THREE ESSAYS ON COMPETITION AND REGULATION

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ABSTRACT

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Chapter 1: Cost-based Termination Charge Regulation when Fixed and Mobile Networks Compete for Subscribers

This paper studies termination charges in the telecommunications industry (i.e., the fees for receiver's network to impose on caller's network for call termination services). I address two unsettled questions on termination charges: (i) why mobile networks have incentives to set above-cost termination charges and (ii) what are the welfare consequences of symmetric cost-based termination charge regulation. I propose an oligopolistic Hotelling model which explicitly considers the competition for subscribers between fixed and mobile networks and show that such competition can potentially explain high mobile termination charges. When both mobile-to-mobile and fixed-to-mobile substitutions are present, there exists a tradeoff from above-cost mobile termination charges: (i) profit gain from mobile market expansion and (ii) profit loss from intense price competition. I show that above-cost mobile termination charges are profitable when the market share effect outweighs the price competition effect - which is likely to occur for a large inter-network customer base or a small inter-network product differentiation. Moreover, the cost-based regulation on fixed and mobile termination charges, which was recommended by European Commission (2009), may have potential welfare-enhancing effects.

Chapter 2: Exclusive Dealing and Investment Incentives in the Presence of Risk of Renegotiation Breakdown

Exclusive dealing (i.e., a contract that prohibits a buyer from trading with other sellers) may affect competition through the investment incentives and entry. My model considers the case where the contracts are renegotiable and the incumbent seller facing a potential entry threat is able to invest in the relationship with a buyer. My paper departs from the existing literature by considering the risk of breakdown in the renegotiation process. In this setup, exclusivity may have contrasting effects on competition through (i) investment promotion and (ii) foreclosure of efficient entry. The profitability and welfare consequences of exclusive dealing are decided by the relative importance of these two effects which in turn mainly relies on the risk of renegotiation breakdown. More specifically, if the risk of breakdown is very low, exclusive contracts will be profitable and welfare-enhancing. However, the profitable and welfare-reducing exclusive dealing is feasible for a sufficiently high risk of breakdown. This paper restores the inefficient foreclosure by exclusive dealing even considering investments and renegotiation, highlighting the role of risk of renegotiation breakdown.

Chapter 3: Dynamic Incentives of Tying in Two-sided Markets

This paper investigates tying arrangements in two-sided markets. Optimal pricing structure of two-sided markets differs from that of standard one-sided markets. In two-sided markets, platforms charge subscription fees in order to utilize inter-group externalities. The main purpose of this paper is to explore how inter-group externalities affect tying incentives through platforms' price and R&D competition. I adopt a two-sided Hotelling model where two platforms compete in prices and investments and show that tying leads to the distortion of R&D incentives as well as the exclusion of rival platforms. Moreover, there exist certain parameter configurations such that tying is profitable and welfare-reducing through foreclosing rival's R&D investments. Dynamic incentives of tying, which have not been considered in the existing literature, provide a new rationale for the regulation on tying in two-sided markets.

Dedicated to my parents and family

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TABLE OF CONTENTS

LIST OF FIGURES vii

CHAPTER 1: COST-BASED TERMINATION CHARGE REGULATION WHEN FIXED AND MOBILE NETWORKS COMPETE FOR SUBSCRIBERS 1
1.1 Introduction 1
1.2 The Model 7
1.3 Fixed-Mobile Substitution with Singlehoming Subscribers 14
1.4 Fixed-Mobile Substitution with Multihoming Subscribers 20
1.5 Concluding Remarks 27
Appendix 30
Bibliography 37

CHAPTER 2: EXCLUSIVE DEALING AND INVESTMENT INCENTIVES IN THE PRESENCE OF RISK OF RENEGOTIATION BREAKDOWN 39
2.1 Introduction 39
2.2 The model 45
2.3 Exclusive Dealing and Imperfect Renegotiation 46
2.4 Extensions 59
2.5 Concluding Remarks 61
Appendix 65
Bibliography 72

CHAPTER 3: DYNAMIC INCENTIVES OF TYING IN TWO-SIDED MARKETS 74
3.1 Introduction 74
3.2 The Model 79
3.3 Two-sided Singlehoming 81
3.4 Competitive Bottlenecks 93
3.5 Concluding Remarks 100
Appendix 102
Bibliography 107

LIST OF FIGURES

1.1 Competition structure among fixed and mobile networks.. 9

1.2 Network competition with singlehoming subscribers..15

1.3 Network competition with multihoming subscribers...21

A.1 Network competition in the full mobile penetration model......................................33

2.1 Payoffs under non-exclusivity and exclusivity...49

2.2 Investment incentives under non-exclusivity and exclusivity (α = 0.5, θ = 0.1).......53

2.3 Profitability and social welfare under non-exclusivity and exclusivity.....................57

2.4 Profitability and welfare effects of exclusive dealing (α = 0.5)...............................59

3.1 Platform competition in the two-sided singlehoming model.....................................80

3.2 Effects of tying on R&D investments...86

3.3 Tying incentives in the two-sided singlehoming model (α = 0.5) 91

3.4 Platform competition in the competitive bottlenecks model 93

3.5 Tying incentives in the competitive bottlenecks model...99

Chapter 1

Cost-based Termination Charge Regulation when Fixed and Mobile Networks Compete for Subscribers

1.1 Introduction

In the telecommunications industry, when a caller places a phone call, the receiver's network imposes a fee to the caller's network for call termination services, known as 'termination charges.' In many countries, the regulatory authorities have deemed the termination charges for mobile networks to be much higher than the relevant costs.[1] However, the existing models on termination charges predict that above-cost termination charges are suboptimal when network operators compete in two-part tariffs and may charge different prices for on-net and off-net calls.

The equilibrium termination charges critically depend on the assumption regarding a

[1]For instance, European Commission (2009) states that "the absolute level of mobile termination rates remains high in a number of Member States compared to those applied in a number of countries outside of the European Union, and also compared to fixed termination rates generally, thus continuing to translate into high, albeit decreasing, prices for end consumers (p. 67)."

specific pricing strategy which network operators choose. Assuming a linear pricing, high termination charges serve as an instrument of collusion due to the "raise-each-other's-cost" effect (Armstrong, 1998; Laffont, Rey and Tirole, 1998a). In contrast, under two-part tariffs with termination-based price discrimination, above-cost termination charges are suboptimal in the standard duopoly model (Laffont, Rey and Tirole, 1998b; Gans and King, 2001).[2] As two-part tariffs and termination-based price discrimination are commonly adopted in the telecommunications industry, above-cost termination charges remain a puzzle to be explained.[3]

This study proposes an answer to this puzzle − why mobile networks may charge above-cost termination fees − by incorporating the inter-network (i.e., between fixed and mobile networks) competition for subscribers. My model departs from the existing literature by endogenizing the market shares between fixed and mobile networks. The existing literature mostly has treated fixed and mobile network subscribers as disjoint groups. In practice, however, the recent dramatic increase in mobile network subscribers has been accompanied by a significant decline in the number of fixed network subscribers in many developed countries.[4] I explore whether above-cost mobile termination charges can be supported as an equilibrium in the presence of inter-network competition for subscribers.

Furthermore, I assess the desirability of symmetric and cost-based termination charge regulation (i.e., both fixed and mobile termination charges are regulated at marginal costs).

[2]Correcting the analysis of Laffont, Rey and Tirole (1998b), Gans and King (2001) show that network operators have incentives to negotiate termination charges below marginal costs to reduce price competition.

[3]OECD (2009) shows that 44% of mobile subscribers choose prepaid cards in OECD countries. This fact implies that most of the other 56% may choose a plan of two-part tariffs. Also, Table 4 in Armstrong and Wright (2009) shows that there exists a significant price discrimination between on-net and off-net calls in the UK.

[4]According to the statistics from International Telecommunication Union, the mobile penetration rate has increased but the fixed penetration rate has decreased in most developed countries between 2000 and 2009. For instance, in the US, the mobile penetration rate has increased by 56.80%p (38.03 → 94.83%) but the fixed penetration rate has decreased by 17.62%p (66.88 → 49.26%) during this period. In the UK, the mobile penetration rate has increased by 56.79%p (73.76 → 130.55%) but the fixed penetration rate has decreased by 5.20%p (59.80 → 54.60%). Further information can be available at http://www.itu.int/ITU-D/icteye/Indicators/Indicators.aspx

Regulatory authorities often adopt a cost-based termination charge regulation in order to prevent network operators from transferring high termination charges to final consumers. In many countries, however, this cost-based termination charge regulation has been implemented asymmetrically between fixed and mobile networks; usually fixed networks' termination charges has been more tightly regulated than mobile networks' termination charges. European Commission (2009) stresses the potential competitive distortions from asymmetric treatment on fixed and mobile termination charges and recommends the symmetric and cost-based termination charge regulation to the national regulatory authorities.

> "Significant divergences in the regulatory treatment of fixed and mobile termination rates create fundamental competitive distortions [...]. Where termination rates are set above efficient costs, this creates substantial transfers between fixed and mobile markets and consumers [...]. NRAs *(National Regulatory Authorities)* should set termination rates based on the costs incurred by an efficient operator. This implies that they would also be symmetric." (European Commission (2009), pages 67 and 70, italics added)

This recommendation aims to build a consistent regulation which applies to both fixed and mobile networks and to all the European Union (EU) member countries. However, it causes a controversy among related groups due to the different position each group is placed in.[5] This paper proposes a formal model to evaluate the symmetric and cost-based termination charge regulation.

I extend a standard duopoly model to an oligopoly model within a Hotelling framework. My model considers the oligopoly competition structure where two symmetric mobile networks and a fixed network compete for subscribers each other. In many developed countries

[5] In 2007, European Regulators Group (ERG) performed a public consultation on a draft "Common position on symmetry of mobile/fixed call termination rates" and received responses from 33 operators in member countries. According to the ERG report on the consultation, "mobile operators are in principle against converging MTRs *(mobile termination rates)* and FTRs *(fixed termination rates)*, mainly arguing that fixed and mobile networks are technologically different."

(e.g., EU and US), the competition among network operators can be well characterized by the oligopoly structure.[6] My model allows the asymmetry between fixed and mobile networks in the customer base (represented by α and $1-\alpha$) and product differentiation (represented by t and $\tilde{t}$). I consider two different models regarding consumers' subscription decision: (i) singlehoming subscription model (i.e., all consumers subscribe to a single network) and (ii) multihoming subscription model (i.e., some consumers subscribe to both fixed and mobile networks). In this setup, I explore the profitability and welfare effects of above-cost mobile termination charges when fixed termination charges are regulated at marginal costs.

This study brings out two main findings. First, mobile networks may have incentives to set their termination charges above marginal costs when fixed and mobile networks compete for subscribers. The intuition behind this result is as follows. When both mobile-to-mobile and fixed-to-mobile substitutions are present, there exists a tradeoff from above-cost mobile termination charges: (i) profit gain from mobile market expansion and (ii) profit loss from intense price competition. The equilibrium termination charges are decided by the relative importance of these contrasting effects. In both singlehoming and multihoming subscription models, there exist certain parameter values such that the market share effect outweighs the price competition effect (which ensures the existence of jointly optimal above-cost mobile termination charges). This finding suggests a potential explanation for the prevalence of high mobile termination charges in the telecommunications industry where a nonlinear pricing and termination-based price discrimination are common.

More specifically, my model shows that above-cost termination charges may be profitable for a large inter-network customer base ($1-\alpha$) or a small inter-network product differentiation ($\tilde{t}$). The intuition behind this result is as follows. The market share effect (which raises mobile networks' profit) is strengthened for a large inter-network customer base or a small inter-network product differentiation. In contrast, the price competition effect (which reduces

[6] In the EU countries (e.g., UK, Spain, France and Sweden), a single fixed network operator has a monopolistic market share but there exist multiple (more than two) mobile network operators having significant market shares. See Armstrong and Wright (2009), and Harbord and Pagnozzi (2010) for further details.

mobile networks' profit) is weakened for a large inter-network customer base.[7] As a result, the market share effect outweighs the price competition effect for a large inter-network customer base or a small inter-network product differentiation. The parameter values regarding the customer base and product differentiation can be interpreted in terms of the development stages of telecommunications industry. It would be typical that the inter-network customer base decreases and the inter-network product differentiation increases in a more developed telecommunications industry.[8] This implies that above-cost termination charges are more likely to be profitable in a less developed telecommunications industry. This also explains why high mobile termination charges have been prevalent over the past few decades.

In addition, the mobile market expansion from above-cost termination charges suggests a new channel for fixed-to-mobile substitution which has not been considered in the existing literature.[9] This paper shows that regulatory handicaps on fixed networks can facilitate fixed-to-mobile substitution.

Second, the asymmetric regulation on fixed and mobile termination charges may have welfare-reducing effects. In my model, the asymmetric regulation induces the social inefficiency from the excessive expansion of mobile market. The symmetric and cost-based termination charge regulation, which was recommended by European Commission (2009), can reduce competitive distortions caused by the asymmetric regulation.

Related literature. As discussed above, this paper extends the existing literature on termination charges to bridge the gap between theory and practice.[10] Several articles have analyzed the termination charge pricing in the symmetric duopoly framework (Armstrong, 1998; Laffont, Rey, and Tirole, 1998a, 1998b; Gans and King, 2001). In this framework,

[7] This feature follows from Assumption 1 which states that the product differentiation is larger within inter-network than within intra-network (i.e., $\tilde{t} > t$).

[8] Recently, mobile networks provide more differentiated services from fixed networks (e.g., internet, camera, game and movie).

[9] Vogelsang (2010) presents several potential channels for fixed-to-mobile substitution including the relative reduction in mobile call prices and costs, the network effects in demand, and the quality improvements of mobile services.

[10] See Armstrong (2002) for the general review of the literature on termination charges.

above-cost termination charges are optimal under a linear pricing but are suboptimal when two-part tariffs and termination-based price discrimination are feasible.

More recently, several authors have extended the symmetric duopoly model to capture the practice in the telecommunications industry: (i) to allow an elastic subscription and a heterogeneous demand (Dessein, 2003; Hurkens and Jeon, 2009; Jullien, Rey and Sand-Zantman, 2009), (ii) to introduce an oligopolistic network competition (Calzada and Valletti, 2008; Jeon and Hurkens, 2008) and (iii) to consider biased calling patterns (Gabrielsen and Vagstad, 2008). Some of these extensions were able to restore the optimality of above-cost termination charges under a nonlinear pricing (e.g., Calzada and Valletti, 2008; Gabrielsen and Vagstad, 2008; Jullien, Rey and Sand-Zantman, 2009). However, none of these works consider the subscription level competition between fixed and mobile networks which is central in my model.

Another avenue of extension introduces the asymmetric competition between fixed and mobile networks (which is the main focus of my paper). Armstrong and Wright (2009), and Hansen (2006) have considered both (symmetric) intra-network competition and (asymmetric) inter-network competition in the oligopoly model.

Armstrong and Wright (2009) adopt an oligopoly model to introduce the inter-network difference in cost and demand structures. However, the inter-network competition for subscribers is not considered in their model. While they introduce the mobile market expansion through the creation of new demands, the increase in mobile market share does not result in the decline of fixed network's market share due to the absence of inter-network competition for subscribers. They show that above-cost mobile termination charges can be optimal when there exists a sufficiently large inter-network difference in call demands.[11] In my model, the mobile market expansion occurs as a result of the decline in fixed network subscribers and fixed-to-mobile substitution is the key factor to induce the optimality of above-cost mobile

[11] They consider several cases depending on the determination of termination charges: (i) non-uniform fixed-to-mobile and mobile-to-mobile termination charges, (ii) jointly-chosen uniform termination charges and (iii) unilateral choice of uniform termination charges. Note that (ii) is the case that my model considers.

termination charges. The model in Armstrong and Wright (2009) and mine are complementary in several respects. Most of all, they incorporate the inter-network cost and demand difference without inter-network subscription level competition, but I introduce the inter-network subscription level competition by assuming the symmetric inter-network cost and demand structures.

Hansen (2006) develops a model where both intra-network and inter-network competition for subscribers are present. He adopts a two-dimensional (both horizontal and vertical) differentiation model but does not allow termination-based price discrimination. I present a simple horizontal differentiation model which allows both two-part tariffs and termination-based price discrimination. Unlike Hansen (2006), my model shows that the market shares play a crucial role in determining the market outcomes in the presence of termination-based price discrimination.

