a result, manufacturer 2 would also stop raising its product price. Consequently, the intermediary no longer benefits from raising the fee once it goes beyond the cap.

In addition, when we deeply look into the optimal transaction fee, we observe that $\tilde{r}$ is decreasing in $c_1$ and $c_2$. In other words, it is optimal for the intermediary to raise up the transaction fee with lower product costs. Since manufacturers benefit from lower costs by setting lower product prices and attracting more consumers, the intermediary shares benefit by utilizing higher transaction fee naturally.

## 4.2 Optimal model selection

With the basic knowledge of the equilibria under various market structures, we are now ready to address our main research question: Merchant or platform, which one is better? To demonstrate the effect of cost difference between manufacturers, we set $c_1 = c \in [0, 1]$



doi:10.6342/NTU201704144

and $c_2 = 0$ in the following comparisons.

In the next proposition we show the relative profitability of the two pure models, the pure merchant model and the pure platform model. An illustration is shown in Figure 4.1.

**Proposition 1.** *There exists a unique* $\bar{b} \in (0,1)$ *such that for all* $b > \bar{b}$, $\pi^{RR} > \pi^{WW}$. *For all* $b < \bar{b}$, *there exists a unique* $\bar{c}(b) \in (0,1)$ *such that* $\pi^{RR} > \pi^{WW}$ *if and only if* $c < \bar{c}(b)$.

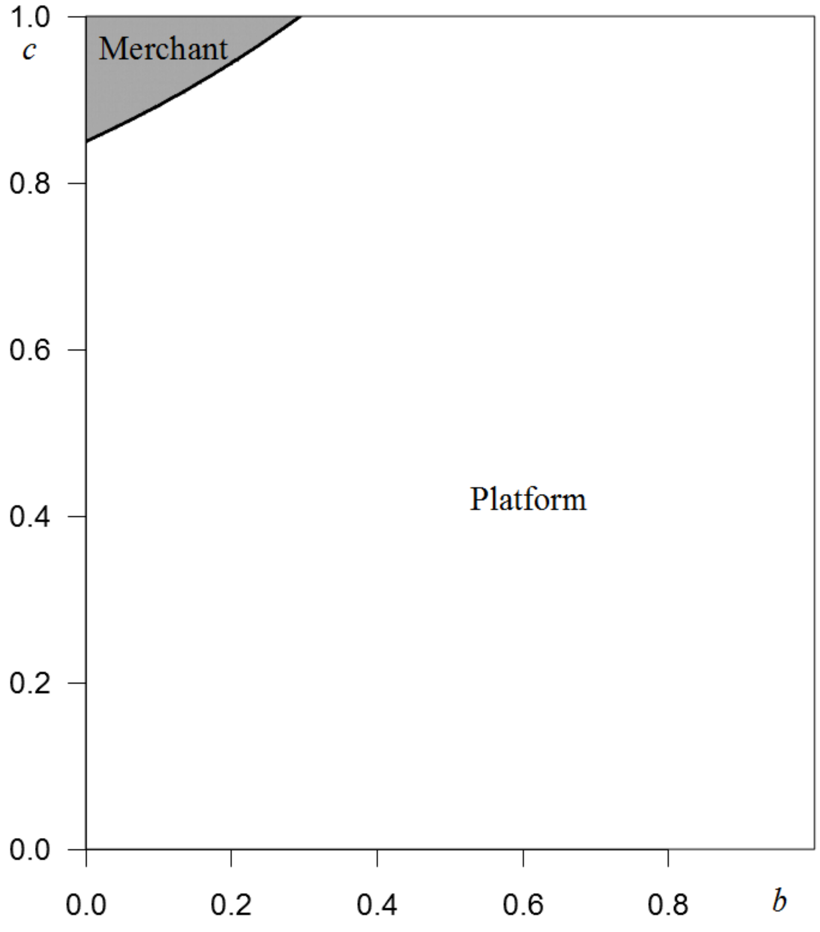


Figure 4.1: Comparison of pure models

In most scenarios, the intermediary would choose the platform model as the better one. Notice that in the platform model, the transaction fee, which is first set by the



doi:10.6342/NTU201704144

intermediary, inevitably affects the decisions of manufacturers. By capitalizing on this first-mover advantage, the intermediary is able to indirectly manipulate prices of products to her benefit. Restricted by the fee, the manufacturers may only set the prices of products in a sub-optimal level. To sum up, the intermediary is greatly rewarded with her first-mover advantage by adopting the platform model.

Moreover, when $b$ is large or $c$ is small, the intermediary prefers the platform model; when $b$ is small and $c$ is large, the merchant model is more attractable. When $b$ increases, the two products becomes more similar at demand side. Therefore, the detriment resulting from the inflexibility of one single transaction fee is mitigated. Furthermore, higher $b$ leads to higher products prices. Thus, the negative effect of prisoner's dilemma is extenuated. In conclusion, the intermediary prefers the platform model when $b$ increases.

Under the merchant model, the two manufacturers will decide their wholesale prices differently considering their different production costs. When $c$ increases, the discrepancy between the products at the production side increases, and the resulting difference in wholesale prices increases. Nevertheless, if the intermediary chooses the platform model, only one single transaction fee must be applied to both manufacturers. Such inflexibility would hurt the intermediary when the two products are highly different at the production side, as in that case the two manufacturers' actually prefer quite different transaction fees. As a result, the intermediary prefers the merchant model when $c$ increases.

One may argue that this finding is prone to the assumption that only one transaction fee is applied to both products. While this may be true from the perspectives of model and analysis, we would like to note that in practice most platforms do adopt this single fee policy for each product category. In other words, different transaction fees may be applied



doi:10.6342/NTU201704144

for different kinds of products (3C, apparels, books, etc.), but only one transaction fee is set for all products from all manufacturers within one category. We set up our model to fit this feasibility constraint faced by real-world platforms in industry.

In conclusion, the two business models exhibit quite different natures. Under the merchant model, the notorious "double marginalization" problem increases the retail prices to an inefficient level due to the multi-layer structure of the supply chain. The platform model is an effective tool for the intermediary to bypass the double marginalization problem and increase the profits of the industry and itself. Furthermore, the first-mover advantage over manufacturers makes it more profitable than the merchant model. Nevertheless, it suffers from the restriction that only one transaction fee can be applied to all products and manufacturers in the same product category. The drawbacks make the platform model a less preferred model when the products are quite different (when $b$ is small and $c$ is large).

## 4.3 Comparison of system profits

In the previous section, we have shown the optimal business model selection in all cases from the perspective of the intermediary. By utilizing the first-mover advantage, the intermediary prefers the platform model in most of the cases. Nevertheless, if the intermediary is now cooperating with manufacturers using the traditional merchant model, whether the platform model is a win-win option for all players is a critical issue. Although the intermediary is satisfied with the platform model, the manufacturers would not agree with the new model if it is not profitable for them.



doi:10.6342/NTU201704144

To verify if the platform model is a win-win solution, we have to compare the system profits between two models. We define that the system profit of the merchant model as $\pi_s^{WW} = \pi_I^{WW} + \pi_1^{WW} + \pi_2^{WW}$ and the system profit of the platform model as $\pi_s^{RR} = \pi_I^{RR} + \pi_1^{RR} + \pi_2^{RR}$. The following proposition shows the result of the comparison.

**Proposition 2.** *If* $2(2+b) - (6+b-3b^2)c_1 + (2+3b-b^2)c_2 \geq 0$*,* $\pi_s^{WW} \leq \pi_s^{RR}$ *for all* $b \in [0,1)$*,* $c_1 \in [0,1]$ *and* $c_2 \in [0,1]$*.*

Proposition 2 indicates that when the intermediary sets the transaction fee under the first-order condition, the system profit of the platform model is greater than that of the merchant model. In other words, manufacturers would agree to transform their original merchant model to the platform model if the intermediary is willing to share some profit earned from the platform model. Since the system profit of the platform model is greater than that of the merchant model, the intermediary may share some profit with the manufacturers (e.g., by paying each of them a fixed fee) but still earn more in the platform model than in the merchant one. Therefore, the platform model is a win-win solution at least when the platform strategy does not result in one manufacturer leaving the industry.

In conclusion, even if the intermediary is currently cooperating with manufacturers using the traditional merchant model, she can persuade manufacturers to change to the platform model, because the system profit is higher.



doi:10.6342/NTU201704144

doi:10.6342/NTU201704144

# Chapter 5

# Extensions

## 5.1 Mixed model (WR)

In the mixed model, one manufacturer cooperates with the intermediary in the traditional merchant model, but the other sells his products through the intermediary, which is the platform model. One important issue is that which manufacturer should the intermediary choose to implement the merchant model or the platform model? Is the cost-effective one more suitable for the merchant model or the platform model instead? To answer these questions, we must have what would happen in mind first if we adopt the mixed model.