The rest of the paper proceeds as follows. Section 2 describes the basic model of this paper and reproduces a standard below-cost termination charge result in the oligopoly model without inter-network competition for subscribers. In Section 3, I allow the inter-network competition for subscribers and explore the profitability and welfare consequences of above-cost termination charges in the singlehoming subscription model. Section 4 extends the model to allow some customers to subscribe to both fixed and mobile networks (multihome). Section 5 concludes and discusses the future research. All proofs are given in Appendix A.

1.2 The Model

My model explicitly considers the subscription level competition between fixed and mobile networks to explore the competition effects of asymmetric regulation on fixed and mobile termination charges.

1.2.1 Basic Model

Two mobile networks (denoted by M_1 and M_2) and a fixed network (denoted by F) compete for subscribers. Fixed and mobile networks are symmetric in cost and demand structures but they are asymmetric in the customer base and product differentiation.[12]

Cost structure. All networks are assumed to have the symmetric cost structure. Serving a consumer involves a fixed cost f. Per call, each network incurs a marginal cost $c = c_o + c_t$ where c_o and c_t respectively denote the marginal costs for originating and terminating a call.

Termination charges. I consider the uniform termination charges in which network operators are not allowed to set different termination charges according to originating (i.e., caller's) network.[13] This assumption is adopted to capture the practice of uniform termination charges and also to represent the regulatory principle of non-discriminatory termination charges adopted in the EU and US.[14] Accordingly, each network has a single termination fee which applies to all calls terminating on its own network. Let a_1, a_2 and a_f denote the termination charges of M_1, M_2 and F. To terminate off-net calls, the originating (caller's) network must pay termination fee a_i to the terminating (receiver's) network. My model focuses on the case where mobile networks jointly choose their uniform termination charges (denoted by a). Thus, mobile networks' termination mark-up is equal to $m \equiv a - c_t$. On the other hand, I assume that fixed termination charges are regulated at marginal termination costs (i.e., $a_f = c_t$) to represent the practice of strict regulation on fixed termination charges in many countries.

[12] I assume the symmetric cost and demand structures in order to focus on the effects of asymmetric termination charges on the market outcomes.

[13] Uniform termination charges are commonly assumed in the literature. See, for instance, Armstrong (1998), Laffont, Rey and Tirole (1998a, 1998b), Gans and King (2001), and Armstrong and Wright (2009).

[14] In the EU, Directive 2002/19/EC establishes the principle that termination charges should be non-discriminatory. US establishes the same principle in Telecommunications Act of 1996.

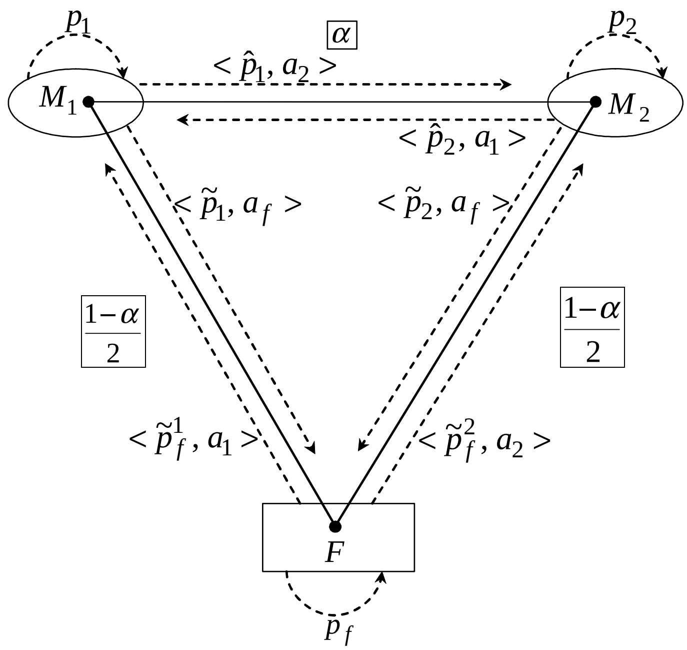

Figure 1.1: Competition structure among fixed and mobile networks

Retail pricing. On the retail pricing of network operators, I allow both two-part tariffs and termination-based price discrimination. Nonlinear tariffs and termination-based price discrimination are commonly used in practice, and also several authors adopt the same retail pricing structure as mine to analyze the network competition in the telecommunications industry.[15] Each mobile network offers two-part tariffs $\{r_i, p_i, \hat{p}_i, \tilde{p}_i\}$ where r_i represents the subscription fee for M_i and p_i refers to the per-minute price for on-net calls while $\hat{p}_i$, $\tilde{p}_i$ denote the variable prices for off-net calls to M_j $(i \neq j)$ and F. Similarly, the fixed network offers two-part tariffs $\{r_f, p_f, \tilde{p}_f^1, \tilde{p}_f^2\}$ where r_f denotes the subscription fee for F and p_f, $\tilde{p}_f^i$ refer to the variable prices for on-net calls and off-net calls. Figure 1.1 summarizes the price competition structure among fixed and mobile networks.

Demand structure. I assume the balanced calling patterns in which the call volume terminated on each network is proportional to the market share of terminating (i.e., receiver's)

[15]See, for example, Laffont, Rey and Tirole (1998b), Gans and King (2001), Calzada and Valleti (2008), Armstrong and Wright (2009), Hurkens and Jeon (2009), and Lopez and Rey (2009).

network.[16] I extend a standard duopoly model to an oligopoly model within a Hotelling framework. M_1, M_2 and F are located at each end of a triangle and each side of the triangle corresponds to a Hotelling line between each pair of competing networks. Consumers are uniformly distributed on the Hotelling lines where the length of each line is equal to 1. There exist three different customer types.[17]

(i) Mobile type: α proportion of consumers characterized by subscribing to M_1 or M_2.

(ii) M_1-F type: $(1-\alpha)/2$ proportion of consumers characterized by subscribing to M_1 or F.

(iii) M_2-F type: $(1-\alpha)/2$ proportion of consumers characterized by subscribing to M_2 or F.

This configuration implies that the density of mobile (intra-network) customer base is equal to α and the density of fixed-mobile (inter-network) customer base is equal to $1-\alpha$.

Mobile type customer located at s_1 from M_1 incurs a transportation cost ts_1 for subscribing to M_1 and $t(1-s_1)$ for subscribing to M_2. Similarly, M_i-F type customer located at $\tilde{s}_i$ from M_i incurs a transportation cost $\tilde{t}\tilde{s}_i$ for subscribing to M_i and $\tilde{t}(1-\tilde{s}_i)$ for subscribing to F. Transportation costs t and $\tilde{t}$ represent the intra-network and inter-network product differentiation respectively. The parameter values on the customer base and product differentiation are assumed as follows.

Assumption 1 (Customer base and product differentiation) *Parameter values satisfy the following conditions.*

(i) Density of mobile type customer: $0 < \alpha < 1$

(ii) Degree of product differentiation: $0 < t < \tilde{t}$.

The assumption of $\alpha \in (0,1)$ ensures the positive fraction of each type customer. I additionally assume $\tilde{t} > t$ to capture the degree of product differentiation is larger within

[16] The balanced calling patterns are commonly adopted in the literature. See, for instance, Armstrong (1998), Laffont, Rey and Tirole (1998a, 1998b), Gans and King (2001), and Armstrong and Wright (2009).

[17] I assume that the total mass of subscribers is normalized to 1 and the fraction of customers on the mobile type and fixed-mobile type are given by α and $1-\alpha$. I also assume fixed-mobile type consumers are equally distributed between M_1-F and M_2-F customer types due to the symmetry of two mobile networks.

inter-network than within intra-network.

Let $v(p)$ denote the consumer surplus associated with the demand function $q(p)$ such that $v'(p) = -q(p)$ (I also assume all networks have the same demand function). Utilities from subscribing to mobile network i (denoted by u_i) and fixed network (denoted by u_f) are written as

$$\begin{aligned} u_i &= v_0 - r_i + n_i v(p_i) + n_j v(\hat{p}_i) + n_f v(\tilde{p}_i) \\ u_f &= v_0 - r_f + n_i v(\tilde{p}_f^i) + n_j v(\tilde{p}_f^j) + n_f v(p_f) \end{aligned}$$

where v_0 denotes a fixed surplus from subscribing to each network and is assumed to be sufficiently large to ensure the full coverage of markets. Net utilities (excluding transportation costs) of a customer located at s_i from M_i and subscribing to M_i and M_j are $u_i - ts_i$ and $u_j - t(1 - s_i)$. Consequently, the market share of M_i on the intra-network customer base is given by

$$s_i = \frac{1}{2} + \frac{u_i - u_j}{2t} \tag{1.1}$$

Similarly, net utilities of a customer located at $\tilde{s}_i$ from M_i and subscribing M_i and F are $u_i - \tilde{t}\tilde{s}_i$ and $u_f - \tilde{t}(1 - \tilde{s}_i)$. The market share of M_i on the inter-network customer base is given by

$$\tilde{s}_i = \frac{1}{2} + \frac{u_i - u_f}{2\tilde{t}} \tag{1.2}$$

Timing. The timing of the game is as follows.

- Stage 1: Mobile networks jointly determine their uniform termination charges.
- Stage 2: All networks simultaneously determine their two-part tariffs.
- Stage 3: Consumers make subscription and consumption decisions.

1.2.2 Benchmark Case: Absence of Fixed-Mobile Substitution

Before examining the model of fixed-mobile substitution, as a benchmark, I explore whether the standard below-cost termination charge result holds in the oligopoly model without fixed-mobile substitution.[18] I use the backward induction to find a subgame perfect equilibrium. First, I examine how retail call prices are determined given termination charges. Next, I check whether the equilibrium termination charges are above or below marginal costs.

Retail tariffs. Suppose the market shares of fixed and mobile networks are constant at $1-\alpha$ and α. Each network has two sources of profit: (i) profit from providing retail services to its own subscribers and (ii) profit from providing call termination services to other networks. The profit functions of mobile network i (denoted by π_i) and fixed network (denoted by π_f) are written as

$$\begin{aligned}
\pi_i &= \underbrace{n_i\left[r_i - f + n_i(p_i - c)q(p_i) + n_j(\hat{p}_i - c - m)q(\hat{p}_i) + n_f(\tilde{p}_i - c)q(\tilde{p}_i)\right]}_{\text{retail profit}} \\
&\quad \underbrace{+ n_i n_j m q(\hat{p}_j) + n_i n_f m q(\tilde{p}_f^i)}_{\text{termination profit}} \qquad (1.3) \\
\pi_f &= \underbrace{n_f[r_f - f + n_f(p_f - c)q(p_f) + n_i(\tilde{p}_f^i - c - m)q(\tilde{p}_f^i) + n_j(\tilde{p}_f^j - c - m)q(\tilde{p}_f^j)]}_{\text{retail profit}} \qquad (1.4)
\end{aligned}$$

where $n_j = \alpha - n_i$ and $n_f = 1 - \alpha$. Note that fixed network's profit consists of retail profit only as fixed network's termination charges are regulated at marginal costs.

In this model, network operators set their call prices at 'perceived' marginal costs and extract the whole consumer surplus using subscription fees. The marginal-cost pricing is well-known result when firms compete in two-part tariffs.[19]

[18] See, for instance, Gans and King (2001) and Armstrong and Wright (2009) for below-cost termination charges under two-part tariffs with termination-based price discrimination.

[19] See, for instance, Laffont, Rey and Tirole (1998b), Gans and King (2001), Calzada and Valletti (2008), Hurkens and Jeon (2009), and Lopez and Rey (2009) for the margial-cost

Lemma 1 (Marginal-cost pricing) *In two-part tariffs with termination-based price discrimination, the equilibrium call prices are determined at 'perceived' marginal costs. That is,*

(i) mobile networks' profit-maximizing call prices are $p_i = c$, $\hat{p}_i = c + m$ *and* $\tilde{p}_i = c$

(ii) fixed network's profit-maximizing call prices are $p_f = c$ *and* $\tilde{p}_f^i = c + m$.

From Lemma 1, mobile network i's profit function is reduced to

$$\pi_i = n_i(r_i - f) + n_i(1 - n_i)mq(c + m)$$

From (1.1), the market share of mobile network i is decided by

$$n_i = \frac{\alpha}{2} + \frac{\alpha(r_j - r_i)}{2\left[t + \alpha v(c + m) - \alpha v(c)\right]} \tag{1.5}$$

In a symmetric equilibrium ($r_i = r_j = r$), the mobile subscription fees are given by

$$r = f + t - (1 - \alpha)\, mq\,(c + m) + \alpha\left[v(c + m) - v(c)\right] \tag{1.6}$$

Mobile termination charges. From (1.6) and $n_i = n_j = \alpha/2$ in a symmetric equilibrium, mobile networks's joint profit (denoted by $\pi_{12} \equiv \pi_1 + \pi_2$) is given by

$$\pi_{12}(m) = \alpha\left\{t + \frac{\alpha}{2}mq(c + m) + \alpha\left[v(c + m) - v(c)\right]\right\} \tag{1.7}$$

As the first-order derivative of (1.7) is negative at $m = 0$, above-cost mobile termination charges are suboptimal in the oligopoly model without fixed-mobile substitution. Above-cost termination charges induce more intense price competition between mobile networks which reduces mobile networks' profits. The result implies that the inclusion of an exogenous fixed network in the mobile network competition model does not have a significant impact on the pricing under two-part tariffs.

equilibrium mobile termination charges.[20]

In the following sections, I introduce fixed-mobile substitution in the oligopoly model to explain why mobile networks may have incentives to set above-cost termination charges. I consider two different models regarding customers' subscription decision: (i) singlehoming subscription model (Section 3) and (ii) multihoming subscription model (Section 4).

1.3 Fixed-Mobile Substitution with Singlehoming Subscribers

This section investigates the determination of call prices and termination charges in the presence of fixed-mobile substitution. With fixed-mobile substitution, termination charges can affect both price competition and market shares. I consider the case where all customers subscribe to a single network (i.e., singlehoming subscription model). Figure 1.2 summarizes customers' subscription decision in the singlehoming subscription model.

1.3.1 Retail tariffs

The market shares of each network are no longer constant in the mobile and fixed networks' profit functions (which are given by (1.3) and (1.4)). Moreover, the market share of the fixed network can be determined by the residual of mobile networks' market shares (i.e., $n_f = 1 - n_1 - n_2$).[21]

In this subsection, I investigate how subscription fees and market shares are affected by above-cost termination charges. Recall that M_i's market share is decided by $n_i = \alpha s_i + (1-\alpha)\tilde{s}_i/2$ where s_i and $\tilde{s}_i$ denote M_i's proportions on the intra-network and inter-network

[20] Note that below-cost termination charges hold in a more general setting. Armstrong and Wright (2009) show that above-cost mobile termination charges are suboptimal in the absence of fixed-mobile substitution even allowing inter-network cost and demand differences.

[21] This feature is the main difference from existing literature which allows elastic subscription demands (e.g., Dessein, 2003; Armstrong and Wright, 2009; Hurkens and Jeon, 2009; Rey and Sand-Zantman, 2009). The only exception is Hansen (2006) which explicitly considers fixed-mobile substitution.

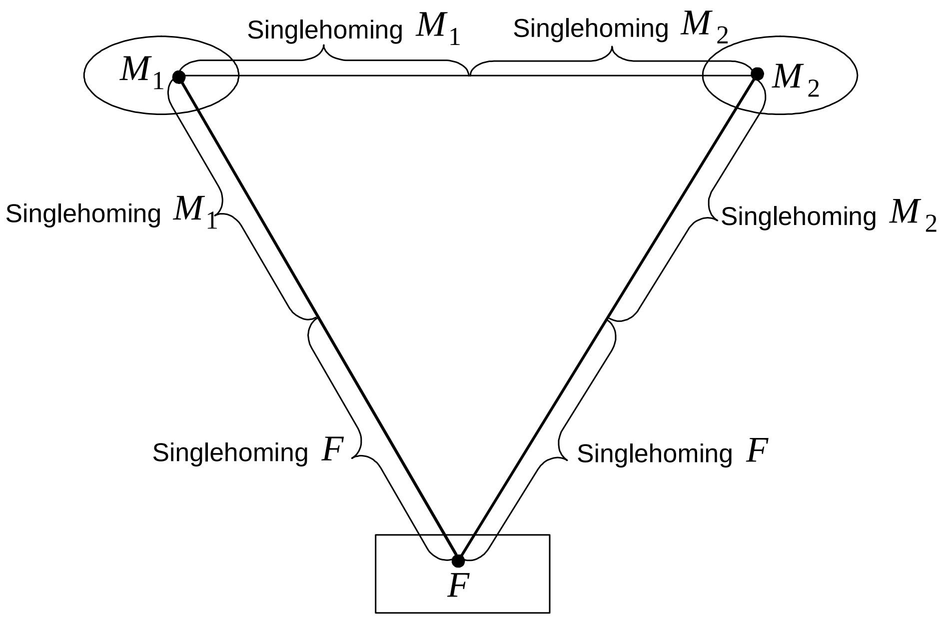

Figure 1.2: Network competition with singlehoming subscribers

customer bases. From (1.1) and (1.2), the total mobile market share (defined as $N \equiv n_1 + n_2$) is written as

$$N = \frac{2\tilde{t}(1+\alpha) + (1-\alpha)(2r_f - r_i - r_j)}{4\tilde{t} - (1-\alpha)\left[v(c) - v(c+m)\right]} \tag{1.8}$$

In a symmetric equilibrium ($r_j = r_i = r$) and marginal-cost termination charges ($m = 0$), the total mobile market share is given by

$$N = \underbrace{\alpha}_{\text{intra-network subscribers}} + \underbrace{\frac{1-\alpha}{2}\left(1 + \frac{r_f - r}{\tilde{t}}\right)}_{\text{inter-network subscribers}}$$

This expression implies that customers' subscription decision depends on the relative size of fixed and mobile subscription fees. More customers subscribe to the network which charges lower subscription fees.

The equilibrium call prices are set equal to 'perceived' marginal costs when networks compete in two-part tariffs (Lemma 1). Thus, the profit functions are reduced to

$$\begin{aligned}\pi_i &= n_i(r_i - f) + n_i(1 - n_i)mq(c + m) \\ \pi_f &= n_f(r_f - f)\end{aligned}$$

In a symmetric equilibrium, the equilibrium subscription fees are decided by

$$r = f - (1 - N)\, mq\,(c + m) + \frac{N}{2\theta} \tag{1.9}$$

$$r_f = f + \frac{1 - N}{2\mu} \tag{1.10}$$

where $\theta \equiv -\partial n_i/\partial r_i$ and $\mu \equiv \partial n_i/\partial r_f$. Note that the equilibrium subscription fees depend on the impacts of subscription fees on market shares (θ and μ). From (1.8)−(1.10), the total mobile market share is decided by

$$N = \frac{2\tilde{t}(1 + \alpha) + (1 - \alpha)\,[2mq(c + m) + 1/\mu]}{4\tilde{t} + (1 - \alpha)\,[v(c + m) - v(c) + 2mq(c + m) + 1/\theta + 1/\mu]} \tag{1.11}$$

From these equations, one can notice that the market outcomes are decided by the interaction between subscription fees and market shares. I focus on the effects of above-cost termination charges on the market outcomes. Lemma 2 characterizes the effects of above-cost mobile termination charges on the equilibrium subscription fees and market shares.

Lemma 2 *In the singlehoming subscription model with fixed-mobile substitution, above-cost mobile termination charges (i) reduce subscription fees of both fixed and mobile networks and (ii) raise mobile networks' market share but reduce fixed network's market share.*

The effects on subscription fees are unambiguous. Above-cost mobile termination charges induce network operators to compete more aggressively for both intra-network and inter-network subscribers. This result confirms the existence of "waterbed" effect (i.e., the negative relationship between termination charges and subscriptions fees) in the presence of fixed-mobile substitution.[22]

On the market shares, above-cost mobile termination charges have the asymmetric impacts on fixed and mobile networks' market shares through the asymmetric effects on fixed and mobile networks' call prices and subscription fees. The intuition behind this result is as follows. With termination-based price discrimination, above-cost mobile termination charges lead to higher mobile call prices compared to fixed call prices, which in turn induce mobile networks to set subscription fees more aggressively.[23] Lower mobile subscription fees make mobile networks more attractive to customers and result in the increase of subscription to mobile networks.

1.3.2 Mobile termination charges

This subsection explores the conditions under which above-cost mobile termination charges are profitable. In equilibrium, mobile networks' joint profit (defined as $\pi_{12} \equiv \pi_1 + \pi_2$) is given by

$$\pi_{12}(m) = N(m)[r(m) - f] + N(m)\left[1 - \frac{N(m)}{2}\right] mq(c+m) \tag{1.12}$$

The effect on mobile networks' retail profit is ambiguous because above-cost termination charges raise the profit source ($N(m)$) but reduce the profit margin ($r(m) - f$). On the other hand, the termination profit unambiguously increases with above-cost termination charges. Consequently, the profitability of above-cost termination charges is decided by the relative importance of these countervailing effects which in turn depends on the parameter values characterizing the inter-network differences in the customer base (α and $1-\alpha$) and product differentiation (t and $\tilde{t}$).

The sign of first-order derivative of (1.12) with respect to m at $m = 0$ is determined by

[22] See Cunningham, Alexander and Candeub (2010) and Genakos and Valletti (2008) for the empirical evidence for the exisitence of "waterbed" effect in the mobile telephone industry.

[23] Among the off-net call prices, above-cost mobile termination charges ($m > 0$) lead to higher fixed-to-mobile call prices compared to mobile-to-fixed call prices (i.e., $\tilde{p}^i_f = c + m > c = \tilde{p}_i$).

the sign of (1.13) (see Proof of Proposition 1 in Appendix A for details).

$$\phi(\alpha,\widehat{t}) \equiv (1-\alpha)^3(19+4\alpha)\widehat{t}^3+4\alpha(1-\alpha)^2(17+4\alpha)\widehat{t}^2+4\alpha^2(1-\alpha)(13+5\alpha)\widehat{t}-16\alpha^3(3+\alpha) \quad (1.13)$$

where $\widehat{t} \equiv t/\tilde{t} \in (0,1)$ measures the relative intra-network product differentiation compared to inter-network differentiation. As $\phi(\alpha,\widehat{t})$ is decreasing in α but is increasing in $\widehat{t}$, above-cost termination charges are more likely to be optimal for a small α or a large $\widehat{t}$ (equivalently, for a large $1-\alpha$ or a small $\tilde{t}$).

Proposition 1 *In the singlehoming subscription model with fixed-mobile substitution, there exists cutoff functions $\bar{\alpha}(\widehat{t})$: $(0,1) \to (0,1)$ or $\bar{t}(\alpha)$: $(0,1) \to (0,1)$ such that*

(i) above-cost mobile termination charges raise the joint profit if $\alpha < \bar{\alpha}(\widehat{t})$ or $\widehat{t} > \bar{t}(\alpha)$

(ii) above-cost mobile termination charges reduce the joint profit if $\alpha > \bar{\alpha}(\widehat{t})$ or $\widehat{t} < \bar{t}(\alpha)$.

Proposition 1 shows that above-cost mobile termination charges may be profitable for a large inter-network customer base $(1-\alpha)$ or a small inter-network product differentiation $(\tilde{t})$. The intuition behind this result is as follows. The market share effect (which raises mobile networks' profit) is strengthened for a large inter-network customer base and a small inter-network product differentiation. In contrast, the price competition effect (which reduces mobile networks' profit) is weakened for a large inter-network customer base.[24] As a result, the market share effect outweighs the price competition effect for a large inter-network customer base or a small inter-network product differentiation.

In addition, the parameter values regarding the customer base and product differentiation can be interpreted in terms of the development stages of telecommunications industry. It would be typical that the inter-network customer base decreases and the inter-network product differentiation increases in a more developed telecommunications industry.[25] This

[24]This feature follows from Assumption 1 which states that the product differentiation is larger within inter-network than within intra-network (i.e., $\tilde{t} > t$).

[25]Recently, mobile networks provide more differentiated services from fixed networks (e.g., internet, camera, game and movie).

implies that above-cost termination charges are more likely to be profitable in a less developed telecommunications industry. This also explains why high mobile termination charges have been prevalent over the past few decades.

1.3.3 Welfare analysis

I also study the welfare implications of above-cost mobile termination charges. The social welfare can be defined as the sum of consumer surplus (denoted by CS) and total network profits ($\pi_{12} + \pi_f$). In equilibrium, this can be written as

$$\begin{aligned} W(m) &= v_0 - f + \frac{1}{2}\left[2N(m) - N(m)^2\right]\left[v(c+m) + mq(c+m)\right] \\ &\quad + \frac{1}{2}\left[2 - 2N(m) + N(m)^2\right] v(c) - TC(m) \end{aligned} \tag{1.14}$$

where TC denotes the transportation costs. Proposition 2 shows that the social welfare is unambiguously reduced by above-cost mobile termination charges.

Proposition 2 *In the singlehoming subscription model with fixed-mobile substitution, above-cost mobile termination charges reduce the social welfare.*

With symmetric cost and demand structures among network operators, the symmetric market shares on both intra-network and inter-network segments are socially optimal. However, higher mobile termination charges cause an excessive mobile market expansion in my model. More rigorously, with a covered market assumption on the consumer side, the total effects on the social welfare excluding transportation costs are cancelled out. Consequently, the welfare effects are decided by the impact on the transportation costs. By setting above-cost mobile termination charges, mobile networks' market share on inter-network segment ($\tilde{s}_i$) is determined as larger than 1/2 (at which the transportation costs are minimized). This implies that the symmetric and cost-based termination charge regulation, which was recommended by European Commission (2009), can be socially beneficial by reducing competitive distortions from the asymmetric regulation.

1.3.4 Discussion

In my model, the cost and demand structures between fixed and mobile networks are assumed to be symmetric. However, the main results of this paper are robust in the asymmetric cost and demand structures between fixed and mobile networks. As higher (lower) call demands for the fixed network can raise (reduce) both market share effect and price competition effect, the profitable above-cost mobile termination charges are feasible for a large inter-network customer base or a small inter-network product differentiation (with different cutoff values from the case of symmetric costs and demands.[26]

Moreover, the difference in the fixed call demands and mobile call demands may not be large as the demands and costs for fixed and mobile networks usually move in the opposite direction. Let us denote (i) the fixed call demand function as $Q(\cdot)$ and the mobile call demand function as $q(\cdot)$ and (ii) the marginal cost of the fixed network as $C = C_o + C_t$ and that of mobile networks as $c = c_o + c_t$. It would be realistic to assume that $Q(p) < q(p)$ and $C < c$ to capture the various services provided by mobile networks (which raises both mobile call demands and costs). In this case, the equilibrium (off-net) fixed and mobile call demands are respectively $Q(C+m)$ and $q(c+m)$ and the relative size of these call demands are ambiguous.

1.4 Fixed-Mobile Substitution with Multihoming Subscribers

This section considers the case where some customers are allowed to subscribe to both fixed and mobile networks (i.e., multihoming subscription model). As, historically, mobile networks have penetrated into fixed network markets to expand their market shares, the assumption of Section 3 is relaxed to allow customers closely located to mobile networks

[26]Note that, in Armstrong and Wright (2009), above-cost mobile termination charges can be optimal without fixed-mobile substitution when fixed call demands are sufficiently large.

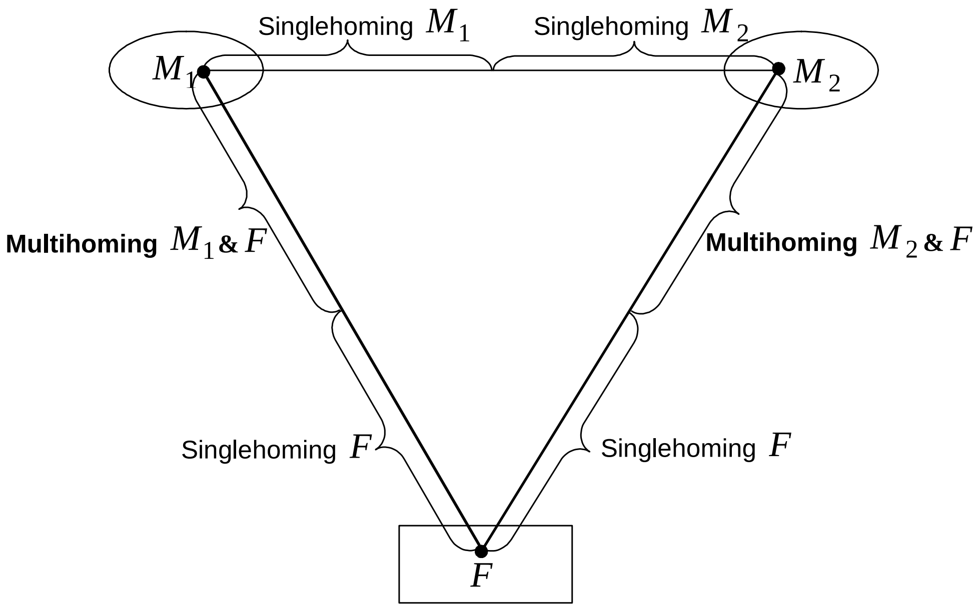

Figure 1.3: Network competition with multihoming subscribers

to multihome. Figure 1.3 summarizes customers' subscription decision in the multihoming subscription model.

Only a few formal models have explicitly considered the case of multihoming subscribers. Armstrong and Wright (2009) introduce the case where all subscribers multihome and analyze how the call level substitution affects mobile termination charges by abstracting the subscription level competition. On the other hand, Hansen (2006) examines fixed-mobile substitution in the mature phase of mobile market expansion without considering call level substitution. I extend these models to consider both subscription level and call level fixed-mobile substitution in the presence of multihoming subscribers.

For the simplicity of analysis, I restrict attention to the case where only inter-network subscribers exist (i.e., $\alpha = 0$).[27] This assumption allows us to focus on how inter-network competition (in both subscription level and call level) plays a role in the determination of termination charges. In this setup, fixed-mobile substitution is feasible by connecting to or disconnecting from the multihoming subscribers' mobile phone. Fixed and mobile

[27]In Section 4.4, I will discuss the robustness and implications of the analyses for the case where both the intra-network and inter-network subscribers exist.

networks compete in call usage as well as customers' subscription because multihoming subscribers can choose either fixed or mobile phones whenever they are available. I assume multihoming subscribers use the cheaper phone to call when both phones are available. Similarly, singlehoming subscribers call to the cheaper phone when the receivers have both fixed and mobile phones. Assumption 2 describes the call usage of subscribers when both fixed and mobile phones are available to callers or receivers.

Assumption 2 (Call usage of subscribers) *Subscribers choose a cheaper phone to call when both fixed and mobile phones are available to callers or receivers. If multiple networks are available at the same price, call usages are equally distributed (i.e., if there exist* h *different ways at the same price, each way can be used with a probability* $1/h$*).*

I also assume the availability of fixed phone to multihoming subscribers because the fixed phone is unavailable and the mobile phone is used to call or receive phone calls when multihoming subscribers are moving. The value of β represents the mobility of multihoming subscribers.

Assumption 3 (Mobility of multihoming subscribers) *Fixed phone is unavailable to multihoming subscribers with a probability* $\beta \in [0, 1]$*.*

1.4.1 Retail tariffs

In the presence of call substitution, the consumer surplus is decided by the lowest price among available call prices (Assumption 2). Utilities of singlehoming and multihoming subscribers are written as

$$\begin{aligned} u_f &= v_0 - r_f + n_f v(p_f) + \beta \left[n_{if} v(\tilde{p}_f^i) + n_{jf} v(\tilde{p}_f^j) \right] \\ &\quad + (1-\beta) \left[n_{if} v(\min\{p_f, \tilde{p}_f^i\}) + n_{jf} v(\min\{p_f, \tilde{p}_f^j\}) \right] \end{aligned}$$

$$
\begin{aligned}
u_{if} &= \tilde{v}_0 - r_i - r_f + \beta n_f v(\tilde{p}_i) + (1-\beta) n_f v(\min\{\tilde{p}_i, p_f\}) + \beta^2 \left[n_{if} v(p_i) + n_{jf} v(\hat{p}_i) \right] \\
&\quad + (1-\beta)^2 \left[n_{if} v(\min\{p_i, p_f, \tilde{p}_i, \tilde{p}_f^i\}) + n_{jf} v(\min\{\hat{p}_i, p_f, \tilde{p}_i, \tilde{p}_f^j\}) \right] \\
&\quad + \beta(1-\beta) \left[n_{if} v(\min\{p_i, \tilde{p}_i\}) + n_{jf} v(\min\{\hat{p}_i, \tilde{p}_i\}) + n_{if} v(\min\{p_i, \tilde{p}_f^i\}) \right. \\
&\quad \left. + n_{jf} v(\min\{\hat{p}_i, \tilde{p}_f^j\}) \right]
\end{aligned}
$$

where v_0 and $\tilde{v}_0$ denote the fixed benefits from singlehoming and multihoming subscription respectively. I also restrict the additional fixed benefits from multihoming subscription to be less than the additional fixed cost to represent the potential duplication of fixed benefits.