### 5.1.1 Equilibrium analysis

We start from WR first, that is, the intermediary is a merchant for manufacturer 1 but a platform for manufacturer 2. First of all, the intermediary sets the transaction fee to



doi:10.6342/NTU201704144

maximize her profit

$$\pi_I^{WR} = \max_r (p_1 - w_1)D_1 + rD_2.$$

Then, manufacturer 1 sets the wholesale price to maximize his profit

$$\pi_1^{WR} = \max_{w_1} (w_1 - c_1)D_1.$$

In the last of all, the intermediary sets the price of product 1 and competes with product 2, whose price is set by manufacturer 2. In other words, they simultaneously decide their price by solving

$$\pi_I^{WR} = \max_{p_1} (p_1 - w_1)D_1 + rD_2 \text{ and } \pi_2^{WR} = \max_{p_2} (p_2 - r - c_2)D_2,$$

where the latter is the profit function of manufacturer 2. All these optimization problems are subject to the demand non-negativity constraints $D_1 \geq 0$ and $D_2 \geq 0$. Similarly, we first characterize firms' equilibrium decisions in the form of transaction fee $r$.

**Lemma 4.** *Assume that a given transaction fee $r$ will result in positive demands of both products in equilibrium. In this case, the equilibrium wholesale price set by manufacturer 1 is*

$$w_1^{WR} = \frac{(2+b) - b(1-b^2)r + (2-b^2)c_1 + bc_2}{2(2-b^2)}.$$

*In addition, the equilibrium retail prices in the mixed model are*

$$p_1^{WR} = \frac{(2+b)(3-b^2) + b(5-2b^2)r + (2-b^2)c_1 + b(3-b^2)c_2}{(4-b^2)(2-b^2)}$$

*and*

$$p_2^{WR} = \frac{(2+b)(4+b-2b^2) + (8-b^2-b^4)r + b(2-b^2)c_1 + (8-3b^2)c_2}{2(4-b^2)(2-b^2)}.$$

*It then follows that the platform's equilibrium profit given $r$ is*

$$\pi_I^{WR}(r) = (p_1^{WR} - w_1^{WR})(1 - p_1^{WR} + bp_2^{WR}) + r(1 - p_2^{WR} + bp_1^{WR}).$$



doi:10.6342/NTU201704144

According to Lemma 4, we can observe that the two retail prices both increase in the transaction fee $r$. It is reasonable for manufacturer 2 since the transaction fee plays a role of cost similar in the platform model. Moreover, the price of product 1 also increases in the transaction fee as they are not directly related. Since the price of product 1 is set by the intermediary, the intermediary strategically raises up the price of product 1 in order to provide manufacturer 2 more incentive to set higher product's price.

Somewhat surprisingly, when the transaction fee $r$ increases, which implies that manufacturer 2 is subject to a higher marginal cost, manufacturer 1 would reduce rather than increase his wholesale price $w_1$ in response to his competitor's cost increase. To understand this non-trivial result, note that when $r$ goes up, the demand of product 1 can be derived as

$$\frac{(2+b)-b(1-b^2)r+(b^2-2)w_1+bc_2}{4-b^2},$$

which decreases in $r$. The same thing happens to product 2. As the increase of the retail prices cuts down the market demand of product 1, manufacturer 1 is forced to reduce $w_1$ to avoid overpricing and having a too low sales volume. This explains his response of reducing the wholesale price.

In the next lemma we present the optimal transaction fee regarding the intermediary's problem.

**Lemma 5.** *The intermediary's optimal transaction fee in the mixed model WR is*

$$r^{WR}=\frac{2(2+b)(8-3b-3b^2+b^3)-2b(1-b)(2-b^2)c_1+2(1-b)(-16+9b^2-b^4)c_2)}{(64-26b^2-3b^4+b^6)(1-b)}.$$

*Furthermore,* $p_1^{WR}(r^{WR})\geq p_2^{WR}(r^{WR})$*,* $D_1(r^{WR})>0$ *and* $D_2(r^{WR})>0$ *unless* $b=0$*.*

Lemma 5 states the optimal transaction fee in the mixed model WR. It can be dis-



doi:10.6342/NTU201704144

covered that the optimal transaction fee $r^W R$ decreases in $c1$ and $c2$ because there is no more room to earn revenue from each sales. As products' costs increase, the prices of products rise and hurt both demands. The intermediary then has no choice but to lower down the transaction fee.

Moreover, we observe that $p_1^{WR}(r^{WR}) \geq p_2^{WR}(r^{WR})$. One may argue that the phenomenon results from the setting that $c_1 \geq c_2$. However, even if $c_1 = c_2 = c$, $p_1^{WR}(r^{WR}) \geq p_2^{WR}(r^{WR})$ for all $c \in [0, 1]$. Consequently, the major difference between two products' prices is the business structure. In other words, $p_1^{WR}(r^{WR})$ is greater because of the merchant model, which reconfirms the effect of the double marginalization.

Furthermore, Lemma 5 indicates that both demands of products are positive. Though the intermediary is able to except the costly product 1 by setting higher price, she finds that it is more profitable to keep both products in the market. Same as the merchant model that the intermediary may properly divide the market into two segments, with the help of the transaction fee and the control of the price of product 1.

Under the RW structure, we may simply reverse the roles of products 1 and 2. Therefore, to derive the equilibrium wholesale price, retail prices, transaction fee, etc., all we need to do is to exchange $c_1$ and $c_2$ in the above expressions.

### 5.1.2 Optimal model selection

By utilizing Lemmas 4 and 5, we are able to (maybe numerically) derive the equilibrium of the market in the mixed model. In addition, given the values of $b$ and $c$, the profit of the intermediary in the mixed model (both WR and RW) can be yielded. In this section



doi:10.6342/NTU201704144

we compare all market structures, including the pure merchant model, the pure platform model and two mixed models (WR and RW). As a result, observations are summarized and listed in the following section. A visualization is presented in Figure 5.1.

**Observation 1.** *There exists a unique* $\bar{b} \in (0,1)$ *such that for all* $b > \bar{b}$, $\pi_I^{RR} > \pi_I^{WR}$. *Moreover, when* $b < \bar{b}$, *there exists a unique* $\bar{c} \in (0,1)$ *such that* $\pi_I^{RR} > \max\{\pi_I^{WR}, \pi_I^{RW}, \pi_I^{WW}\}$ *if* $c < \bar{c}(b)$ *and* $\pi_I^{WR} > \max\{\pi_I^{RR}, \pi_I^{RW}, \pi_I^{WW}\}$ *if* $c > \bar{c}(b)$.

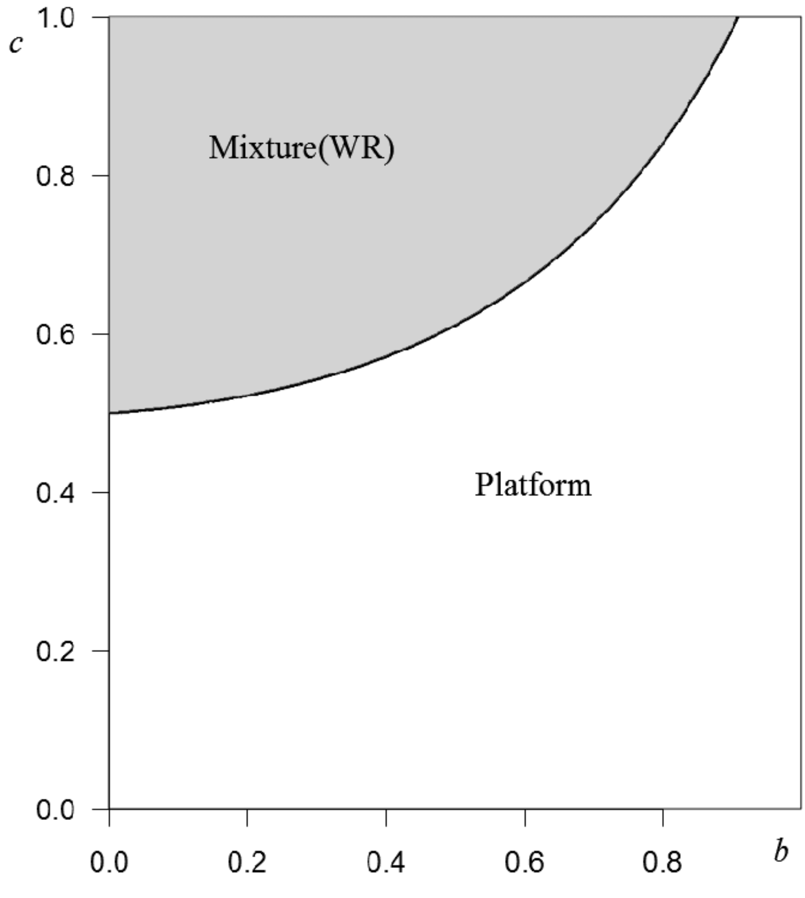


Figure 5.1: Comparison of all models

Somewhat surprisingly, the comparison including all possible models (Figure 5.1) appears like the comparison of pure models (Figure 4.1) except that the merchant model



doi:10.6342/NTU201704144

part is replaced with the mixed model (WR) in Figure 5.1. In other words, the intermediary still prefers the platform model when $b$ is large or $c$ is small. Nevertheless, when $b$ is small and $c$ is large, the mixed model (WR) is the better solution comparing with the merchant model. The reason behind this phenomenon is similar. In the platform model, the first-mover advantage still exists. However, since the intermediary only relies on one single transaction fee to share the benefit from manufacturers, she is restricted when products are greatly different. The negative effect is more critical when products become more distinct at either production side or consumer side.

Looking at Figure 4.1 and Figure 5.1 more deeply, one may wonder that if the mixed model (WR) overpowers the merchant model from the perspective of intermediary. The numerical result confirms the hypothesis.