Assumption 4 (Fixed benefits of multihoming subscription) $0 < \Delta v_0 < f$ *where* $\Delta v_0 \equiv \tilde{v}_0 - v_0$.

I focus on $m > 0$ case. In equilibrium, the utility functions are reduced to

$$
\begin{aligned}
u_f &= v_0 - r_f + n_f v(c) + n_{if} \left[\beta v(c+m) + (1-\beta) v(c) \right] + n_{jf} \left[\beta v(c+m) + (1-\beta) v(c) \right] \\
u_{if} &= \tilde{v}_0 - r_i - r_f + n_f v(c) + n_{if} v(c) + n_{jf} \left[\beta v(c+m) + (1-\beta) v(c) \right]
\end{aligned}
$$

As the proportion of multihoming subscribers on each Hotelling line is decided by $s_{if} = 1/2 + (u_{if} - u_f)/2\tilde{t}$, the market share of multihoming subscribers ($n_{if} = s_{if}/2$) is given by

$$
n_{if} = \frac{\tilde{t} + \Delta v_0 - r_i}{4\tilde{t} - \beta \left[v(c) - v(c+m) \right]} \tag{1.15}
$$

Note that the market share of singlehoming subscribers can be derived from $n_f = 1 - n_{if} - n_{jf}$.

From Lemma 1, the profit function of mobile networks is given by

$$
\pi_{if} = n_{if}(r_i - f) + \beta n_{if}(n_f + n_{jf}) m q(c+m)
$$

In a symmetric equilibrium ($r_i = r_j = r$), the mobile subscription fees are written as[28]

$$r = f + \left\{4\tilde{t} - \beta\left[v(c) - v(c+m)\right]\right\} n_{if} + \beta(2n_{if} - 1)mq(c+m)$$

Thus, the equilibrium mobile subscription fees and market shares are given by

$$r = \frac{\left\{4\tilde{t} - \beta\left[v(c) - v(c+m)\right]\right\}\left[f + \tilde{t} + \Delta v_0 - \beta mq(c+m)\right]}{2\left\{4\tilde{t} - \beta\left[v(c) - v(c+m)\right] + \beta mq(c+m)\right\}} \tag{1.16}$$

$$n_{if} = \frac{\left\{4\tilde{t} - \beta\left[v(c) - v(c+m)\right]\right\}\left[\tilde{t} + \Delta v_0 - f + \beta mq(c+m)\right] + 2(\tilde{t} + \Delta v_0)\beta mq(c+m)}{2\left\{4\tilde{t} - \beta\left[v(c) - v(c+m)\right]\right\}\left\{4\tilde{t} - \beta\left[v(c) - v(c+m)\right] + \beta mq(c+m)\right\}} \tag{1.17}$$

Lemma 3 *Suppose that there exist only inter-network subscribers (i.e., $\alpha = 0$). In the multihoming subscription model with fixed-mobile substitution, above-cost mobile termination charges (i) reduce mobile networks' subscription fees and (ii) raise multihoming subscribers but reduce singlehoming subscribers.*

The intuition for the effect on the mobile subscription fees is similar to the singlehoming subscription model. Above-cost mobile termination charges lead more intense competition for subscribers which results in the reduction of mobile subscription fees. In turn, lower mobile subscription fees make mobile networks more attractive to customers and result in the increase of subscription to mobile networks (which is feasible only through the multihoming subscription in the current model).

1.4.2 Mobile termination charges

Mobile networks' joint profit is given by

$$\pi_{12}(m) = 2n_{if}(m)[r(m) - f] + 2\beta n_{if}(m)[1 - n_{if}(m)]mq(c+m) \tag{1.18}$$

[28] I implicitly assume that the fixed subscription fee is regulated by regulatory authorities (say at $\bar{r}_f$). In the current model, the fixed network has an incentive to set subscription fee as high as possible without regulation.

Proposition 3 *Suppose that there exist only inter-network subscribers (i.e., $\alpha = 0$). In the multihoming subscription model with fixed-mobile substitution, above-cost mobile termination charges raise mobile networks' joint profit.*

By setting above-cost mobile termination charges, (i) the subscription profit gain from market share effect outweighs the loss from price competition effect and (ii) the termination profit is unambiguously raised. Note that the unambiguous result on the joint profit crucially relies on the assumption of $\alpha = 0$ (see Section 4.4 for the discussion on $\alpha > 0$ case).

1.4.3 Welfare analysis

The social welfare can be defined as $W \equiv CS + \pi_{12} + \pi_f$. In equilibrium, this can be written as

$$\begin{aligned} W(m) &= v_0 - f + v(c) + 2n_{if}(m)(\Delta v_0 - f) \\ &\quad +2\beta n_{if}(m)[1 - n_{if}(m)]\left[v(c+m) - v(c) + mq(c+m)\right] - TC(m) \end{aligned} \tag{1.19}$$

Proposition 4 *Suppose that there exist only inter-network subscribers (i.e., $\alpha = 0$). In the multihoming subscription model with fixed-mobile substitution, above-cost mobile termination charges reduce the social welfare.*

In the presence of multihoming subscribers, above-cost mobile termination charges may reduce the social welfare through two different channels: (i) the duplication of fixed costs (the excessive multihoming subscription) and (ii) the increase of transportation costs (the excessive mobile market expansion). Proposition 4 shows that the symmetric and cost-based termination charge regulation can be socially beneficial even considering customers' multihoming subscription.

1.4.4 Discussion

The analyses on this section have focused on the case where only inter-network subscribers exist ($\alpha = 0$), but the main results can be extended to more general case where intra-network subscribers exist ($\alpha > 0$). In the presence of intra-network competition, the profitability of above-cost termination charges may not be unambiguous as the market share effect is weakened but the price competition effect is strengthened. However, the profitable above-cost mobile termination charges are still feasible for a sufficiently small α.

More specifically, for $\alpha > 0$, the market share of multihoming subscribers is decided by

$$n_{if} = \frac{2(1-\alpha)\left[\tilde{t} + \Delta v_0 - r(m)\right] + \alpha(1-\alpha)\left[v(c) - v(c+m)\right]}{2\left\{4\tilde{t} - (1-\alpha)\beta\left[v(c) - v(c+m)\right]\right\}} \tag{1.20}$$

From (1.20), the market share effect always exists if above-cost mobile termination charges reduce the equilibrium mobile subscription fees.[29] This implies that there exist some parameter values such that above-cost mobile termination charges are optimal through the mobile market expansion.

Another extension of the model is to consider the alternative multihoming subscription model. The model in this section (i.e., all inter-network subscribers already have a fixed phone and subscribers closely located to mobile networks choose multihoming) is plausible when the mobile penetration rate is very low. On the other hand, when the mobile penetration rate is very high, it is more realistic to assume that all inter-network subscribers have a mobile phone and subscribers closely located to the fixed network choose multihoming. The main results of this section is robust to this alternative model. Although fixed-mobile substitution does not occur when mobile networks have fully penetrated into fixed network markets, above-cost mobile termination charges can be optimal for a large inter-network customer base or a small inter-network product differentiation (see Appendix B for detailed

[29] Consider $r'(0) < 0$. $n'_{if}(0) > 0$ because the first-order derivative of numerator is positve $(-2(1-\alpha)r'(0) + \alpha(1-\alpha)q(c) > 0)$ but the first-order derivative of denominator is negative $(-2(1-\alpha)\beta q(c) < 0)$.

analyses in this alternative model).

1.5 Concluding Remarks

This paper addresses two unsettled questions on termination charges: (i) why mobile networks may have incentives to set termination charges above marginal costs and (ii) what are the policy implications of the symmetric and cost-based regulation on fixed and mobile termination charges.

I present a model with fixed-mobile substitution in which above-cost termination charges may be optimal under two-part tariffs with termination-based price discrimination. In the presence of fixed-mobile substitution, above-cost mobile termination charges have two contrasting effects on mobile networks' profits. While high mobile termination rate cause more intense price competition among network operators, it also helps mobile networks to expand their market shares. I show that above-cost termination charges are likely to be profitable for a large inter-network customer base or a small inter-network product differentiation. Moreover, the regulatory movement in the EU (which requires the symmetric and cost-based termination charges on fixed and mobile termination charges) may raise the social welfare by reducing competitive distortions.

In addition, the main results of this paper are robust in the asymmetric cost and demand structures between fixed and mobile networks. As higher (lower) call demands for the fixed network raise (reduce) both market share effect and price competition effect, the profitable above-cost mobile termination charges are more likely for a large inter-network customer base or a small inter-network product differentiation.

I conclude by discussing the potential future research. First, my model can be extended to consider the vertical integration between fixed and mobile networks which are often observed in many countries. The vertically integrated network may have different incentives from independent networks in determining termination charges. The integrated network can internalize network externalities for the calls between its sub-networks and also has less incentives to penetrate into fixed network markets.

Second, the network competition for singlehoming and multihoming subscribers can be analyzed in the competitive bottlenecks model of two-sided markets. The growing literature on the optimal pricing structure in two-sided markets might be helpful to understand the relatively high mobile termination charges (see, for instance, Armstrong (2006) and Rochet and Tirole (2006) for details).

APPENDIX

Appendix

A. Proofs omitted in the text

Proof of Lemma 2.

(1) Effect on mobile subscription fee. From (1.9), the first-order derivative of r with respect to m is at $m = 0$,

$$r'(0) = \frac{-(1-\alpha)(2-\alpha)t + 2\alpha(1+\alpha)\tilde{t}}{2\left[3t(1-\alpha)+4\tilde{t}\alpha\right]}q(c) - \frac{2(1-\alpha)t + \alpha(3+\alpha)\tilde{t}}{\left[3t(1-\alpha)+4\tilde{t}\alpha\right]^2}a_\theta q(c) \qquad \text{(A.1)}$$

$$\text{where } a_\theta = \frac{t^2(1-\alpha)^2 + 4t\tilde{t}\alpha(1-\alpha) + 8\tilde{t}^2\alpha^2}{t^2(1-\alpha)^2 + 4t\tilde{t}\alpha(1-\alpha) + 4\tilde{t}^2\alpha^2}$$

Using $a_\theta > 1$, (A.1) can be rewritten as

$$r'(0) < -\frac{(1-\alpha^2)(3-\alpha)t^2 + 4\alpha(1-\alpha)(8-3\alpha)t\tilde{t} + 8\alpha^2(1-\alpha)\tilde{t}^2}{4\left[3t(1-\alpha)+4\tilde{t}\alpha\right]^2}q(c)$$

This implies $r'(0) < 0$ because the right-hand side of the equation is negative under Assumption 1.

(2) Effect on market shares. From (1.11), the first-order derivative of N with respect to m is at $m = 0$,

$$N'(0) = \frac{(1-\alpha)\left[t(1-\alpha)+2\tilde{t}\alpha\right]}{4\tilde{t}\left[3t(1-\alpha)+4\tilde{t}\alpha\right]}q(c) + \frac{(1-\alpha)(1+3\alpha)\left[t(1-\alpha)+2\tilde{t}\alpha\right]^2}{8\tilde{t}\left[3t(1-\alpha)+4\tilde{t}\alpha\right]^2}a_\theta q(c) \qquad \text{(A.2)}$$

(A.2) is positive since $0 < \alpha < 1$ and $a_\theta > 1$. Also, $n'_f(0) < 0$ follows from $n_f = 1 - N$.

(3) Effect on fixed subscription fee. From (1.10), the first-order derivative of r_f with respect to m is at $m = 0$,

$$r'_f(0) = -\frac{1}{2}\left[\frac{4\tilde{t}}{1-\alpha}N'(0) + \left[1 - N(0)\right]q(c)\right] \qquad \text{(A.3)}$$

(A.3) is negative since $N'(0) > 0$ and $\alpha < 1$. ■

Proof of Proposition 1. From (1.12), (A.1) and (A.2), the first-order derivative of π_{12} with respect to m is at $m = 0$,

$$\pi'_{12}(0) = \frac{3+\alpha}{8\left[3\widehat{t}(1-\alpha)+4\alpha\right]^3}\phi(\alpha,\widehat{t})q(c) \tag{A.4}$$

where $\phi(\alpha,\widehat{t})$ is given by (1.13) and the sign of (A.4) is determined by the sign of $\phi(\alpha,\widehat{t})$. For $\widehat{t},\alpha \in (0,1)$, the following properties (i)$-$(iv) hold. (i) $\phi(\alpha,\hat{t})$ is continuous in α and $\widehat{t}$, (ii) $\phi(0,\widehat{t}) > 0$ and $\phi(1,\widehat{t}) < 0$, (iii) $\phi(\alpha,0) < 0$, $\phi(\alpha,1) > 0$ for $\alpha < \overline{\overline{\alpha}}$ and $\phi(\alpha,1) < 0$ for $\alpha \geq \overline{\overline{\alpha}}$, (iv) $\partial\phi(\alpha,\widehat{t})/\partial\widehat{t} > 0$ and $\partial\phi(\alpha,\widehat{t})/\partial\alpha < 0$ as (A.5) is negative and (A.6) is positive for any $\widehat{t},\alpha \in (0,1)$.

$$\begin{aligned}\frac{\partial\phi(\alpha,\widehat{t})}{\partial\alpha} &= -(1-\alpha)^2(16\alpha+53)\widehat{t}^3 - 4(1-\alpha)(12\alpha^2+57\alpha-21)\widehat{t}^2 \\ &\quad -8\alpha(10\alpha^2+12\alpha-13)\widehat{t} - 16\alpha^2(2\alpha+9)\end{aligned} \tag{A.5}$$

$$\frac{\partial\phi(\alpha,\widehat{t})}{\partial\widehat{t}} = (1-\alpha)\left[3(1-\alpha)^2(4\alpha+19)\widehat{t}^2 + 8\alpha(1-\alpha)(4\alpha+17)\widehat{t} + 4\alpha^2(5\alpha+13)\right] \tag{A.6}$$

Case 1 ($\alpha < \overline{\overline{\alpha}}$): There exists a unique threshold of α and $\widehat{t}$ such that $\phi(\alpha,\widehat{t}) = 0$ because of $\partial\phi(\alpha,\widehat{t})/\partial\widehat{t} > 0$ and $\partial\phi(\alpha,\widehat{t})/\partial\alpha < 0$ (by intermediate value theorem).

Case 2 ($\alpha \geq \overline{\overline{\alpha}}$): There exists a unique threshold of α such that $\phi(\alpha,\widehat{t}) = 0$ because of $\partial\phi(\alpha,\widehat{t})/\partial\widehat{t} > 0$. On the other hand, $\phi(\alpha,\widehat{t}) < 0$ for any $\widehat{t} \in (0,1)$ which means the threshold level $\bar{t}(\alpha) = 1$. ∎

Proof of Proposition 2. From (1.14), the first-order derivative of W with respect to m is at $m = 0$,

$$W'(0) = -TC'(0)$$

As TC is minimized at $\tilde{s}_1 = 1/2$ and $\tilde{s}'_1(0) > 0$, the sign of $W'(0)$ is decided by the sign of $[\tilde{s}_1(0) - 1/2]$ where $\tilde{s}_1(0) = 1/2 + \left[r_f(0) - r_i(0)\right]/2\tilde{t}$. In equilibrium, this is given by

$$\tilde{s}_1(0) - \frac{1}{2} = \frac{\alpha(\tilde{t}-t)}{3(1-\alpha)t + 4\alpha\tilde{t}} \tag{A.7}$$

(A.7) is positive under Assumption 1 which implies $W'(0) < 0$. ■

Proof of Lemma 3.

(1) Effect on mobile subscription fee. From (1.16), the first-order derivative of r with respect to m is at $m = 0$,

$$r'(0) = -\frac{\beta(5\tilde{t} + f + \Delta v_0)}{8\tilde{t}} q(c) \tag{A.8}$$

(A.8) is negative under Assumption 1.

(2) Effect on market shares. From (1.17), the first-order derivative of n_{if} with respect to m is at $m = 0$,

$$n'_{if}(0) = \frac{\beta(3\tilde{t} + \Delta v_0)}{16\tilde{t}^2} q(c) \tag{A.9}$$

(A.9) is positive under Assumption 1. Also, $n'_f(0) < 0$ follows from $n_f = 1 - 2n_{if}$. ■

Proof of Proposition 3. From (1.18), (A.8) and (A.9), the first-order derivative of π_{12} with respect to m is at $m = 0$,

$$\pi'_{12}(0) = \frac{\beta(\tilde{t} + \Delta v_0 - f)}{4\tilde{t}} q(c) \tag{A.10}$$

(A.10) is positive under Assumption 1 and $t + \Delta v_0 - f > 0$ which follows from $n_{if}(0) > 0$. ■

Proof of Proposition 4. From (1.19), the first-order derivative of W with respect to m is at $m = 0$,

$$W'(0) = \frac{3(\Delta v_0 - f) - \tilde{t}}{2} n'_{if}(0) \tag{A.11}$$

(A.11) is negative since $\Delta v_0 < f$ from Assumption 4 and $n'_{if}(0) > 0$. ■

B. Supplementary analysis in the full mobile penetration model

This appendix explores the case where mobile networks have fully penetrated into fixed network markets. Alternative to the model in Section 4, customers closely located to mobile networks choose singlehoming on mobile networks and customers closely located to the fixed network choose multihoming. Figure A.1 summarizes customers' subscription decision in this model.

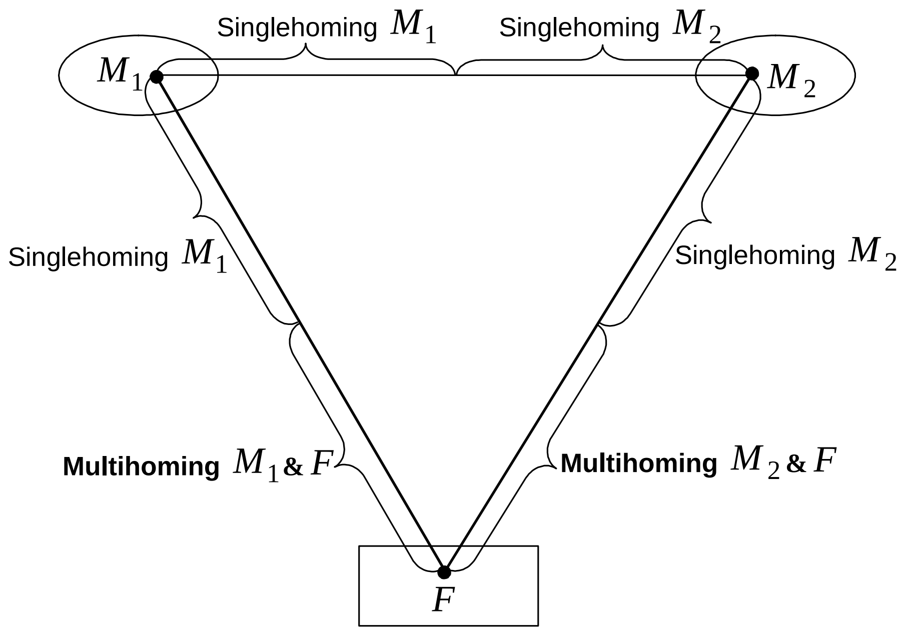

Figure A.1: Network competition in the full mobile penetration model

Retail tariffs. Utilities of singlehoming and multihoming subscribers are written as

$$\begin{aligned} u_i &= v_0 - r_i + n_i v(p_i) + n_j v(\hat{p}_i) + \beta \left[n_{if} v(p_i) + n_{jf} v(\hat{p}_i) \right] \\ &\quad + (1-\beta) \left[n_{if} v(\min\{p_i, \tilde{p}_i\}) + n_{jf} v(\min\{\hat{p}_i, \tilde{p}_i\}) \right] \\ u_{if} &= \tilde{v}_0 - r_i - r_f + \beta \left[n_i v(p_i) + n_j v(\hat{p}_i) \right] + (1-\beta)[n_i v(\min\{p_i, \tilde{p}_f^i\}) + n_j v(\min\{\hat{p}_i, \tilde{p}_f^j\})] \\ &\quad + \beta^2 \left[n_{if} v(p_i) + n_{jf} v(\hat{p}_i) \right] + (1-\beta)^2 [n_{if} v(\min\{p_i, p_f, \tilde{p}_i, \tilde{p}_f^i\}) + n_{jf} v(\min\{\hat{p}_i, p_f, \tilde{p}_i, \tilde{p}_f^j\})] \\ &\quad + \beta(1-\beta)[n_{if} v(\min\{p_i, \tilde{p}_i\}) + n_{jf} v(\min\{\hat{p}_i, \tilde{p}_i\}) + n_{if} v(\min\{p_i, \tilde{p}_f^i\}) + n_{jf} v(\min\{\hat{p}_i, \tilde{p}_f^j\})] \end{aligned}$$

In equilibrium, utility functions are reduced to

$$\begin{aligned} u_i &= v_0 - r_i + n_i v(c) + n_j v(c+m) + n_{if} v(c) + n_{jf} \left[\beta v(c+m) + (1-\beta) v(c) \right] \\ u_{if} &= \tilde{v}_0 - r_i - r_f + n_i v(c) + n_j v(c+m) + n_{if} v(c) + n_{jf} \left[\beta v(c+m) + (1-\beta) v(c) \right] \end{aligned}$$

The market shares of singlehoming subscribers and multihoming subscribers ($n_i = \alpha s_i + (1-\alpha)\tilde{s}_i/2$ and $n_{if} = (1-\alpha)(1-\tilde{s}_i)/2$) are written as

$$
\begin{aligned}
n_i &= \frac{1+\alpha}{4} + \frac{(1-\alpha)(r_f - \Delta v_0)}{4\tilde{t}} + \frac{r_j - r_i}{2\left\{t - \alpha\left[v(c) - v(c+m)\right]\right\}} \\
n_{if} &= \frac{1-\alpha}{4} - \frac{r_f - \Delta v_0}{4\tilde{t}}
\end{aligned}
$$

From Lemma 1, the profit functions are given as

$$
\begin{aligned}
\pi_i &= (n_i + n_{if})(r_i - f) + (n_i + \beta n_{if})(n_j + n_{jf}) m q(c+m) \\
\pi_f &= (n_{if} + n_{jf})(r_f - f)
\end{aligned}
$$

In a symmetric equilibrium, the subscription fees and market shares are given by

$$
\begin{aligned}
r &= f + t - \alpha\left[v(c) - v(c+m)\right]; \quad r_f = \frac{1}{2}(f + \tilde{t} + \Delta v_0) \\
n_i &= \frac{1+\alpha}{4} + \frac{1-\alpha}{8\tilde{t}}(f + \tilde{t} - \Delta v_0); \quad n_{if} = \frac{1-\alpha}{4} - \frac{1-\alpha}{8\tilde{t}}(f + \tilde{t} - \Delta v_0)
\end{aligned}
$$

Lemma 4 *In the full mobile penetration model with fixed-mobile substitution, above-cost mobile termination charges (i) reduce mobile subscription fees but have no impact on fixed subscription fee and (ii) have no impact on market shares between singlehoming and multihoming subscribers.*

Above-cost termination charges have no impact on the market shares and fixed termination charges since they do not depend on termination charges. However, above-cost mobile termination charges reduce mobile subscription fees because of $r'(0) = -\alpha q(c) < 0$.

Mobile termination charges. From $n_i + n_{if} = n_j + n_{jf} = 1/2$, mobile networks' joint profit is given by

$$\pi_{12}(m) = r(m) - f + [n_i(m) + \beta n_{if}(m)] m q(c+m)$$

Proposition 5 *In the full mobile penetration model with fixed-mobile substitution, there exist certain parameter values such that above-cost mobile termination charges raise mobile networks' joint profit.*

Proof. The first-order derivative of π_{12} with respect to m is at $m = 0$,

$$\pi_{12}'(0) = \frac{[(1-\alpha)(1+\beta) + 2(1-3\alpha)]\,\tilde{t} + (1-\alpha)(1-\beta)\,(f - \Delta v_0)}{8\tilde{t}} q(c) \tag{A.12}$$

(A.12) is positive for a sufficiently small α (e.g., $\alpha < 1/3$). ■

(A.12) implies that above-cost termination charges are more likely to be optimal for a small α or a small $\tilde{t}$ in which the price competition effect is weakened.

Welfare analysis. The welfare function can be written as

$$\begin{aligned} W(m) &= v_0 - f + 2n_{if}(m)(\Delta v_0 - f) + n_i(m)v(c) + n_j(m)v(c+m) + \beta n_{jf}(m)\,[v(c+m) - v(c)] \\ &\quad + [n_i(m) + \beta n_{if}(m)]mq(c+m) - TC(m) \end{aligned}$$

Proposition 6 *In the full mobile penetration model with fixed-mobile substitution, above-cost mobile termination charges do not affect the social welfare.*

Proof. From Lemma 4, the market shares and transportation costs are not affected by mobile termination charges. Thus, the first-order derivative of W with respect to m is at $m = 0$,

$$W'(0) = -(n_j + \beta n_{jf})q(c) + (n_i + \beta n_{if})q(c)$$

$W'(0) = 0$ follows from $n_i + \beta n_{if} = n_j + \beta n_{jf}$ in a symmetric equilibrium. ■

BIBLIOGRAPHY

Bibliography

[1] Armstrong, M. (1998), "Network Interconnection." *Economic Journal*, Vol. 108, pp. 545–564.

[2] Armstrong, M. (2002), "The Theory of Access Pricing and Interconnection." In M. Cave, S. Majumdar, and I. Vogelsang, eds., *Handbook of Telecommunications Economics*. Amsterdam: North Holland.

[3] Armstrong, M. (2006), "Competition in Two-Sided Markets." *RAND Journal of Economics*, Vol. 37, pp. 668−691.

[4] Armstrong, M. and Wright, J. (2009), "Mobile Call Termination." *Economic Journal*, Vol. 119, pp. 270–307.

[5] Calzada, J. and Valletti, T. (2008), "Network Competition and Entry Deterrence." *Economic Journal*, Vol. 118, pp. 1223–1244.

[6] Cambini, C. (2001), "Competition Between Vertically Integrated Networks." *Information Economics and Policy*, Vol. 13, pp. 137–165.

[7] Cunningham, B.M., Alexander, P.J. and Candeub, A. (2010), "Network Growth: Theory and Evidence form the Mobile Telephone Industry." *Information Economics and Policy*, Vol. 22, pp. 91–102.

[8] Dessein, W. (2003), "Network Competition in Nonlinear Pricing." *Rand Journal of Economics*, Vol. 34, pp. 593–611.

[9] European Commission (2009), "Commission Recommendation of 7 May 2009 on the Regulatory Treatment of Fixed and Mobile Termination Rates in the EU." Brussels, available at http://ec.europa.eu/information_society/policy/ecomm/library/recomm_guidelines.

[10] Gabrielsen, T.S. and Vagstad, S. (2008), "Why Is On-net Traffic Cheaper than Off-net Traffic? Access Markup as a Collusive Device." *European Economic Review*, Vol. 52, pp. 99–115.

[11] Gans, J.S. and King, S.P. (2001), "Using 'Bill and Keep' Interconnect Arrangements to Soften Network Competition." *Economics Letters*, Vol. 71, pp. 413–420.

[12] Genakos, C. and Valletti, T. (2008), "Testing the "Waterbed" Effect in Mobile Telephony." CEIS Working Paper 110.

[13] Hansen, B. (2006), "Termination Rates and Fixed Mobile Substitution." Mimeo, Norwegian School of Management.

[14] Harbord, D. and Pagnozzi, M. (2010), "Network-Based Price Discrimination and 'Bill-and-Keep' vs. 'Cost-Based' Regulation of Mobile Termination Rates." *Review of Network Economics*, Vol. 9, pp. 1–44.

[15] Hurkens, S. and Jeon, D.S. (2009), "Mobile Termination and Mobile Penetration." IEDI Working Papers 575.

[16] Jeon, D.S. and Hurkens, S. (2008), "A Retail Benchmarking Approach to Efficient Two-Way Access Pricing: No Termination-based Price Discrimination." *Rand Journal of Economics*, Vol. 39, pp. 822–849.

[17] Jullien, B., Rey, P. and Sand-Zantman, W. (2009), "Mobile Call Termination Revisited." IEDI Working Papers 551.

[18] Laffont, J.J., Rey, P. and Tirlole, J. (1998a), "Network Competition I: Overview and Nondiscriminatory Pricing." *RAND Journal of Economics*, Vol. 29, pp. 1–37.

[19] Laffont, J.J., Rey, P. and Tirlole, J. (1998b), "Network Competition II: Price Discrimination." *RAND Journal of Economics*, Vol. 29, pp. 38–56.

[20] Lepez, A.L and Rey, P. (2009), "Foreclosing Competition Through Access Charges and Price Discrimination." IEDI Working Papers 570.

[21] OECD (2009), "OECD Communications Outlook 2009." Paris.

[22] Rochet, J.-C. and Tirole, J. (2006), "Two-Sided Markets: A Progress Report." *RAND Journal of Economics*, Vol. 37, pp. 645−667.

[23] Vogelsang, I. (2010), "The Relationship between Mobile and Fixed-line Communications: A Survey." *Information Economics and Policy*, Vol. 22, pp. 4–17.

Chapter 2

Exclusive Dealing and Investment Incentives in the Presence of Risk of Renegotiation Breakdown

2.1 Introduction

Exclusive dealing is a contract between a buyer and a seller that prohibits the buyer from trading with other sellers.[1] The competition effects of exclusive dealing have been at the center of attention from economists and regulatory authorities for a long time but are still controversial.[2]

The Chicago School argument for exclusive contracts remains highly influential in the debate on the effects of exclusive dealing. According to Posner (1976) and Bork (1978), buyers will not accept exclusive dealing that prevents competition and lowers the total

[1]This paper focuses on the case where exclusive contracts specify only the exclusivity provision except for a lump-sum payment. See Segal (1999) for a formal justification of incomplete contracts. Also, note that this type of exclusive contracts was adopted in many articles examining the effects of exclusive dealing on investment incentives (e.g., Segal and Whinston, 2000b; de Meza and Selvaggi, 2007; Fumagalli, Motta and Persson, 2009).

[2]Regarding the recent cases involving exclusive dealing, see U.S. v. Microsoft (1995 Consent Decree), U.S. v. Dentsply (399 F.3d 181 [2001]), Conwood v. United States Tobacco (290 F.3d 768 [2002]) and U.S. v. Visa USA (344 F.3d 229 [2003]).

surplus available to buyers because the incumbent seller is not able to compensate buyers' loss fully. In the simple model where buyers are final consumers, buyers' loss amounts to the difference between consumer surplus under entry and under monopoly and the monopoly profit is insufficient to compensate buyers' loss from exclusivity due to the deadweight loss.[3] My paper introduces both investments and renegotiation (which are key elements to induce the pro-competitive effect of exclusive dealing) in their frameworks to assess their arguments in a more realistic setup.[4]

Beginning in the mid-1980s, two divergent strands of literature have investigated the competition effects of exclusive dealing. One strand stresses the pro-competitive effect through investment promotion and the other focuses on the anti-competitive effect from foreclosure of efficient entry.[5] The assumption on the renegotiation plays a central role in inducing these contrasting competition effects. The articles stressing the investment promotion effect mostly allows the renegotiation of initial contracts. The foreclosure effect can be ignored in their model as the *ex post* trade efficiency is always ensured by the renegotiation. In contrast, the articles emphasizing the foreclosure effect do not consider the renegotiation of original contracts and investment incentives. The anti-competitive effect from foreclosure may be pronounced without considering the renegotiation and investments. In my model, exclusive dealing induces both investment promotion and inefficient foreclosure and the interaction between these two effects is a key factor to determine the effects on competition.

My paper departs from the existing literature by considering the risk of renegotiation breakdown by which the inefficient foreclosure is driven. While most articles assume a perfect renegotiation or an absent renegotiation, the probabilistic breakdown of renegotiation is more

[3]See Motta (2004) and Whinston (2006) for a formal illustration of the Chicago School argument.

[4]Farrell (2005), and Fumagalli, Motta and Persson (2009) also assess the Chicago School argument in different setups. Farrell (2005) introduces a quantity competition instead of a price competition and restores the anti-competitiveness of exclusive dealing. Fumagalli, Motta and Persson (2009) allows a merger between the incumbent and entrant which facilitates an inefficient foreclosure.