**Observation 2.** $\pi_I^{WR} > \pi_I^{WW}$ *for all* $b \in [0, 1)$ *and* $c \in [0, 1]$.

If we only consider the mixed model (WR) and the pure merchant model, the former one is much better. The mixed model (WR) combines parts of merchant model and parts of platform model. First, considering the effect of first-mover advantage, the intermediary has the ability to set the transaction fee in the mixed model (WR). Then, for the flexibility part, there are two methods for the intermediary to share benefit from two manufacturers, the transaction fee for manufacturer 1 and the price of product 2 for manufacturer 2. Therefore, the intermediary owns partial first-mover advantage without lost of flexibility.

In contrast, the advantage of the merchant model is only the flexibility as aforementioned. The effect of inflexibility comes out when the products are quite distinct. However, the mixed model (WR) also allows the intermediary to adapt herself to distinct



doi:10.6342/NTU201704144

products. Consequently, the mixed model (WR) is still better than the merchant model when products are different. In conclusion, the mixed model (WR) dominates the pure merchant model in all cases.

Now we take a look at the comparison of the mixed models, WR and RW. Since in both cases the partial first-mover advantage exists, a selection issue then arises. Which mixed model can better capitalize on the advantage?

**Observation 3.** $\pi_I^{WR} > \pi_I^{RW}$ *for all* $b \in [0,1)$ *and* $c \in [0,1]$.

Observation 3 indicates that in the mixed model, the intermediary prefers the merchant model for the manufacturer with higher production cost. The cost-effective manufacturer is more suitable to the platform model. In other words, the product with lower production cost is more profitable. Therefore, the intermediary should choose to apply the first-mover advantage to the product with higher potential.

## 5.2 Implementation of the platform model with revenue sharing

In the platform model, there exists other mechanism for the intermediary to cooperate with manufacturers. Instead of transaction fee, it is also possible for the intermediary to share profit by a revenue sharing proportion $\phi$. In this section we would discuss the profitability of revenue sharing in the platform model.



doi:10.6342/NTU201704144

### 5.2.1 Equilibrium analysis

First of all, we have to find out the equilibrium under the platform model. The intermediary sets the revenue sharing proportion $\phi \in [0,1]$ to maximize her profit

$$\Pi_I^{RR}(\phi) = \phi(p_1 D_1 + p_2 D_2).$$

Then the two manufacturers simultaneously set their retail prices by solving

$$\Pi_i^{RR} = \max_{p_i}((1-\phi)p_i - c_i)D_i, \quad i = 1, 2.$$

All these optimization problems are subject to the demand non-negativity constraints $D_1 \geq 0$ and $D_2 \geq 0$. In Lemma 6, we first characterize the manufacturers' equilibrium decisions given the revenue sharing proportion $\phi$.

**Lemma 6.** *Given the revenue sharing proportion $\phi$, the equilibrium retail prices in the platform model are $p_1^* = \frac{(2+b)(1-\phi)+2c}{(4-b^2)(1-\phi)}$ and $p_2^* = \frac{(2+b)(1-\phi)+bc}{(4-b^2)(1-\phi)}$, where $p_1^* \geq p_2^*$. The manufacturers earn the profits $\Pi_1^{RR} = \frac{1}{1-\phi}\left(\frac{(2+b)(1-\phi)+(-2+b^2)c}{4-b^2}\right)^2$ and $\Pi_2^{RR} = \frac{1}{1-\phi}\left(\frac{(2+b)(1-\phi)+bc}{4-b^2}\right)^2$. The intermediary's profit is $\Pi_I^{RR}(\phi) = \frac{\phi(2((1-\phi)(2+b))^2+b(2+b)^2(1-\phi)c+(3b^2-4)c^2)}{(4-b^2)^2(1-\phi)^2}$.*

Lemma 6 summarizes the equilibrium prices of products in response to the revenue sharing proportion $\phi$ from the manufactures' perspective. Both products' prices increase in the revenue sharing proportion since the revenue sharing proportion acts as sales cost. Furthermore, similar to the merchant model, manufacturer 2 benefits from his lower production cost. With the cost advantage, he sets a lower price and attracts more consumers. With the manufacturers' responses in mind, the intermediary looks for $\phi$ to maximize $\Pi_I^{RR}(\phi)$ derived in Lemma 6. Though the complicated structure of $\Pi_I^{RR}(\phi)$ makes it impossible to have a closed-form expression for the intermediary's optimal $\phi$,



doi:10.6342/NTU201704144

in the next lemma we present some analytical properties regarding the intermediary's problem.

**Lemma 7.** *The function* $\Pi_I^{RR}(\phi)$ *is quasi-concave in* $\phi \in [0,1]$. *Therefore, there exists a unique* $\tilde{\phi} \in [0,1]$ *that satisfies* $\frac{d\Pi_I^{RR}(\phi)}{dr}|_{\phi=\tilde{\phi}} = 0$. *The intermediary's optimal revenue sharing proportion* $\phi^*$ *satisfies*

$$\phi^* = \begin{cases} \tilde{\phi} & \text{if } \tilde{\phi} \leq \hat{\phi} = 1 - \frac{(2-b^2)c}{2+b} \\ \hat{\phi} & \text{otherwise} \end{cases}.$$

Lemma 7 states the existence and uniqueness of the optimal revenue sharing proportion $\phi^*$ to maximize the profit of the intermediary in the platform model. There are two special values of $\phi$ mentioned in Lemma 7. On the one hand, $\tilde{\phi}$ is the ideal optimal $\phi$ which satisfies the first-order condition of the quasi-concave profit function. $\hat{\phi}$, on the other hand, is the cap of the feasible region of $\phi$ derived from the demand constraints. Therefore, the first-order point $\tilde{\phi}$ is the optimal feasible revenue sharing proportion for the intermediary when it does not reach the cap $\hat{\phi}$. Once $\tilde{\phi}$ violates the cap, $\hat{\phi}$ is the optimal feasible revenue sharing proportion.

As aforementioned, the product prices increase in the revenue sharing proportion. While the revenue sharing proportion represents a tool for the intermediary to extract revenue from manufacturers, once it goes beyond the cap, manufacturer 1 earns nothing and stops raising its product price. As a result, manufacturer 2 would also stop raising its product price. Consequently, the intermediary no longer benefits from raising the proportion once it goes beyond the cap.

By utilizing Lemmas 6 and 7, we are able to numerically derive the equilibrium of the market in the platform model. Given the values of $b$ and $c$, the intermediary can first



doi:10.6342/NTU201704144

numerically search for the first-order point $\tilde{\phi}$ and compare it with the upper bound $\hat{\phi}$ to find the optimal $\phi^*$. Substituting $\phi^*$ into Lemma 6 then gives us the equilibrium retail prices, product demands, and manufacturers' profits.

### 5.2.2 Optimal model selection

As Lemma 7 shows, there is no closed-form expression for $\phi^*$ in the platform model. As it is hard to derive the profit of the intermediary, we do a numerical study to obtain some intuitions first. For each combination of $b \in [0, 1)$ and $c \in [0, 1)$, we numerically find $\phi^*$ and the associated platform's profit $\Pi_I^{RR}$ under the merchant model. We then compare that with the platform's profit $\pi_I^{WW}$ under the merchant model, which may be calculated by the closed-form formula we derived. Figure 5.2 is a visualization of our result.

A first look at Figure 5.2 will give us the following idea: When $b$ or $c$ is large, the merchant model is better; on the contrary, when $b$ and $c$ are both small, the platform model is better. This idea is analytically proved in the following proposition.

**Proposition 3.** *There exist two cut-off values $\hat{b}_1 \in (0, 1)$ and $\hat{c}_1 \in (0, 1)$ such that for all $(b, c) < (\hat{b}_1, \hat{c}_1)$, we have $\pi_I^{WW} < \Pi_I^{RR}$. On the contrary, there exist $\hat{b}_2 \in (\hat{b}_1, 1)$ and $\hat{c}_2 \in (\hat{c}_1, 1)$ such that for all $(b, c) > (\hat{b}_2, \hat{c}_2)$, we have $\pi_I^{WW} > \Pi_I^{RR}$.*