[5]Excellent surveys on the articles about exclusive dealing are found in Motta (2004), and Rey and Tirole (2007).

realistic. The insight was pointed out by Binmore, Rubinstein and Wolinsky (1986), "they *[bargaining parties]* face a risk that if agreement is delayed, then the opportunity they hope to exploit jointly may be lost (italics added, p. 178)."[6]

I adopt their insight to the renegotiation of exclusive dealing in which the renegotiation is exposed to the risk of irrevocable breakdown.[7] In the renegotiation of exclusive contracts, the renegotiation may break down for several reasons even when both contracting parties' payoffs can be improved. First, the negotiation breaks down in random if the impatient parties get fed up with the delay of agreement and walk away from the negotiating table (Muthoo, 1999). Alternatively, the probabilistic breakdown of renegotiation can be explained by the irrational behavior of buyer or seller. In terms of bounded rationality, the risk of breakdown can be interpreted as the probability that contracting parties behave irrationally or miscalculate the surplus from renegotiation.[8]

The inefficient foreclosure from renegotiation breakdown causes the *ex post* trade inefficiency. In this setup, the interaction between investment promotion and inefficient foreclosure plays a crucial role in determining the market outcomes. This implies that the separate consideration of these two effects by abstracting the other effect (which has been adopted in most existing literature) may misrepresent the competition effects of exclusive dealing. The main purpose of this article is to propose a formal model to assess the competition effects when exclusive dealing induces both investment promotion and inefficient foreclosure.

For this purpose, I propose a model in which (i) the incumbent can engage in relationship-specific investments after the contract is signed but before potential rival's entry decision

[6]They introduced the risk of negotiation breakdown to formalize the Nash bargaining solution in the alternating bargaining model. See, for instance, Binmore, Rubinstein and Wolinsky (1986), and Muthoo (1999) for details. de Meza and Selvaggi (2007) also adopt the risk of negotiation breakdown in the analysis of investment effects of exclusive dealing to formalize the use of Nash bargaining solution.

[7]Although the cases of renegotiation breakdown have not been found extensively in the real world (partly because the breakdown of renegotiation may not be publicly known), the unplentiful evidence of renegotiation agreement indirectly suggests the existence of breakdown.

[8]See Ellison (2006), and Armstrong and Huck (2010) for the excellent surveys on the growing industrial organization literature that incorporates the bounded rationality.

is made and (ii) the initial contract may be renegotiated after the entry decision is taken. I also assume that (iii) the incumbent differs in the efficiency of cost-reducing investments (represented by k), (iv) the renegotiation process is exposed to an exogenous risk of breakdown (represented by θ) and (v) the renegotiation surplus is distributed by the bargaining power between contracting parties (represented by α). This paper explores how the competition effects of exclusive dealing depend on the abovementioned parameter values which characterize the contracting environments.

This paper presents two key findings. First, exclusive dealing raises relatively inefficient incumbent's investment incentives (but reduces sufficiently efficient incumbent's investments). The intuition behind this result is as follows. In my model with a potential entry, exclusive dealing may have a tradeoff on incumbent's investment incentives: (i) investment promotion from resolving a hold-up problem and (ii) investment reduction from reducing entry deterrence incentives. On the one hand, exclusive dealing helps the incumbent to be less concerned about the *ex post* profit loss from relationship-specific investments. This effect encourages the incumbent to invest in the relationship with a buyer. On the other hand, the incumbent may have less incentives to deter rival's entry under exclusivity. By signing exclusive contracts with a buyer, the incumbent is able to earn larger profits when more efficient rivals enter the market. As the entry deterrence is feasible through investments (i.e., higher investments reduce the probability of entry in my model), exclusive dealing plays a role to reduce investment incentives.[9] Thus, the relative size of these countervailing effects determines whether exclusive contracts promote or reduce incumbent's relationship-specific investments. My model shows that the investment promotion effect outweighs the investment reduction effect for a relatively inefficient incumbent as the inefficient seller has strong incentives to mitigate the hold-up problem.

The indecisive investment effects of this paper does not contradict to the "irrelevance result" of Segal and Whinston (2000b). Their result relies on the assumption that relationship-specific investments do not affect the value of trade between non-contracting parties. In my

[9]Note that this investment reduction effect has not been considered in most literature.

model, relationship-specific investments may have impacts on the value of trade between non-contracting parties through the effects on potential rival's entry. Externalities on non-contracting parties are key elements to induce the different investment effects from Segal and Whinston (2000b).

Second, the profitability and welfare effects of exclusivity are decided by the relative importance between investment promotion and foreclosure. My model shows that exclusive dealing has different implications on the profitability and social welfare depending on the level of risk of breakdown (θ). More specifically, exclusive dealing is profitable and welfare-enhancing when the risk of breakdown is very low. However, it can be profitable but welfare-reducing when there exists a sufficiently high risk of breakdown. Moreover, contrary to the Chicago School critique, the profitable and welfare-reducing exclusive dealing is always feasible for certain parameter configurations.

The intuition behind this result is as follows. Although both profitability and welfare effects are decided by the interaction between investment promotion and foreclosure, these two effects are not symmetric on the joint payoff and social welfare. Investment promotion has stronger impact on the joint payoff but foreclosure has stronger impact on the social welfare. As θ increases, both the joint payoff and social welfare decreases but the joint payoff decreases more slowly than the social welfare (which ensures the existence of profitable and welfare-reducing exclusive contracts). In addition, a numerical example shows that the welfare reduction may occur for reasonable risk levels.

This paper may have important implications for the recent antitrust cases on exclusive dealing where the investments and entry are treated significantly. My model shows that (i) exclusive contracts can have both anti-competitive and pro-competitive effects and (ii) the relative importance of these two effects is decided by the underlying model specifications which characterize the contracting environments. The results imply that regulatory authority needs to take into account the specific contracting environments of each case to assess the overall competition effects of exclusive dealing.

Related literature. As discussed above, this article contributes to the literature on exclusive contracts by filling the gap between two divergent strands of literature.

Several authors have analyzed the anti-competitive effect of exclusive dealing from the foreclosure of efficient entry. Starting from the seminal work by Aghion and Bolton (1987), many economists have stressed that the negative externalities imposed on non-contracting parties are the main sources of inefficient foreclosure (e.g., Rasmusen, Ramseyer and Wiley, 1991; Bernheim and Whinston, 1998; Segal and Whinston, 2000a). More recently, some others extend the models to consider the downstream competition among buyers and show that inefficient foreclosure may occur without negative externalities in the presence of downstream competition (e.g., Fumagalli and Motta, 2006; Simpson and Wickelgren, 2007; Abito and Wright, 2008).

Another strand of literature focuses on the investment effect of exclusive contracts. Segal and Whinston (2000b) show that relationship-specific investments are irrelevant to exclusivity if the renegotiation of original contracts is feasible. Recently, the investment promotion effect has been restored in a different bargaining setup (de Meza and Selvaggi, 2007) and in a different information structure (Vasconcelos, 2009). Specifically, de Meza and Selvaggi (2007) show that exclusive contracts can promote investment incentives in the three-party bargaining model where the resale of product is feasible. Vasconcelos (2009) finds that exclusivity may restore the investment efficiency by resolving the conflict between information signalling and distortion of investment incentives when there exists asymmetric information among contracting parties.

None of abovementioned articles consider both investments and entry in their model. It is notable that Spier and Whinston (1995), and Fumagalli, Motta and Rϕnde (2009) introduce these two important elements in the unifying model. Spier and Whinston (1995) present the *ex ante* over-investment incentives to deter entry as a main driving force of inefficiency under a perfect renegotiation.[10] In Fumagalli, Motta and Rϕnde (2009), the interaction

[10] Under a perfect renegotiation, inefficient foreclosure does not occur given the equilibrium investment level. In this case, only the *ex ante* over-investments caused by exclusivity is the source of social inefficiency.

between investment promotion and foreclosure plays an important role in determining the competition effects in the absence of renegotiation. However, none of these papers consider the risk of renegotiation breakdown (i.e., the imperfectness of renegotiation). The novel part of my analyses is to show how inefficient foreclosure resulting from the risk of renegotiation breakdown interacts with investment promotion and to present its implications on the profitability and social welfare.

The rest of this paper proceeds as follows. Section 2 presents the basic model of this paper. Section 3 analyzes the effects of exclusive dealing on the investment incentives, profitability and social welfare when the renegotiation process faces an exogenous risk of breakdown. Section 4 extends the basic model and checks the robustness. Section 5 summarizes and concludes. All proofs are relegated to Appendix.

2.2 The Model

This paper presents a model in which exclusive contracts affect both incumbent's investment incentives and potential rival's entry decision.

Players. An incumbent seller (I) offers a buyer (B) an exclusive contract which prohibits B from trading with a potential entrant (E) in exchange for a lump-sum payment. After B decides whether to sign the contract but before E decides whether to enter the market, I is able to invest in the relationship with B. If the entry occurs, I and E compete à la Bertrand. In this setup, exclusivity can affect both I's investment decision and E's entry decision.

In addition, the renegotiation of original contracts is allowed after E's entry decision is taken. The renegotiation surplus is divided by the bargaining power between I and B. In other words, I receives α proportion and B receives $1-\alpha$ proportion of renegotiation surplus where $\alpha \in [0,1]$ represents the bargaining power of I.[11] More importantly, the renegotiation

[11]Some articles assume a specific bargaining solution to characterize the division of renegotiation surplus. For instance, Segal and Whinston (2000b), and de Meza and Selvaggi

irrevocably breaks down with probability $\theta \in [0,1]$ and reaches an agreement with probability $1-\theta$. If the renegotiation breaks down, the initial contract must be complied (i.e., B must trade with I if they signed the contracts).

Technology. The buyer's demand is given by $q = q(p)$. For simplicity, I assume the buyer's demand as a simple linear function $q = 1 - p$.[12]

On the cost side, I suppose that the marginal cost of I is decided by $c(r) = \frac{1}{2} - r$ where r denotes the investment level chosen by I. Spending r incurs the investment cost $C(r)$ where $C'(r) > 0$ and $C''(r) > 0$. For simplicity, I assume $C(r) = \frac{k}{2}r^2$ where k denotes the investment cost (in)efficiency parameter (i.e., the incumbent with larger k is less efficient in cost-reducing investments). At the contract and investment stages, the marginal cost of E (denoted by c_E) is unknown by I and B and only the distribution of c_E is a common knowledge. c_E is assumed to be uniformly distributed on $[0,1]$.

Timing. The timing of the game is as follows.

- Stage 1: I offers B an exclusive contract and B decides whether to sign the contract.
- Stage 2: I chooses his relationship-specific investment level.
- Stage 3: c_E realizes and E decides whether to enter the market.
- Stage 4: I and B may renegotiate their initial contract if they signed the contract.
- Stage 5: Active sellers simultaneously determine prices and trade occurs.

2.3 Exclusive Dealing and Imperfect Renegotiation

This section explores how the risk of renegotiation breakdown plays a role in determining the effects of exclusive dealing on the investment incentives and entry. The profitability

(2007) assume the Nash bargaining solution (i.e., $\alpha = 0.5$).

[12] The same form of demand function is assumed in Fumagalli and Motta (2006), and Fumagalli, Motta and Persson (2009). In my model, this simple functional form facilitates the analyses without much loss of generality.

and welfare implications of exclusive dealing are also investigated. Throughout the paper, I consider the *status quo* (which is compared to the outcomes under exclusive dealing) as the market outcomes under non-exclusivity. I look for a subgame perfect equilibrium and solve the game by backward induction.

Price decision. I start from the last stage of the game where prices are determined. I restrict attention to a linear pricing. If no entry occurs, the incumbent I charges a monopoly price. On the other hand, if the potential entrant E enters the market, the price decision depends on the contract decision and renegotiation. I and E compete à la Bertrand upon entry. The optimal pricing strategy can be summarized as follows.[13]

- No entry: I charges $p_I = p^m(c(r))$.
- Entry: I and E set their prices in the following way.[14]

$$p_I^0 = \begin{cases} c(r) & \text{if } c_E < c(r) \\ c_E & \text{if } c_E \geq c(r), \end{cases}$$

$$p_I^1 = \begin{cases} c(r) & \text{if renegotiation was agreed} \\ p^m(c(r)) & \text{if renegotiation broke down,} \end{cases}$$

$$p_E = \begin{cases} c(r) & \text{if } c_E < c(r) \\ c_E & \text{if } c_E \geq c(r). \end{cases}$$

Renegotiation. After observing the realization of c_E and E's entry decision, I and B are allowed to renegotiate the initial contract. If the renegotiation reaches an agreement, B may purchase products from E and the renegotiation surplus (denoted by Δ) is distributed to I

[13] Throughout the paper, I use the superscript 0 and 1 to denote non-exclusivity and exclusivity and the subscript B, I and E to denote each player. For instance, p_I^0 and p_I^1 respectively denote incumbent's prices under non-exclusivity and exclusivity.

[14] With E's entry and the agreement of renegotiation, $p_I^1 = c(r)$ is optimal irrespective of the realization of c_E. For $c_E < c(r)$, it is optimal for I to charge $p_I^1 = c(r)$ from Bertrand competition. We can also show that $\pi_I^1(c(r)) = \frac{1}{4}(1 - c(r))^2 + \frac{\alpha}{8}(1 - c(r))^2$ is always larger than $\pi_I^1(c_E) = (c_E - c(r))(1 - c_E) + \frac{\alpha}{2}(c_E - c(r))^2$ for $c_E \geq c(r)$.

and B according to each party's bargaining power. The final payoffs after renegotiation are determined as $d_I + \alpha\Delta$ for I and $d_B + (1-\alpha)\Delta$ for B where d_i denotes the disagreement payoff of i ($i = I, B$). However, if the renegotiation breaks down, B must trade with I even when there exists the renegotiation surplus.

More specifically, if the renegotiation is agreed, the joint payoff of I and B equals to the consumer surplus at a price $c(r)$. If the renegotiation breaks down, the joint payoff is equal to the sum of consumer surplus and I's profit at a price $p^m(c(r))$. Thus, the renegotiation surplus is measured by the difference between the joint payoffs with or without renegotiation breakdown and it is written as

$$\Delta \equiv CS(c(r)) - [CS(p^m(c(r))) + \pi(p^m(c(r)))] = \frac{1}{8}\left[1 - c(r)\right]^2 \tag{2.1}$$

where $\pi(p^m(c(r)))$ denotes the monopoly profit at a cost $c(r)$ and $CS(c(r))$, $CS(p^m(c(r)))$ denote the consumer surpluses at prices $c(r)$ and $p^m(c(r))$ respectively.