We find that the intermediary prefers the merchant model when $b$ goes up but prefers the platform model when $b$ goes down. The phenomenon is quite different to the platform model with transaction fee, where the platform model is preferred as $b$ increases. To explain the contradiction, we should take a closer look at the difference between the two revenue sharing mechanisms. The transaction fee is a fixed cost from the perspective



doi:10.6342/NTU201704144

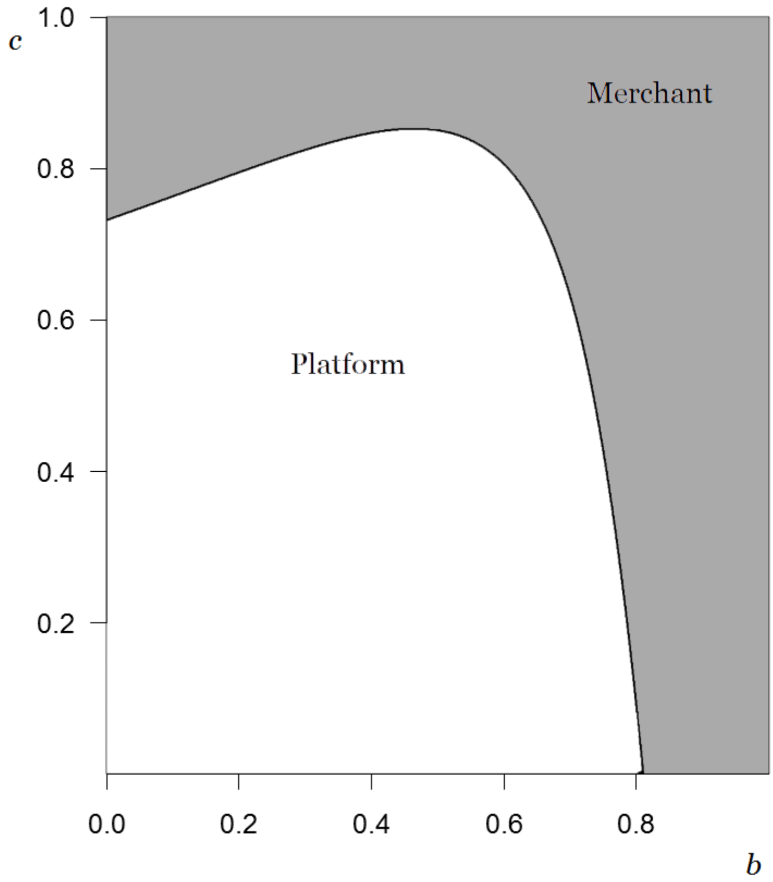


Figure 5.2: Comparison of pure models under revenue sharing

of manufacturers. In contrast, the revenue sharing mechanism dynamically shares more profit as the products' prices increase. As higher product prices hurt demands, manufacturers are more willing to increase price in the case of transaction fee comparing to revenue sharing.

Now that when $b$ goes up the demands of products goes up, which results to the incentive of raising up the products' prices. Because of the different tendency of raising prices, the equilibrium product prices in the case of implementing transaction fee is higher than that using revenue sharing. The system profit and the intermediary's profit are thus lower in the platform model implementing revenue sharing.



doi:10.6342/NTU201704144

If we look at Figure 5.2 more deeply, we would obtain an interesting observation at the top-left corner. There is a region of moderate $c$ (roughly between 0.75 and 0.85) such that the impact of $b$ on the optimal model is non-monotone. When $b$ is either small or large, the intermediary prefers the merchant model; in contrast, the platform model is more advantageous when $b$ stays in the medium. We may again analytically confirm this observation.

**Proposition 4.** *There exist $\tilde{c}_1 \in (0,1)$ and $\tilde{c}_2 \in (\tilde{c}_1, 1)$ such that for all $c \in [\tilde{c}_1, \tilde{c}_2]$, there exist $\tilde{b}_1 \in (0,1)$ and $\tilde{b}_2 \in (\tilde{b}_1, 1)$ such that $\pi_I^{WW} > \pi_I^{RR}$ if $b < \tilde{b}_1$ or $b > \tilde{b}_2$ but $\pi_I^{WW} < \pi_I^{RR}$ if $b \in (\tilde{b}_1, \tilde{b}_2)$.*

While $c$ is large, the impact of the cost difference dominates the selection of models. In other words, with a huge gap between products at the production side, the intermediary has no choice but to adopt the merchant model. Similarly, when $c$ is small, the platform model becomes dominant. When $c$ is moderate, the impact of the competition intensity enlarges. When $b$ is large, the restriction of price from revenue sharing hurts the profit of the intermediary. Therefore, taking control of product prices is a solution to avoid low prices. However, when $b$ is small, the two products are quite different at the consumer side, a situation that is quite similar to the case that $c$ is large. The disadvantage of relying on only one single revenue sharing product is too significant for the intermediary. The merchant model is thus preferred.



doi:10.6342/NTU201704144

## 5.3 Enhanced platform model

According to our previous analysis, the platform model is less profitable than the merchant model when the products are quite distinct due to the inflexibility of setting only one transaction fee. In the enhanced platform model (ERR), we relax the restriction of setting one transaction fee. Namely, the intermediary has the ability to set different transaction fees for each manufacturers, separately. Would the enhanced platform model dominate all possible models?

To complete the analysis, we have to figure out the equilibrium outcome of the interactions among players first. Then, optimal model selection can be made by comparing the profit of the intermediary in the enhanced platform model with that of other models.

### 5.3.1 Equilibrium analysis

The enhanced platform model is the same as the platform model except that the intermediary now can set different transaction fees for manufacturers to maximize her profit

$$\pi_I^{ERR}(r) = r_1 D_1 + r_2 D_2.$$

Then the two manufacturers simultaneously set their product prices by solving

$$\pi_i^{ERR} = \max_{p_i}(p_i - c_i - r_i)D_i,\ \ i = 1, 2.$$

Likely, all these optimization problems are subject to the demand non-negativity constraints $D_1 \geq 0$ and $D_2 \geq 0$. In Lemma 8 we summarize the equilibrium outcomes of all players.



doi:10.6342/NTU201704144

**Lemma 8.** *Under the enhanced platform model, the equilibrium product prices are* $p_1^{ERR} = \frac{(2+b)(3-2b)+2(1-b)c_1+b(1-b)c_2}{2(4-b^2)(1-b)}$ *and* $p_2^{ERR} = \frac{(2+b)(3-2b)+2(1-b)c_2+b(1-b)c_1}{2(4-b^2)(1-b)}$. *The intermediary sets transaction fees* $r_1^{ERR} = \frac{1}{2(1-b)} - \frac{1}{2}c_1$ *and* $r_2^{ERR} = \frac{1}{2(1-b)} - \frac{1}{2}c_2$ *and earns the profit*

$$\pi_I^{ERR} = \frac{2(2+b) - 2(2+b)(1-b)(c_1+c_2) + (2-b^2)(1-b)(c_1^2+c_2^2) - 2b(1-b)c_1c_2}{4(4-b^2)^2(1-b)}.$$

Lemma 8 lists the equilibrium actions of the manufacturers and intermediary. The price of product 1 is higher than that of product 2 because of the higher production cost of product 1. In addition, since the transaction fee and the demand of product 1 are smaller than those of product 2 ( $r_1 \leq r_2$ and $D_1 = 1 - p_1 + bp_2 \leq 1 - p_2 + bp_1 = D_2$ ), the intermediary earns less from product 1.

### 5.3.2 Optimal model selection

With the market equilibrium in the enhanced platform model, we are now ready to address the main research question: How profitable is the enhanced platform model? Would the enhanced platform model dominates all possible models?

According to Observation 1, when products are quite different, the mixed model (WR) is the better solution. As products are similar, the platform model is more profitable. Now we have the fifth model, the enhanced platform model. All we need to do is to compare the profit of the intermediary in the enhanced platform model with the two winners.

For the comparison with the platform model, the only difference between the two model is that the intermediary may set different transaction fees for manufacturers. Therefore, in the enhanced platform model the intermediary still has the ability to keep



doi:10.6342/NTU201704144

the two transaction fees the same for both manufacturers and all players act the same as in the platform model. In other words, the platform model is a degenerated version of the enhanced model. Consequently, the enhanced platform model is at least not worse than the platform model for the intermediary.

For the comparison with the mixed model, the result is shown in Propotition 5.

**Proposition 5.** $\pi_I^{ERR} \geq \pi_I^{WR}$ *for all* $b \in [0, 1)$, $c_1 \in [0, 1]$ *and* $c_2 \in [0, 1]$.

According to Propotition 5, the enhanced platform model also outperforms the mixed model (WR). Collectively, the enhanced platform model is the best business model in all cases. The reason is quite reasonable. As the enhanced platform model is improved from the platform model, it also owns the first-mover advantage which the platform model owns. Moreover, since the restriction of setting one transaction fee is relaxed, the disadvantage of inflexibility in the platform model no longer exists. This explains its superiority



doi:10.6342/NTU201704144

doi:10.6342/NTU201704144

# Chapter 6

# Conclusions and future works

## 6.1 Conclusions

In this study, we establish a game-theoretic model to examine the model selection problem of an online intermediary. There are manufacturers offering heterogeneous products, and the intermediary has the option to decide how to cooperate with them by choosing either the merchant model or the platform model. The main difference between the two models is whether the intermediary owns the power of setting prices. Through our analysis, we discover the significance of first-mover advantage under the platform model. The entire market would be properly manipulated by the intermediary capitalizing on the transaction fee, which induces the victory of the platform model over most scenarios. Moreover, we show that the profitability of the two models are governed by the similarity of the products at the production and consumer sides. When the two products are quite different at either side, the platform model is less profitable due to the inflexibility of setting different transaction fees for different products. Furthermore, we compare the



doi:10.6342/NTU201704144

system profit between the two models. Our analysis indicates that the system profit under the FOC condition of the platform model is higher than that of the merchant model.

We further study the mixed model that combines both the merchant and platform models. Considering the first-mover advantage, the intermediary should adopt the platform model for the cost-effective manufacturer as his product owns greater commercial potential. On the other hand, we investigate the implementation of the platform model with revenue sharing. Restriction of high price hurts the intermediary's profit when the product similarity goes up. Finally, we relax the restriction of setting only one transaction fee for both manufacturers in the enhanced platform model. After improved, the enhanced platform model is the most profitable model.

## 6.2 Future works

The result has several avenues for further research. First, there may exist other intermediaries. Competition between intermediaries may occur and can be further studied. Second, in our current study, the intermediary cannot influence the demand of customers. In reality, intermediary might provide mechanism that affect customers' valuation on the product such as advertisement, data technology, better services, etc. It is interesting how these options may influence the decisions of the players in the environment.

To highlight the impact of industry structure and product similarity on the pricing decisions, we omit demand uncertainty in our model; otherwise, the intermediary would have a strong incentive favoring the platform model. We also assume that there is no



doi:10.6342/NTU201704144

information asymmetry in the market. If the product quality is hidden to consumers, quality risk may force the intermediary to choose the merchant model. Nevertheless, it would contribute more to the literature if we further study the joint impact of these factors.



doi:10.6342/NTU201704144

doi:10.6342/NTU201704144

# Appendix A

# Proofs of lemmas and propositions

**Proof of Lemma 1.** We first verify the concavity of the objective function. Since $\nabla^2 \pi_I^{WW}(p_1, p_2) = \begin{bmatrix} -2 & 2b \\ 2b & -2 \end{bmatrix}$, and its leading principals are $-2 < 0$ and $\begin{vmatrix} -2 & 2b \\ 2b & -2 \end{vmatrix} = 4 - 4b^2 > 0$, $\pi_I^{WW}(p_1, p_2)$ is negative definite. This implies that the first-order condition will be necessary and sufficient for an optimal solution. Let's omit the constraints for a while. The first-order condition gives us $\frac{\delta \pi_I^{WW}}{\delta p_1} = (1 - 2p_1^* + bp_2 + w_1) + b(p_2 - w_2) = 0$, i.e., $p_1^* = \frac{1+2bp_2+w_1-bw_2}{2}$. Similarly, we have $p_2^* = \frac{1+2bp_1+w_1-bw_2}{2}$. Solving the two equations leads to $p_1^* = \frac{1+(1-b)w_1}{2(1-b)}$ and $p_2^* = \frac{1+(1-b)w_2}{2(1-b)}$.

Based on the response of the intermediary, manufacturer $i$ maximizes his profit $\pi_i^{WW}(w_i) = (w_i - c_i)\frac{1-w_i+bw_{3-i}}{2}$, $i = 1, 2$. As $\pi_i^{WW}(w_i)$ is concave ($\frac{d^2\pi_i^{WW}(w_i)}{dw_i^2} = -1 < 0$), the first-order condition requires the optimal wholesale price $w_i^*$ to satisfy $w_i^* = \frac{1+bw_{3-i}+c_i}{2}$, $i = 1, 2$, where $c_1 = c$ and $c_2 = 0$. Solving the two equations for the two manufacturers results in $w_1^* = \frac{(2+b)+2c_1+bc_2}{4-b^2}$ and $w_2^* = \frac{(2+b)+2c_2+bc_1}{4-b^2}$. By plugging in $w_1^*$ and $w_2^*$ to the expressions of $p_i^*$, $\pi_i^{WW}$, and $\pi_I^{WW}$, we may obtain the equilibrium retail prices and profits



doi:10.6342/NTU201704144

given in the lemma.

Finally, we check the ignored constraints. We have $D_1 = 1 - p_1 + bp_2 = \frac{(2+b)+(b^2-2)c}{2(4-b^2)} \geq 0$ if and only if $c \leq \frac{2+b}{2-b^2}$, which is true because $c \leq 1 \leq \frac{2+b}{2-b^2}$. We also have $D_2 = 1 - p_2 + bp_1 = \frac{(2+b)+bc}{2(4-b^2)} > 0$. This completes the proof. $\square$

**Proof of Lemma 2.** Since $\pi_i^{RR}$ is concave ($\frac{d^2\pi_i^{RR}}{dp_i^2} = -2 < 0$), we get the optimal $p_i$ by applying the first-order condition $\frac{d\pi_i^{RR}}{dp_i} = 0$ for manufacturer $i$ and yield $p_i^* = \frac{1+bp_{3-i}+c_i+r}{2}$. Solving the two equations results in $p_i^*(r) = \frac{(2+b)(1+r)+2c_i+bc_{3-i}}{(4-b^2)}$, which is the optimal price responding to $r$. Note that whatever $r$ is, $p_1^*(r) \geq p_2^*(r)$ owing to the fact that $c_1 \geq c_2$. $\square$

**Proof of Lemma 3.** While our main focus is the intermediary's profit, it can be obtained as a function of $r$ by plugging in $p_i^*$ into her profit function. Afterwards, the intermediary decides $r$ to maximize her profit $\pi_I^{RR}(r) = \max_r \frac{r}{2-b}\left(2 - 2(1-b)r - (1-b)c\right)$. Note that $\pi_I^{RR}$ is concave ($\frac{d^2\pi_I^{RR}}{dr^2} = \frac{-4(1-b)}{2-b} < 0$), a unique $\tilde{r}$ can be obtained by applying the first-order condition $\frac{d\pi_I^{RR}}{dr} = 0$ and yield $\tilde{r} = \frac{2-(1-b)(c_1+c_2)}{4(1-b)}$.

Now we take the constrains into account. First, $D_2 = 1 - p_2^* + bp_1^* \geq 1 - p_1^* + bp_2^* = D_1$ in equilibrium. However, $D_1 = \frac{(2+b)(1-(1-b)r)-(2-b^2)c_1+bc_2}{4-b^2} \geq 0$ if $r \leq \hat{r} = \frac{(2+b)-(2-b^2)c_1+bc_2}{(2+b)(1-b)}$. Therefore, if $\tilde{r} \leq \hat{r}$, $\tilde{r}$ is optimal; if not, then $\hat{r}$ is optimal. Furthermore, by utilizing lemma 2, we are able to derive that $\pi_I^{RR}(\tilde{r}) = \frac{(2-(1-b)(c_1+c_2))^2}{8(1-b)(2-b)}$ and $\pi_I^{RR}(\hat{r}) = \frac{(2+b)(2-b)(1-b)c_1+(2+b)(-2+3b+b^2)c_2+(2+b)^2(1-b)^2c_1c_2-(2-b^2)(2-b)(1+b)c_1^2+b(-2+3b+b^2)c_2^2}{(2+b)^2(2-b)(1-b)}$. $\square$

**Proof of Proposition 1.** According to Lemma 3 and given $c_1 = c \in [0,1]$, $c_2 = 0$, there are two possible equilibrium profit functions in the platform model. That is,

$$\pi_I^{RR} = \begin{cases} \pi_I^{RR}(\tilde{r}) = \frac{(2-(1-b)c)^2}{8(1-b)(2-b)} & \text{if } c < \bar{c} = \frac{2(2+b)}{-3b^2+b+6} \\ \pi_I^{RR}(\hat{r}) = \frac{(1+b)(2+b)c-(2-b^2)(1+b)c^2}{(2+b)(1-b)} & \text{o/w} \end{cases},$$

where the former is the first-order condition (FOC) case and the latter is the boundary



doi:10.6342/NTU201704144

case. We would discuss the two cases separately.

Taking account of the FOC case first, after tedious calculations we get $\pi_I^{RR} - \pi_I^{WW} = \frac{G}{8(2+b)^2(2-b)^2}$, where $G = 4(2+b)^2 - 4(2+b)^2(1-b)c + (b^3+b-4)bc^2$. Taking $G$ as a function of $b$, since $G|_{b=0} = 16(1-c) \geq 0$ and $\frac{dG}{db} = 8(2+b) + 12b(2+b)c + (4b^3+3b^2-4)c^2 > 0$ (because $\frac{dG}{db}|_{b=0} = 16 - 4c^2 > 0$ and $\frac{d^2G}{db^2} = 16 + 24(1+b)c + 6(2b+1)bc^2 > 0$ ), we prove $G > 0$. Therefore, $\pi_I^{RR} - \pi_I^{WW} > 0$ in the FOC case.

Then considering the boundary case, after calculations we get $\pi_I^{RR} - \pi_I^{WW} = \frac{T}{4(2+b)^2(2-b)^2(1-b)}$, where $T = -2(2+b)^2 + (20-2b-14b^2+4b^3)(2+b)c - (-4b^5+12b^4+11b^3-43b^2-4b+36)c^2$. First, we discover that $T$ is concave in $c$ because $U = \frac{d^2T}{dc^2} = 8b^5 - 24b^4 - 22b^3 + 86b^2 + 8b - 72 \leq 0$ (since $\frac{dU}{db} = 40b^4 - 96b^3 - 66b^2 + 172b + 8 > 0$ and $U|_{b=1} = -16 < 0$ ). Second, we can prove that the first-order condition point of $T$, $\dot{c}$, resides at the left side of $\bar{c}$, the point that distinguishes the FOC case and boundary case. More precisely, $\bar{c} - \dot{c} = \frac{2(2+b)}{-3b^2+b+6} - \frac{(4b^3-14b^2-2b+20)(2+b)}{-U} = \frac{(2+b)H}{-U(-3b^2+b+6)} \geq 0$, where $H = -4b^5 + 2b^4 + 28b^3 - 26b^2 - 24b + 24 = (b-1)(b+1)(b-2)(-4b^2-6b+12) \geq 0$. $\square$