The disagreement payoff is defined as the payoff that each player would get if the renegotiation broke down and the original contract was complied. Thus, the disagreement payoffs of I and B are respectively equal to the consumer surplus and profit at a monopoly price $p^m(c(r))$.

$$\begin{cases} d_B \equiv CS(p^m(c(r))) = \frac{1}{8}\left[1 - c(r)\right]^2 \\ d_I \equiv \pi(p^m(c(r))) = \frac{1}{4}\left[1 - c(r)\right]^2 \end{cases} \tag{2.2}$$

Entry decision. I assume that E enters the market only when the expected profit from entry is positive. As E could not earn positive profits if $c_E \geq c(r)$, E will not enter the market in this case. On the other hand, E will enter the market if $c_E < c(r)$ as the expected profits of E under non-exclusivity and exclusivity are given by

$$\begin{cases} \pi_E^0 = \left[c(r) - c_E\right]\left[1 - c(r)\right] \\ \pi_E^1 = (1-\theta)\left[c(r) - c_E\right]\left[1 - c(r)\right] \end{cases}$$

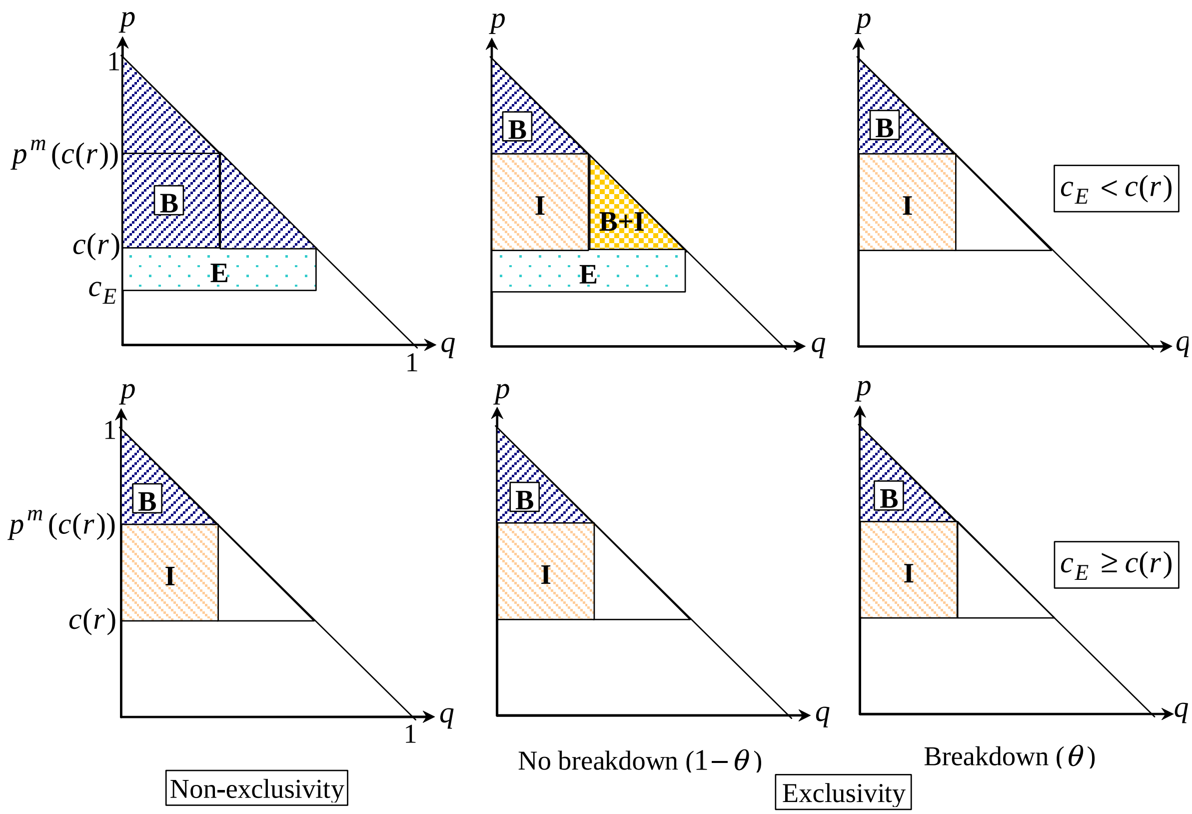

Figure 2.1: Payoffs under non-exclusivity and exclusivity

"For interpretation of the references to color in this and all other figures, the reader is referred to the electronic version of this dissertation."

In both exclusive and non-exclusive regimes, E enters the market if its marginal cost c_E is lower than I's marginal cost $c(r)$. Figure 2.1 summarizes each player's payoffs depending on whether (i) the contract has been signed, (ii) the entry has occurred and (iii) the renegotiation has broken down or not.

2.3.1 Investment incentives

Now we can examine the effects of exclusive dealing on I's relationship-specific investments. At the investment stage, I determines the investment level to maximize his expected profit.

Without exclusive contracts, I earns a positive profit only when more efficient rival E does not enter the market (i.e., $c_E \geq c(r)$). The expected profit of I under non-exclusivity is written as

$$\pi_I^0(r) = [1 - c(r)]\,\pi(p^m(c(r)) - C(r) = \frac{1}{4}\,[1 - c(r)]^3 - C(r) \tag{2.3}$$

I assume that the equilibrium investment levels cannot exceed 1/2 to exclude negative marginal costs which is not plausible in the real world. The equilibrium investment level under non-exclusivity is given by

$$r^0 = \begin{cases} \frac{1}{6}\left[4k - 3 - 2\sqrt{2k(2k-3)}\right] & \text{if } k \geq \frac{3}{2} \\ \frac{1}{2} & \text{if } 0 < k < \frac{3}{2} \end{cases} \tag{2.4}$$

In what follows, the analyses are restricted to $k \geq 3/2$ as the consideration of $0 < k < 3/2$ case does not have much difference except exclusive dealing has no impact on investment incentives for sufficiently small k.

With exclusive contracts, I earns a positive profit in both entry and no entry case. With entry, I earns the renegotiation payoff $(d_I + \alpha\Delta)$ if the renegotiation reaches an agreement (the probability of this event is $1 - \theta$) but earns the disagreement payoff (d_I) if the renegotiation breaks down (the probability of this event is θ). Without entry, I earns a monopoly profit. Ignoring a lump-sum payment (which has no effect on investment incentives), the expected profit of I under exclusivity is written as

$$\begin{aligned} \pi_I^1(r) &= c(r)\,[(1-\theta)(d_I + \alpha\Delta) + \theta d_I] + [1 - c(r)]\,\pi(p^m(c(r)) - C(r) \\ &= \frac{1}{4}\,[1 - c(r)]^2 + \frac{\alpha(1-\theta)}{8} c(r)\,[1 - c(r)]^2 - C(r) \end{aligned} \tag{2.5}$$

where Δ and d_I are given by (2.1) and (2.2) respectively. The following proposition characterizes the effect of exclusivity on I's investment incentives.

Proposition 7 (Investment incentives) *Suppose that the renegotiation breaks down with a probability* $\theta \in [0, 1]$. *For* $k \geq 3/2$ *and* $\alpha \in [0, 1]$, *there exists a cutoff value of investment* *cost efficiency* $\bar{k}$ *such that exclusive dealing raises* I*'s investments if* $k > \bar{k}$ *but reduces* I*'s investments otherwise.* $\bar{k} = 2$ *is uniquely determined.*

Proposition 7 shows that exclusive dealing raises relatively inefficient incumbent's investment incentives. The intuition behind this proposition is as follows. In my model with a potential entry, exclusive dealing may have a tradeoff on incumbent's investment incentives: (i) investment promotion from resolving a hold-up problem and (ii) investment reduction from reducing entry deterrence incentives. On the one hand, exclusive dealing helps the incumbent to be less concerned about the *ex post* profit loss from relationship-specific investments. This effect encourages the incumbent to invest in the relationship with a buyer. On the other hand, however, the incumbent may have less incentives to deter rival's entry under exclusivity. By signing exclusive contracts with a buyer, the incumbent can earn larger profits when more efficient rivals enter the market. As the entry deterrence is feasible through investments (i.e., higher investments reduce the probability of entry in my model), exclusive dealing plays a role to reduce investment incentives. Thus, the relative size of these countervailing effects determines whether exclusive contracts promote or reduce incumbent's relationship-specific investments. My model shows that the investment promotion effect outweighs the investment reduction effect for a relatively inefficient incumbent seller as the inefficient seller has strong incentives to mitigate the hold-up problem.

More formally, given investments at $r = r^0$, the difference between I's exclusive and non-exclusive profits is given by

$$\pi_I^1(r^0) - \pi_I^0(r^0) = \frac{2 + \alpha(1-\theta)}{8} \underbrace{c(r^0)}_{(-)} \underbrace{\left[1 - c(r^0)\right]^2}_{(+)} \tag{2.6}$$

As is clear in (2.6), exclusivity has a tradeoff on I's investment incentives: (i) investment reduction through the impact on entry probability and (ii) investment promotion through the impact on the *ex post* profits. The relative size of these effects depends on the investment level under non-exclusivity which in turn depends on the investment cost efficiency k. Specifically, the investment promotion effect outweighs the investment reduction effect for a sufficiently low r^0 (high k). Also, the sign of investment effect solely depends on k and other exogenous parameter values (e.g., α and θ) are irrelevant to the sign of investment effect because the investment level under non-exclusivity (which is the *status quo* compared to the investment level under exclusivity) is determined by k only.

I would also like to mention that the "irrelevance result" of Segal and Whinston (2000b) does not contradict to this proposition. The "irrelevance result" relies on the assumption that relationship-specific investments do not affect the value of trade between non-contracting parties. In my model, relationship-specific investments may have impacts on the value of trade between non-contracting parties through the effect on potential rival's entry.

Example (Investment incentives: $\alpha = 0.5$, $\theta = 0.1$ case) [15]

A numerical example illustrates Proposition 7. At $\alpha = 0.5$ and $\theta = 0.1$, the equilibrium investment level under exclusivity is given for $k \geq 3/2$,

$$r^1 = \frac{1}{54}\left(71 - 160k + 2\sqrt{6400k^2 - 5680k + 2401}\right) \tag{2.7}$$

Figure 2.2 plots (2.4) and (2.7) which represent the investment levels under non-exclusivity and exclusivity associated with the investment cost efficiency k. We can observe that the investment promotion occurs for $k > 2$ but the investment reduction occurs for $k < 2$. The same qualitative result can be obtained for any $\alpha, \theta \in [0, 1]$.

2.3.2 Profitability and welfare analysis

Given I's investment decision, I study whether (i) exclusive dealing can be signed in equilibrium and (ii) the profitable contracts raise or reduce the social welfare. To check the profitability (which I define as the existence of contracts improving contracting parties' joint

[15] The assumpiton of $\alpha = 0.5$ can be justified by the Nash bargaining solution and has been adopted in many articles. See, for instance, Segal and Whinston (2000b), and de Meza and Selvaggi (2007) to adopt this assumption in the analysis of exclusive dealing.

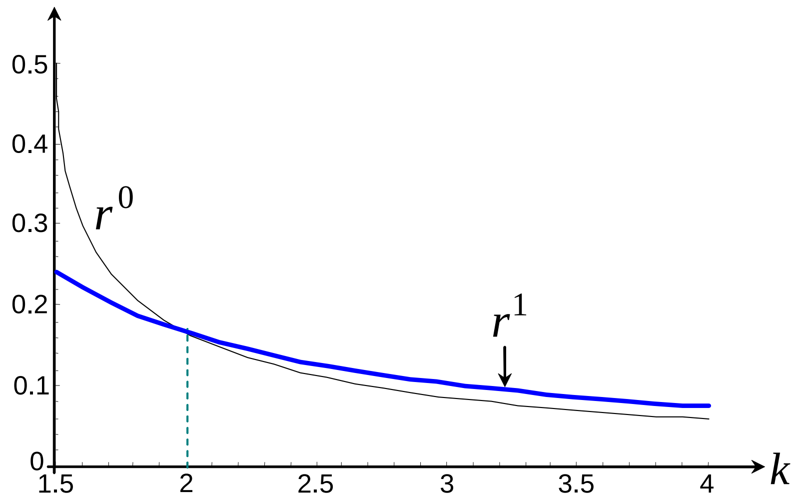

Figure 2.2: Investment incentives under non-exclusivity and exclusivity ($\alpha = 0.5$, $\theta = 0.1$)

payoff), I compare I and B's joint payoffs under non-exclusivity and exclusivity. Moreover, I identify the conditions under which exclusive contracts are more likely to be anti-competitive or pro-competitive.

The joint payoff under non-exclusivity is written as

$$\begin{aligned}\pi^0_{IB}(r^0) &= c(r^0)CS(c(r^0)) + \left[1 - c(r^0)\right]\left[CS(p^m(c(r^0))) + \pi(p^m(c(r^0)))\right] - C(r^0) \\ &= \frac{1}{8}\left[1 - c(r^0)\right]^2\left[3 + c(r^0)\right] - C(r^0) \qquad (2.8)\end{aligned}$$

where r^0 denotes the equilibrium investment level under non-exclusivity and it is given by (2.4). On the other hand, the joint payoff under exclusivity is written as

$$\begin{aligned}\pi^1_{IB}(r^1) &= c(r^1)\left\{(1-\theta)CS(c(r^1)) + \theta\left[CS(p^m(c(r^1))) + \pi(p^m(c(r^1)))\right]\right\} \\ &\quad + \left[1 - c(r^1)\right]\left[CS(p^m(c(r^1))) + \pi(p^m(c(r^1)))\right] - C(r^1) \\ &= \left(\frac{1}{2} - \frac{\theta}{8}\right)c(r^1)\left[1 - c(r^1)\right]^2 + \frac{3}{8}\left[1 - c(r^1)\right]^3 - C(r^1) \qquad (2.9)\end{aligned}$$

where r^1 denotes the equilibrium investment level under exclusivity.

I also compare the social welfare under non-exclusivity and exclusivity to explore welfare consequences of exclusive dealing. The social welfare under non-exclusivity is written as

$$\begin{aligned} W^0(r^0) &= \int_0^{c(r^0)} \left[CS(c(r^0)) + \pi_E(c(r^0))\right] dc_E \\ &\quad + \left[1 - c(r^0)\right] \left[CS(p^m(c(r^0))) + \pi(p^m(c(r^0)))\right] - C(r^0) \\ &= \frac{1}{2}c(r^0)\left[1 - c(r^0)\right] + \frac{3}{8}\left[1 - c(r^0)\right]^3 - C(r^0) \end{aligned} \tag{2.10}$$

where $\pi_E(c(r)) = [c(r) - c_E][1 - c(r)]$. On the other hand, the social welfare under exclusivity is written as

$$\begin{aligned} W^1(r^1) &= \int_0^{c(r^1)} \{(1-\theta)[CS(c(r^1)) + \pi_E(c(r^1))] + \theta[CS(p^m(c(r^1))) + \pi(p^m(c(r^1)))]\} dc_E \\ &\quad + \left[1 - c(r^1)\right] \left[CS(p^m(c(r^1))) + \pi(p^m(c(r^1)))\right] - C(r^1) \\ &= \frac{1}{2}(1-\theta)c(r^1)\left[1 - c(r^1)\right] + \frac{3}{8}\theta c(r^1)\left[1 - c(r^1)\right]^2 + \frac{3}{8}\left[1 - c(r^1)\right]^3 - C(r^1) \end{aligned} \tag{2.11}$$

As a benchmark, I first consider two extreme cases on the risk of renegotiation breakdown: i.e., (i) perfect renegotiation ($\theta = 0$) and (ii) absent renegotiation ($\theta = 1$).[16] The results on these two cases highlight the role of risk of breakdown in determining the effects of exclusivity on the profitability and social welfare. Finally, I will generalize the analyses to the imperfect renegotiation case ($0 < \theta < 1$) using the results on the extreme cases.

• ***Case 1: Perfect renegotiation.*** In the perfect renegotiation case, the condition of profitability is the same as the condition of investment promotion. As the inefficient foreclosure does not occur (since the buyer always purchases products from the lower-cost seller in equilibrium), the profitability is solely decided by the investment effect. In other words, the total surplus available to I and B increases with investment promotion but decreases with

[16] Note that most existing literature supposes these two cases in either explicitly or implicitly. See, for instance, Spier and Whinston (1995), Segal and Whinston (2000b), de Meza and Selvaggi (2007), and Vasconcelos (2009) for a perfect renegotiation. In contrast, an absent renegotiation is implicitly assumed in most articles which analyze the foreclosure effect of exclusive dealing (e.g., Fumagalli and Motta, 2006; Simpson and Wickelgren, 2007; Abito and Wright, 2008).

investment reduction.

On the social welfare, exclusive dealing raises the social welfare irrespective of investment effect because the inefficient foreclosure does not occur under a perfect renegotiation. For the inefficient incumbent, exclusivity resolves a hold-up problem and mitigates *ex ante* under-investment incentives. On the other hand, exclusive dealing reduces efficient seller's over-investment incentives. Lemma 1 demonstrates these results.

Lemma 5 (Perfect renegotiation) *Suppose that the renegotiation always reaches an agreement (i.e., $\theta = 0$). For $k \geq 3/2$ and $\alpha \in [0, 1]$,*

(i) there exists a cutoff value of investment cost efficiency ($\bar{k} = 2$) such that exclusive dealing raises the joint payoff for $k > \bar{k}$ but reduces the joint payoff otherwise

(ii) exclusive dealing raises the social welfare for any $k \geq 3/2$.

Lemma 5 shows that the profitable exclusive dealing is always welfare-enhancing through investment promotion under a perfect renegotiation. This implies that the pro-competitiveness of exclusive dealing through investment promotion critically relies on the perfect renegotiation assumption.

• ***Case 2: Absent renegotiation.*** On the other extreme case where the renegotiation is not feasible, the profitability of exclusive dealing changes dramatically. Without renegotiation, the profitable exclusive contracts are not feasible for any parameter values. The buyer has no incentive to lock his trade to the incumbent because he knows the incumbent has no way to compensate his loss fully due to the monopoly deadweight loss.

On the welfare effect, exclusive dealing is always welfare-reducing. As the probability of foreclosure (which is equal to $\theta c(r)$) is pronounced at $\theta = 1$, the welfare loss from foreclosure outweighs the welfare gain from investment promotion. The results are characterized by Lemma 6.