**Proof of Proposition 2.** To compare the system profits of the two models, we have to derive the system profit of each model first. For the merchant model part, according to Lemma 1, the system profit of the merchant model is

$$\begin{aligned}
\pi_s^{WW} &= \pi_I^{WW} + \pi_1^{WW} + \pi_2^{WW} \\
&= \frac{(2(2+b)^2-2(2+b)^2(1-b)(c_1+c_2)-(3b^2-4)(1-b)(c_1^2+c_2^2)-2b^3(1-b)c_1c_2)}{4(4-b^2)^2(1-b)} + \frac{((2+b)+(b^2-2)c_1+bc_2)^2}{(2(4-b^2)^2)} \\
&\quad + \frac{((2+b)+bc_1+(b^2-2)c_2)^2}{2(4-b^2)^2} \\
&= \frac{2(3-2b)(2+b)^2-2(2+b)^2(1-b)(3-2b)(c_1+c_2)+(1-b)(12-9b^2+2b^4)(c_1^2+c_2^2-2(1-b)b(8-3b^2)c_1c_2)}{4(4-b^2)^2(1-b)}.
\end{aligned}$$

On the other hand, according to Lemma 2 and 3 and given $r^{RR} = \tilde{r} = \frac{2-(1-b)(c_1+c_2)}{4(1-b)}$, we



doi:10.6342/NTU201704144

can derive

$$\begin{aligned}\pi_1^{RR}(\tilde{r}) &= (p_1^{RR}(\tilde{r}) - c_1 - \tilde{r})(1 - p_1^{RR}(\tilde{r}) + bp_2^{RR}(\tilde{r}))\\ &= \left(\tfrac{(2+b)(1-(1-b)\tilde{r})-(2-b^2)c_1+bc_2}{4-b^2}\right)^2\\ &= \left(\tfrac{2(2+b)-(6+b-3b^2)c_1+(2+3b-b^2)c_2}{4(4-b^2)}\right)^2.\end{aligned}$$

Likewise, $\pi_2^{RR}(\tilde{r}) = \left(\frac{2(2+b)-(6+b-3b^2)c_2+(2+3b-b^2)c_1}{4(4-b^2)}\right)^2$. Then, if $r^{RR} = \tilde{r}$, the system profit of the platform model is

$$\begin{aligned}\pi_s^{RR}(\tilde{r}) &= \pi_I^{RR}(\tilde{r}) + \pi_1^{RR}(\tilde{r}) + \pi_2^{RR}(\tilde{r})\\ &= \tfrac{(2-(1-b)(c_1+c_2))^2}{8(1-b)(2-b)} + \left(\tfrac{2(2+b)-(6+b-3b^2)c_1+(2+3b-b^2)c_2}{4(4-b^2)}\right)^2 + \left(\tfrac{2(2+b)-(6+b-3b^2)c_2+(2+3b-b^2)c_1}{4(4-b^2)}\right)^2\\ &= \tfrac{1}{16(4-b^2)^2(1-b)}(8(3-2b)(2+b)^2 + (1-b)(56+16b-42b^2-10b^3+12b^4)(c_1^2+c_2^2)\\ &\quad -8(1-b)(2+b)^2(3-2b)(c_1+c_2) - 4(1-b)(4+24b-3b^2-11b^3+2b^4)c_1c_2).\end{aligned}$$

Now we are ready to compare the system profits.

$$\begin{aligned}\pi_s^{RR} - \pi_s^{WW} &= \tfrac{(1-b)(8+16b-6b^2-10b^3+4b^4)(c_1^2+c_2^2)-4(1-b)(4+8b-3b^2-5b^3+2b^4)c_1c_2}{16(4-b^2)^2(1-b)}\\ &= \tfrac{(1+b)(1+2b)(c_1-c_2)^2}{8(2+b)^2}\\ &\geq 0.\end{aligned}$$

This competes the proof. □

**Proof of Lemma 4.** Applying backward induction, we start from the optimal prices. First, since $\pi_I^{WR}$ and $\pi_2^{WR}$ are concave ( $\frac{d^2\pi_I^{WR}}{dp_1^2} = \frac{d^2\pi_2^{WR}}{dp_2^2} = -2$ ), we get the optimal $p_i$ by applying the first-order condition $\frac{d\pi_I^{RR}}{dp_1} = 0$ and $\frac{d\pi_2^{RR}}{dp_2} = 0$, and yield $p_1^* = \frac{1+bp_2+w_1+br}{2}$ and $p_2^* = \frac{1+bp_1+c_2+r}{2}$. Solving the two equations results in $p_1^* = \frac{(2+b)+3br+2w_1+bc_2}{4-b^2}$ and $p_2^* = \frac{(2+b)(3-b^2)+(2+b^2)r+bw_1+2c_2}{4-b^2}$.

Considering the interaction between manufacturer 2 and the intermediary, manufacturer 1 sets $w_1$ to maximize his profit $\pi_1^{WR} = (w_1 - c_1)\frac{(2+b)+b(b^2-1)r+(b^2-2)w_1+bc_2}{4-b^2}$. Due to the concavity of the profit function ($\frac{d^2\pi_1^{WR}}{dw_1^2} = \frac{-2(2-b^2)}{4-b^2} < 0$ as $b \in [0, 1)$), he optimally sets the wholesale price by applying the first-order condition $\frac{d\pi_1^{WR}}{dw_1} = 0$ and derives



doi:10.6342/NTU201704144

$w_1^* = \frac{(2+b)-b(1-b^2)r+(2-b^2)c_1+bc_2}{2(2-b^2)}$. Plugging $w_1^*$ back to prices of products leads to $p_1^* = \frac{(2+b)(3-b^2)+b(5-2b^2)r+(2-b^2)c_1+b(3-b^2)c_2}{(4-b^2)(2-b^2)}$ and $p_2^* = \frac{(2+b)(4+b-2b^2)+(8-b^2-b^4)r+b(2-b^2)c_1+(8-3b^2)c_2}{2(4-b^2)(2-b^2)}$. In addition, we also derive that $D_1 = 1 - p_1 + bp_2 = \frac{(2+b)-b(1-b^2)r-(2-b^2)c_1+bc_2}{2(4-b^2)}$ and likewise $D_2 = 1 - p_2 + bp_1 = \frac{(2+b)(4+b-2b^2)-(1-b^2)(8-3b^2)r+b(2-b^2)c_1+(-8+9b^2-2b^4)c_2}{2(4-b^2)(2-b^2)}$. Consequently, $\pi_I^{WR}(r) = (p_1 - w_1)D_1 + rD_2 = \frac{(2+b)+b(7-b^2)r-(2-b^2)c_1+bc_2}{2(4-b^2)} \times \frac{(2+b)-b(1-b^2)r-(2-b^2)c_1+bc_2}{2(4-b^2)} + r\frac{(2+b)(4+b-2b^2)-(1-b^2)(8-3b^2)r+b(2-b^2)c_1+(-8+9b^2-2b^4)c_2}{2(4-b^2)(2-b^2)}$. □

**Proof of Lemma 5.** Following Lemma 4, we first check the concavity of $\pi_I^{WR}(r)$. Since $\frac{d^2\pi_I^{WR}(r)}{dr^2} = \frac{-2b^2(1-b^2)(7-b^2)}{4(4-b^2)^2} + \frac{(1-b^2)(-16+6b^2)}{2(4-b^2)(2-b^2)} < 0$, $\pi_I^{WR}(r)$ is concave in $r$. Therefore, the first-order condition $\frac{d\pi_I^{WR}(r)}{dr} = 0$ results to the optimal transaction fee $r^* = \frac{2(2+b)(8-3b-3b^2+b^3)-2b(1-b)(2-b^2)c_1+2(1-b)(-16+9b^2-b^4)c_2)}{(64-26b^2-3b^4+b^6)(1-b)}$.

We have to verify the non-negative demand constraints in the mixed model (WR). Starting from the demand of product 1, since $D_1^{WR} = \frac{(2+b)B'+(2-b^2)C'c_1+bD'c_2}{2(4-b^2)A'}$ where $A' = 64 - 26b^2 - 3b^4 + b^6 > 0$, $B' = 64 - 16b - 36b^2 + 12b^3 + b^4 - 2b^5 + b^6 \geq 0$, $C' = -64 + 28b^2 + b^4 - b^6 \leq 0$, and $D' = 96 - 76b^2 + 17b^4 - b^6 \geq 0$, $D_1^{WR}$ decreases in $c_1$ but increases in $c_2$. In addition, if $c_1 = 1$ and $c_2 = 0$, $D_1^{WR} = \frac{(2+b)b(16+8b-10b^2-b^3-b^4-b^5+b^6)}{2(4-b^2)A'} > 0$ if $b \in (0,1)$. In conclusion, $D_1^{WR} > 0$ for all $c_1 \in [0,1]$, $c_2 \in [0,1]$ and $b \in (0,1)$.

Considering the demand of product 2, since $D_2^{WR} = \frac{(2+b)B''+b(2-b^2)C''c_1+(4-b^2)D''c_2}{2(4-b^2)(2-b^2)A''}$ where $A'' = 64 - 26b^2 - 3b^4 + b^6 > 0$, $B'' = 128 - 16b - 88b^2 + 36b^3 - 12b^4 - 15b^5 + 16b^6 + b^7 - 2b^8 \geq 0$, $C'' = 80 - 48b^2 + 3b^4 + b^6 \geq 0$, and $D'' = -64 + 56b^2 + 7b^4 - 13b^6 + 2b^8 \leq 0$, $D_2^{WR}$ increases in $c_1$ but decreases in $c_2$. Additionally, if $c_1 = 0$ and $c_2 = 1$, $D_2^{WR} = \frac{(2+b)b(48+24b-20b^2+2b^3-22b^4-10b^5+14b^6+2b^7-2b^8)}{2(4-b^2)(2-b^2)A''} > 0$ if $b \in (0,1)$. To sum up, $D_2^{WR} > 0$ for all $c_1 \in [0,1]$, $c_2 \in [0,1]$ and $b \in (0,1)$. Following above, since $D_1^{WR}(r^*) > 0$ and $D_2^{WR}(r^*) > 0$, $r^*$ is feasible considering the non-negative demand constraints.



doi:10.6342/NTU201704144

Now we are able to compare $p_1^{WR}$ and $p_2^{WR}$. First, since $p_1^{WR}-p_2^{WR}=\frac{(2+b)B+(2-b^2)Cc_1+Dc_2}{2(2+b)(2-b^2)A}$ where $A=64-26b^2-3b^4+b^6\geq 0$, $B=b\left(8+20b-8b^2-11b^3+2b^4+b^5\right)\geq 0$, $C=(64+8b-32b^2-4b^3-b^4+b^6)\geq 0$ and $D=-128-32b+96b^2+60b^3+4b^4-27b^5-14b^6+3b^7+2b^8\leq 0$, $p_1^{WR}-p_2^{WR}$ increases in $c_1$ but decreases in $c_2$. Moreover, if $c_1=c_2=c$, $p_1^{WR}-p_2^{WR}=\frac{B(1-(1-b)c)}{2(2-b^2)A}\geq 0$. Collectively, $p_1^{WR}\geq p_2^{WR}$ for all $c_1\geq c_2$. $\square$

**Proof of Lemma 6.** Since $\Pi_i^{RR}$ is concave ($\frac{d^2\Pi_i^{RR}}{dp_i^2}=-2(1-\phi)<0$), we get the optimal $p_i$ by applying the first-order condition $\frac{d\Pi_i^{RR}}{dp_i}=0$ for manufacturer $i$ and yield $p_i^*=\frac{(1-\phi)(1+bp_{3-i})+c_i}{2(1-\phi)}$, where $c_1=c$ and $c_2=0$. Solving the two equations results to $p_i^*=\frac{(2+b)(1-\phi)+2c_i+bc_{3-i}}{(4-b^2)(1-\phi)}$. The equilibrium demands and the intermediary's profit as a function of $\phi$ can then be obtained by plugging in $p_i^*$ into their formulas. $\square$

**Proof of Lemma 7.** Through several steps of arithmetic, we obtain $h(\phi)=-2(2+b)^2\phi^3+6(2+b)^2\phi^2+(-6(2+b)^2-(2+b)^2bc+(3b^2-4)c^2)\phi+(2(2+b)^2+(2+b)^2bc+(3b^2-4)c^2)=0$ as the first-order condition $\frac{d\Pi_I^{RR}(\phi)}{d\phi}=0$. We then have $h(0)=2(2+b)^2+(2+b)^2bc+(3b^2-4)c^2$. To show that $h(0)>0$, note that $\frac{d^2h(0)}{dc^2}=2(3b^2-4)<0$, which implies that $h(0)$ is concave in $c$ and has its minimum at either $c=0$ or $c=1$. The facts $h(0)|_{c=0}=2(2+b)^2>0$ and $h(0)|_{c=1}=b^3+9b+12b+4>0$ together let us conclude that $h(0)>0$. Moreover, we have $h(1)=2(3b^2-4)c^2<0$. As we also have $\frac{dh(\phi)}{d\phi}=-6(2+b)^2(\phi-1)^2-2(2+b)^2bc+(3b^2-4)c^2<0$, we know $h(\phi)$ starts at $h(0)>0$, monotonically decreases as $\phi$ goes up, and eventually reaches $h(1)<0$. In other words, $\Pi_I^{RR}(\phi)$ is quasi-concave. Therefore, there exists a unique first-order solution $\tilde{\phi}\in(0,1)$ that satisfies $\frac{d\Pi_I^{RR}(\phi)}{d\phi}=0$.

Now we take the constraints into consideration. First, $D_2=\frac{(2+b)(1-\phi)+bc}{(4-b^2)(1-\phi)}\geq 0$. However, $D_1=\frac{(2+b)(1-\phi)+(-2+b^2)c}{(4-b^2)(1-\phi)}\geq 0$ if $c\leq\frac{(1-\phi)(2+b)}{(2-b^2}$, i.e., $\phi\leq\hat{\phi}=1-\frac{(2-b^2)c}{2+b}$. Therefore, if



doi:10.6342/NTU201704144

$\tilde{\phi} \leq \hat{\phi}$, $\tilde{\phi}$ is optimal; if not, then $\hat{\phi}$ is optimal. $\square$

**Proof of Proposition 3.** When $c = 0$ and $b = 0$, $\tilde{\phi} = \max_\phi \frac{\phi}{2} = 1 = \hat{\phi}$. Therefore, we have $\phi^* = 2$ and $\Pi_I^{RR} = \frac{1}{2}$. By plugging $c = 0$ and $b = 0$ into Lemma 1, we derive $\pi_I^{WW} = \frac{1}{8}$. The facts that $\Pi_I^{RR}|_{b=c=0} > \pi_I^{WW}|_{b=c=0}$ and both profit functions are continuous result in our first conclusion regarding the existence of $\hat{b}_1 \in (0,1)$ and $\hat{c}_1 \in (0,1)$. On the contrary, when $c$ and $b$ both approach 1, $\hat{\phi}$ approaches $\frac{2}{3}$ and $\tilde{\phi}$ approaches to a value around 0.81, which is greater than $\hat{\phi}$. Therefore, $\phi^* = \hat{\phi} = \frac{2}{3}$ and $\Pi_I^{RR} = \frac{8}{3}$. In this case, $\pi_I^{WW}$ approaches infinity. Again, because all functions are continuous, we obtain our second conclusion regarding the existence of $\hat{b}_2 \in (0,1)$ and $\hat{c}_2 \in (0,1)$. $\square$

**Proof of Proposition 4.** Consider the case that $c = \frac{4}{5}$. Through several steps of arithmetic, we obtain $h(\hat{\phi})|_{c=\frac{4}{5}} = \frac{2\left(\frac{4}{5}\right)^3(2-b^2)^3}{2+b} + \left(\frac{4}{5}\right)^2 b(2-b^2)(2+b) + \left(\frac{4}{5}\right)^2 \left(2 - \frac{4}{5}\frac{2-b^2}{2+b}\right)(3b^2-4)$. It can be verified that $h(\hat{\phi})|_{c=\frac{4}{5}} > 0$ for all $b \in [0,1)$,which implies that $\phi^* = \hat{\phi}$ when $c = \frac{4}{5}$. We then have $\Pi_I^{RR}(\phi^*)|_{c=\frac{4}{5}} = \frac{(b+1)^2(4b^2+5b+2)}{5(b+2)(b^2-2)^2}$. The comparison between the two models can be conducted by investigating the sign of

$$\begin{aligned}
g(b) &= \Pi_I^{RR}(\phi^*)|_{c=\frac{4}{5}} - \pi_I^{WW}|_{c=\frac{4}{5}} \\
&= \frac{(b+1)^2(4b^2+5b+2)}{5(b+2)(b^2-2)^2} - \frac{44b^3+61b^2+68b+52}{50(b-2)^2(b+2)^2(1-b)} \\
&= \frac{40b^8+54b^7-249b^6-278b^5+478b^4+544b^3-204b^2-208b+48}{50(b-2)^2(b-1)(b+2)^2(b^2-2)^2}
\end{aligned}$$

It can be easily verified that there are exactly 2 roots $\tilde{b}_1$ and $\tilde{b}_2$ for $g(b)$ in $[0,1]$ such that $g(\tilde{b}_1) = 0$, $g(\tilde{b}_2) = 0$ and $\tilde{b}_1 \approx 0.216 < 0.606 \approx \tilde{b}_2$. Given the facts that $g(0) = -\frac{3}{200} < 0$, $g(b) \to -\infty$ as $b \approx 1$, and $g(\frac{1}{2}) \approx 0.0196 > 0$, we conclude that $g(b) > 0$, we conclude that $g(b) < 0$ if $b < \tilde{b}_1$ or $b > \tilde{b}_2$ and $g(b) > 0$ if $b \in (\tilde{b}_1, \tilde{b}_2)$. The statement in the proposition then follows due to the continuity of all profit functions. $\square$



doi:10.6342/NTU201704144

**Proof of Lemma 8.** Applying backward induction, we start from the optimal prices. First, since $\pi_i^{ERR}$ is concave ( $\frac{d^2\pi_i^{ERR}}{dp_i^2} = -2$ ) where $i = 1, 2$, we get the optimal $p_i$ by applying the first-order condition $\frac{d\pi_i^{RR}}{dp_i} = 0$ and yield $p_i^* = \frac{1+bp_{3-i}+c_i+r_i}{2}$. Solving the two equations results in $p_i^*(r_1, r_2) = \frac{(2+b)+2(r_i+c_i)+b(r_{3-i}+c_{3-i})}{4-b^2}$, which is the optimal price responding to $r$.

Considering the interaction between manufacturers, the intermediary sets $r_1$ and $r_2$ to maximize his profit

$$\begin{aligned}\pi_I^{ERR}(r_1, r_2) &= \max_{r_1,r_2} r_1 D_1 + r_2 D_2 \\ &= \max_{r_1,r_2} (r_1 + r_2) - (r_1 - br_2)p_1^*(r) - (r_2 - br_2)p_2^*(r) \\ &= \max_{r_1,r_2} \frac{((2+b)+bc_2-(2-b^2)(c_1+r_1))r_1 + ((2+b)+bc_1-(2-b^2)(c_2+r_2))r_2 + 2br_1r_2}{4-b^2}.\end{aligned}$$

We first check the concavity of the profit function, since

$$\nabla^2\pi_I^{ERR}(r_1, r_2) = \frac{1}{4-b^2}\begin{bmatrix} -2(2-b^2) & 2b \\ 2b & -2(2-b^2) \end{bmatrix},$$

and its leading principals are $\frac{-2(2-b^2)}{4-b^2} \leq 0$ and

$$\begin{aligned}\frac{1}{4-b^2}\begin{vmatrix} -2(2-b^2) & 2b \\ 2b & -2(2-b^2) \end{vmatrix} &= \frac{4(2-b)^2-(2b)^2}{4-b^2} \\ &= \frac{(4+2b-2b^2)(4-2b-2b^2)}{4-b^2} \\ &\geq 0\end{aligned}$$

given $b \in [0, 1)$, $\pi_I^{ERR}(r_1, r_2)$ is negative semi-definite. Therefore, the intermediary optimally sets the transaction fees by applying the first-order condition. Let's omit the constraints for a while. The first-order condition gives us $\frac{\delta\pi_I^{ERR}}{\delta r_1} = 0$, which implies that $r_2 = -\frac{(2+b)+bc_2-(2-b^2)(c_1+2r_1)}{2b}$. Similarly, we have $r_1 = -\frac{(2+b)+bc_2-(2-b^2)(c_1+2r_2)}{2b}$. Solving the



doi:10.6342/NTU201704144

two equations leads to $r_1^* = \frac{1}{2(1-b)} - \frac{1}{2}c_1$ and $r_2^* = \frac{1}{2(1-b)} - \frac{1}{2}c_2$. Furthermore, we can derive the profit of the intermediary

$$\begin{aligned}\pi_I^{ERR}(r_1^*, r_2^*) &= \tfrac{((2+b)+bc_2-(2-b^2)(c_1+r_1^*))r_1^*+((2+b)+bc_1-(2-b^2)(c_2+r_2^*))r_2^*+2br_1^*r_2^*}{4-b^2} \\ &= \tfrac{2(2+b)-2(1-b)(2+b)(c_1+c_2)-2b(1+b)c_1c_2+(2-b^2)(1-b)(c_1^2+c_2^2)}{4(1-b)(4-b^2)}.\end{aligned}$$

Finally, we check the ignored constraints. Plugging $r_1$ and $r_2$ back into $p_1(r_1, r_2)$ and $p_2(r_1, r_2)$ yields $p_1^* = \frac{(2+b)(3-2b)+2(1-b)c_1+b(1-b)c_2}{2(1-b)(4-b^2)}$ and $p_2^* = \frac{(2+b)(3-2b)+2(1-b)c_2+b(1-b)c_1}{2(1-b)(4-b^2)}$. Then we have $D_2 = 1 - p_2 + bp_1 = \frac{(2+b)-(b^2-2)c_2+bc_1}{2(4-b^2)} \geq D_1 = 1 - p_1 + bp_2 = \frac{(2+b)-(b^2-2)c_1+bc_2}{2(4-b^2)} \geq 0$ for all $b \in [0, 1), c_1 \in [0, 1]$ and $c_2 \in [0, 1]$. This completes the proof. $\square$

**Proof of Proposition 5.** We may show that the intermediary can well simulate the product prices in the mixed model by operating the transaction fees in the enhanced platform model. According to Lemma 4, we have $p_1^{WR}(r) = \frac{(2+b)(3-b^2)+b(5-2b^2)r+(2-b^2)c_1+b(3-b^2)c_2}{(4-b^2)(2-b^2)}$ and $p_2^{WR}(r) = \frac{(2+b)(4+b-2b^2)+(8-b^2-b^4)r+b(2-b^2)c_1+(8-3b^2)c_2}{2(4-b^2)(2-b^2)}$. In contrast, according to Lemma 8, we have $p_i^{ERR}(r_1, r_2) = \frac{(2+b)+2(r_i+c_i)+b(r_{3-i}+c_{3-i})}{4-b^2}$, where $i = 1, 2$. Solving the two equations $p_1^{ERR} = p_1^{WR}$ and $p_2^{ERR} = p_2^{WR}$ leads to $r_1 = \frac{(2+b)+(3-b^2)br-(2-b^2)c_1+bc_2}{2(2-b^2)}$ and $r_2 = r$.

In addition, we have to prove that the profit of the intermediary is higher in the enhanced platform model than that in the mixed model. Since the product prices are the same, the demands of both products are also the same. Consequently, we only have to compare the margin profit of each products. For the product 2 part, the margin profits are the same in both models, i.e., $r_2 = r$. For the product 1, the margin profit is $r_1$ in the enhanced platform model and the margin profit is $p_1^{WR} - w_1^{WR}$ in the mixed model. The difference between the margin profits in two models is $D(r) = r_1 - (p_1^{WR} - w_1^{WR}) = \frac{(2+b)+(3-b^2)br-(2-b^2)c_1+bc_2}{2(2-b^2)} - (\frac{(2+b)(3-b^2)+b(5-2b^2)r+(2-b^2)c_1+b(3-b^2)c_2}{(4-b^2)(2-b^2)} - \frac{(2+b)-(1-b^2)br+(2-b^2)c_1+bc_2}{2(2-b^2)}) = \frac{(2+b)-b(1-b^2)r-(2-b^2)c_1+bc_2}{(4-b^2)(2-b^2)}$.



doi:10.6342/NTU201704144

It can be observed that $D(r)$ is decreasing in $r$. Therefore, if we can find a $r'$ greater than the optimal transaction fee $r^{WR}$ such that $D(r') \geq 0$, we show that $D(r^{WR}) \geq 0$. By plugging $r' = \frac{2(2+b)(8-3b-3b^2+b^3)}{(1-b)(62-29b)} \geq \frac{2(2+b)(8-3b-3b^2+b^3)-2b(1-b)(2-b^2)c_1+2(1-b)(-16+9b^2-b^4)c_2}{(64-26b^2-3b^4+b^6)(1-b)} = r^{WR}$ into $D(r)$, we have $D(r') = \frac{(2+b)(64-45b-10b^2+12b^3+4b^4-2b^5)+(64-29b)(bc_2-(2-b^2)c_1)}{(4-b^2)(2-b^2)(64-29b)}$. It can be prove that $D(r') \geq 0$, since $D(r')$ is increasing in $c_2$ but decreasing in $c_1$, and $D(r')|_{c_1=1,c_2=0} = \frac{b(32-b-15b^2+20b^3-4b^5)}{(4-b^2)(2-b^2)(64-29b)} \geq 0$ for all $b \in [0,1)$, $c_1 \in [0,1]$ and $c_2 \in [0,1]$. $\square$



doi:10.6342/NTU201704144

# Bibliography


Arnold, M., C. Li, C. Saliba, L. Zhang. 2011. Asymmetric market shares, advertising and pricing: Equilibrium with an information gatekeeper. *The Jornal of Industrial Economics* **59**(1) 63–84.

Balasubramanian, Sridhar. 1998. Mail versus mall: A strategic analysis of competition between direct marketers and conventional retailers. *Marketing Science* **17**(3) 181–195.

Baye, M. R., J. Morgan. 2001. Information gatekeepers on the Internet and the competitiveness of homogeneous product markets. *The American Economic Review* **91**(3) 454–474.

Cai, G., Y.-J. Chen. 2011. In-store referrals on the Internet. *Journal of Retailing* **87**(4) 563–578.

Chen, Y., G. Iyer, V. Padmanabhan. 2002. Referral infomediaries. *Marketing Science* **21**(4) 412–434.

Chiang, W.-Y. K., D. Chhajed, J. D. Hess. 2003. Direct marketing, indirect profits: A strategic analysis of dual-channel supply-chain design. *Management Science* **49**(1) 1–20.




doi:10.6342/NTU201704144

Gibbons, R. 1992. *Game Theory for Applied Economists*. Princeton University Press.

Iyer, G., A. Pazgal. 2003. Internet shopping agents: Virtual co-location and competition. *Marketing Science* **22**(1) 85–106.

Ryan, J. K., D. Sun, X. Zhao. 2012. Competition and coordination in online marketplaces. *Production and Operations Management* **21**(6) 997–1014.

Tsay, A. A., N. Agrawal. 2004. Channel conflict and coordination in the e-commerce age. *Production and Operations Management* **13**(1) 93–110.

Viswanathan, S., J.Kuruzovich, S. Gosain, R.Agarwal. 2007. Online infomediaries and price discrimination: Evidence from the automotive retailing sector. *Journal of Marketing* **71**(3) 89–107.

Wu, H., G. Cai, J. Chen, C. Sheu. 2015. Online manufacturer referral to heterogeneous retailers. *Production and Operations Management* **24**(11) 1768–1782.

Yoo, W. S., E. Lee. 2011. Internet channel entry: A strategic analysis of mixed channel structures. *Marketing Science* **30**(1) 29–41.



doi:10.6342/NTU201704144