Lemma 6 (Absent renegotiation) *Suppose that the renegotiation is not feasible (i.e., $\theta = 1$). For $k \geq 3/2$ and $\alpha \in [0, 1]$, exclusive dealing reduces both the joint payoff and social* *welfare.*

Lemma 6 shows that the profitable exclusive dealing is not feasible without renegotiation. Lemma 5 and 6 highlight that the risk of breakdown plays a central role in determining the profitability and welfare effects of exclusive dealing.

• ***Case 3: Imperfect renegotiation.*** As discussed in the introduction, the risk of renegotiation breakdown is feasible in the real world. Thus, I extend the analyses on the profitability and welfare effects to the imperfect renegotiation case ($0 < \theta < 1$). For this purpose, I establish several useful properties regarding the joint payoff and social welfare functions. As r^0 is a function of k and r^1 is a function of θ, k, the associated joint payoff functions under non-exclusivity and exclusivity can be denoted as $\pi^0_{IB}(k)$ and $\pi^1_{IB}(\theta, k)$. Similarly, the welfare functions can be written as $W^0(k)$ and $W^1(\theta, k)$. Lemma 7 states some useful properties on these functions.

Lemma 7 *For* $k \geq 3/2$ *and* $\alpha, \theta \in [0, 1]$, *the joint payoff and welfare functions satisfy the following properties.*

P1. $\pi^1_{IB}(\theta, k) \leq \pi^0_{IB}(k)$ *for* $3/2 \leq k \leq 2$.

P2. $\pi^1_{IB}(\theta, k)$ *and* $W^1(\theta, k)$ *are continuous in* θ.

P3. $\frac{\partial \pi^1_{IB}(\theta,k)}{\partial \theta} < 0$ *for* $k > 2$.

P1 implies that the profitable exclusive dealing is not feasible without investment promotion (i.e., investment promotion is a necessary condition for profitability). The intuition behind this property is straightforward from Figure 2.1. Given investments r, exclusive contracts reduce the joint payoff by Δ (which is equal to the monopoly deadweight loss) with a probability $\theta c(r)$ (which is equal to the joint probability of renegotiation breakdown and entry). Consequently, the profitable exclusive contracts are feasible only with a large investment promotion effect. Afterwards, I restrict the analyses to $k > 2$ which is a potential candidate for profitability.

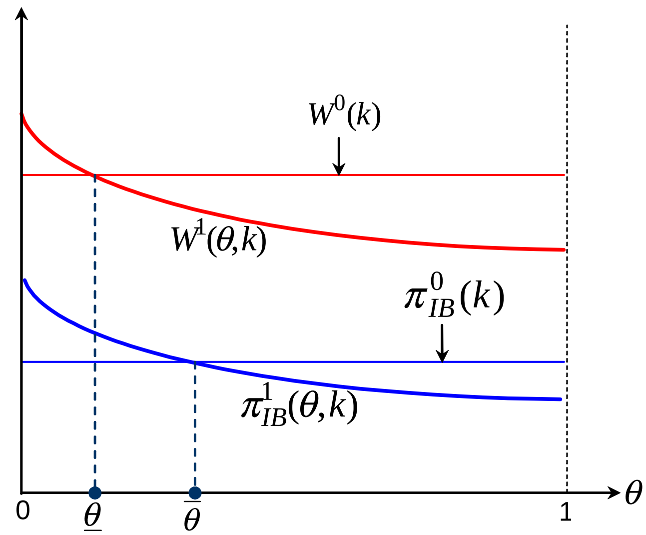

Figure 2.3: Profitability and social welfare under non-exclusivity and exclusivity

P2 and *P3* imply that, given $k > 2$, there exists a unique cutoff value of θ such that the joint payoff is unaffected by exclusivity. In addition, *P2* (combined with Lemma 5 and 6) ensures the existence of cutoff value of θ where the social welfare is unaffected by exclusivity. Lemma 5 and 6 imply that (i) $\pi^1_{IB}(0,k) > \pi^0_{IB}(k)$, $\pi^1_{IB}(1,k) < \pi^0_{IB}(k)$ and (ii) $W^1(0,k) > W^0(k)$, $W^1(1,k) < W^0(k)$. From Lemma 7, $\pi^1_{IB}(\theta,k)$ and $W^1(\theta,k)$ can be represented as a continuous and strictly decreasing function of θ.[17] Moreover, one can show that the cutoff value of joint payoff (denoted by $\overline{\theta}$) is higher than that of social welfare (denoted by $\underline{\theta}$). Figure 2.3 summarizes the joint payoff and welfare functions satisfying Lemma 5 $-$ Lemma 7. From this figure, the profitability and welfare effects in the presence of risk of renegotiation breakdown can be characterized by Proposition 8.

Proposition 8 (Imperfect renegotiation) *Suppose that the renegotiation breaks down with a probability $\theta \in [0,1]$. For $k > 2$ and $\alpha \in [0,1]$, there exist cutoff values of risk of renegotiation breakdown, $\underline{\theta}$ and $\overline{\theta}$, such that*

(i) exclusive dealing raises both the joint payoff and social welfare for $0 \leq \theta < \underline{\theta}$

(ii) exclusive dealing raises the joint payoff but reduces the social welfare for $\underline{\theta} < \theta < \overline{\theta}$

[17]Although the proof of $\partial W^e(\theta,k)/\partial\theta < 0$ is not easy for all possible parameter configurations, one can show that this property holds for reasonable parameter values.

(iii) exclusive dealing reduces both the joint payoff and social welfare for $\overline{\theta} < \theta \leq 1$.

For given k, $\underline{\theta}$ and $\overline{\theta}$ are uniquely determined.

Proposition 8 implies that exclusive contracts can be signed in equilibrium for a sufficiently low θ ($0 \leq \theta < \overline{\theta}$). The intuition is as follows. Exclusive dealing may have a tradeoff on contracting parties' joint payoff: (i) payoff increase from investment promotion and (ii) payoff decrease from foreclosure. As θ increases, the effect of investment promotion becomes weaker but the effect of foreclosure becomes stronger.[18] The positive effect of investment promotion outweighs the negative effect of foreclosure for a low θ (the opposite result applies to a high θ). In addition, exclusive contracts can be welfare-improving for a sufficiently low θ. The intuition for this result is similar to the former one.

Moreover, the cutoff value of profitability is always higher than that of welfare effect. Accordingly, the profitable exclusive dealing raises the social welfare for a low θ ($0 \leq \theta < \underline{\theta}$) but reduces the social welfare for an intermediate θ ($\underline{\theta} < \theta < \overline{\theta}$). The intuition behind this result is as follows. Although both the profitability and welfare effects are decided by the interaction between investment promotion and foreclosure, these two effects are not symmetric on the joint payoff and social welfare. Investment promotion has larger impact on the joint payoff but foreclosure has larger impact on the social welfare. Therefore, as θ increases, both joint payoff and social welfare decreases but the joint payoff decreases more slowly than the social welfare (which ensures the existence of profitable and welfare-reducing exclusive contracts).

Example (Profitability and welfare effect: $\alpha = 0.5$ case)

A numerical example highlights how the risk of breakdown affects the profitability and welfare implications. At $\alpha = 0.5$, the equilibrium investment level under exclusivity is given

[18] The decreasing investment effect can be shown by $\partial r^1 / \partial \theta < 0$ (see Proof of Lemma 7 in Appendix).

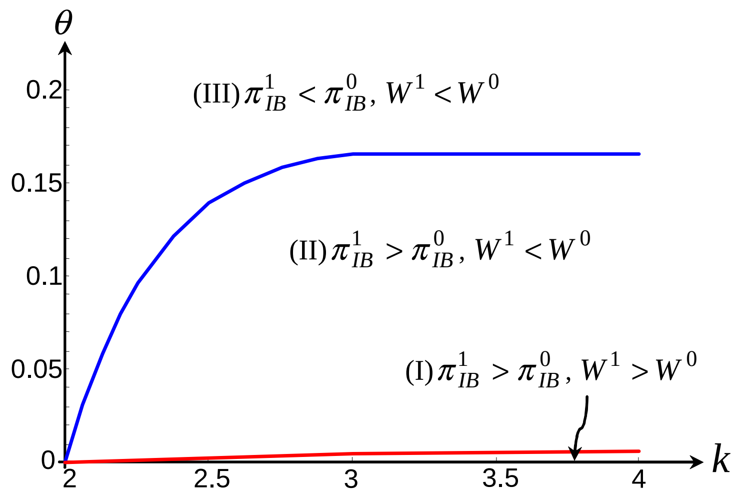

Figure 2.4: Profitability and welfare effects of exclusive dealing ($\alpha = 0.5$)

for $k \geq 3/2$,

$$r^1 = \frac{1}{6(1-\theta)}\left[7 - 16k + \theta + 2\sqrt{64k^2 - 56k + 25 + \theta^2 - 2(4k+5)\theta}\right] \tag{2.12}$$

The area, associated with θ and k, can be divided into three regions depending on the effects on the profitability and social welfare. In Figure 2.4, each region represents the parameter configurations such that exclusive dealing is (I) profitable and welfare-enhancing, (II) profitable and welfare-reducing and (III) unprofitable. This example shows that the necessary probability of breakdown for welfare reduction ($\underline{\theta}$) is not unreasonably high (e.g., $\underline{\theta} < 0.01$ for any $k \geq 3/2$).

2.4 Extensions

In this section, I extend the basic model in two dimensions and illustrate that the main results of the paper are robust to the extensions.

2.4.1 Degree of exclusivity

Suppose the *ex post* probability that the incumbent has exclusivity is $e \in [0,1]$.[19] While the analysis of the previous section was restricted to a fully exclusive regime ($e = 1$), we can easily extend the analysis to $e \in (0,1)$. The expected profit of I under non-exclusivity is written as

$$\pi_I^e(r) = (1-e)\pi_I^0(r) + e\pi_I^1(r) \quad \Leftrightarrow \quad \pi_I^e(r) - \pi_I^0(r) = e[\pi_I^1(r) - \pi_I^0(r)]$$

Above equation implies that the investment effect at $e = 1$ carries over to any $e \in (0,1)$. That is, exclusive contracts raise the relatively inefficient incumbent's investment incentives. One can also easily infer the implications on the profitability and social welfare. For a sufficiently high e, the profitable and welfare-reducing exclusive dealing is feasible for an intermediate θ. However, the necessary probability of breakdown for welfare reduction ($\underline{\theta}$) is negatively related with e (i.e., higher e requires lower $\underline{\theta}$).

2.4.2 Buyer investments

Now suppose that the buyer is able to invest in the relationship with the incumbent. With buyer's investments r, the marginal cost of I is given by $c(r) = 1/2 - r$. The expected profit of B under non-exclusivity is written as

$$\begin{aligned} \pi_B^0(r) &= c(r)CS(c(r)) + [1-c(r)]\, CS(p^m(c(r))) - C(r) \\ &= \frac{1}{8}[1-c(r)]^2\,[1+3c(r)] - C(r) \end{aligned} \tag{2.13}$$

[19]Segal and Whinston (2000b) consider a continuous degree of exclusivity. They interpret $e \in [0,1]$ as the duration of exclusivity.

On the other hand, the expected profit of B under exclusivity is written as

$$\begin{aligned} \pi_B^1(r) &= c(r)\{(1-\theta)[d_B + (1-\alpha)\Delta] + \theta d_B\} + [1-c(r)]\, CS(p^m(c(r))) - C(r) \\ &= \frac{1}{8}[1-c(r)]^2[1+(1-\theta)(1-\alpha)c(r)] - C(r) \end{aligned} \tag{2.14}$$

where Δ and d_B are given by (2.1) and (2.2) respectively. The following proposition characterizes the effect of exclusivity on buyer's investment incentives. Note that, contrary to incumbent's investment case, exclusive dealing raises relatively efficient buyer's investment incentives.

Proposition 9 (Buyer's investment incentives) *Suppose that the renegotiation breaks down with a probability $\theta \in [0,1]$. For $k > 0$ and $\alpha \in [0,1]$, there exists a cutoff value of investment cost efficiency $\bar{k}$ such that exclusive dealing raises B's investments if $k < \bar{k}$ but reduces B's investments otherwise. $\bar{k} = 2$ is uniquely determined.*

We can also obtain the same results on the profitability and social welfare as in incumbent's investment case because the joint payoff and welfare functions are the same irrespective of the identity of investing party. That is, the profitable exclusive dealing will reduce the social welfare when there exists a sufficiently high risk of breakdown.

2.5 Concluding Remarks

Exclusive dealing is widely used in the real world but its effects on competition are still controversial. The coexistence of pro-competitive effect from investment promotion and anti-competitive effect from foreclosure makes it difficult to decide the overall competition effects of exclusive dealing in one direction. Moreover, my paper shows that the investment effect of exclusive dealing also depends on the investing party's cost efficiency when there exists a threat of potential entry. Exclusivity raises relatively inefficient incumbent's investment incentives by resolving a hold-up problem but reduces relatively efficient incumbent's investment incentives by reducing entry deterrence incentives. I would also like to mention that the investment effect of this paper is complementary to the "irrelevance result" of Segal and Whinston (2000b). In my model, relationship-specific investments cannot be purely internal because potential rival's entry is affected by investments. The "irrelevance result" seems to be a special case where relationship-specific investments do not cause any externalities on non-contracting parties.

In the presence of the risk of renegotiation breakdown, exclusive dealing may have both investment promotion effect and foreclosure effect. The main purpose of this paper is to propose a formal model to compare the relative importance between these contrasting effects. In my model, the risk of renegotiation breakdown plays a crucial role in determining the relative size of these effects. As the risk of breakdown increases, the investment promotion effect becomes weaker but the foreclosing effect becomes stronger. Thus, exclusive dealing may have different implications on the profitability and social welfare depending on the level of risk of breakdown. My model shows that exclusive dealing is (i) profitable and welfare-enhancing when the risk of breakdown is very low but (ii) profitable and welfare-reducing for a sufficiently high risk of renegotiation. Moreover, contrary to the Chicago School critique, the profitable and welfare-reducing exclusive dealing is always feasible for certain parameter configurations. This paper restores the inefficient foreclosure by exclusive contracts in the presence of risk of renegotiation breakdown even considering renegotiation and investments. Ironically, the investment promotion effect (which has been considered as a pro-competitive effect of exclusive dealing in most literature) may serve anti-competitive purposes by interacting with inefficient foreclosure.

In my paper, the risk of renegotiation breakdown (θ) has been given exogenously. However, it would be interesting to analyze the implications of exclusive dealing when the risk of breakdown is determined endogenously. For instance, the risk of breakdown would be related with the size of renegotiation surplus (which can be thought as the opportunity cost of renegotiation breakdown). The contracting parties would have strong incentives to reduce the probability of breakdown when the renegotiation surplus is large, which in turn affects investment incentives and entry decision. In future work, it would be interesting to analyze how the risk of negotiation breakdown interacts with investment promotion and foreclosure in more detail.

APPENDIX

Appendix

■ Proofs omitted in the text

Proof of Proposition 7. From (2.6), the first-order derivative of $\pi_I^1(r)$ at $r = r^0$ is given by

$$\pi_I^{1\prime}(r^0) = \pi_I^{0\prime}(r^0) + \frac{2 + (1-\theta)\alpha}{8} c'(r^0) \left[1 - c(r^0)\right] \left[1 - 3c(r^0)\right] \tag{A.1}$$

where r^0 denotes the equilibrium investment level under non-exclusivity and it is given by (2.4). Using $\pi_I^{0\prime}(r^0) = 0$, $c'(r) < 0$ and $0 \le c(r) \le 1/2$, the sign of (A.1) is decided by

$$\pi_I^{1\prime}(r^0) \begin{Bmatrix} \le \\ > \end{Bmatrix} 0, \quad \begin{matrix} \textit{if } 1/6 \le r^0 \le 1/2 \\ \textit{if } 0 \le r^0 < 1/6 \end{matrix}$$

Since r^0 is strictly decreasing in k and solely determined by k, the condition of $1/6 \le r^0 \le 1/2$ ($0 \le r^0 < 1/6$) is equivalent to $3/2 \le k \le 2$ ($k > 2$). ■

Proof of Lemma 5.

(1) Joint payoff: Plugging $\theta = 0$ into (2.9), the joint payoff under non-exclusivity and exclusivity is written as

$$\pi_{IB}^0(r) = \pi_{IB}^1(r) = \frac{1}{8} \left[1 - c(r)\right]^2 \left[3 + c(r)\right] - C(r)$$

which can be rewritten as

$$\pi_{IB}^0(r) = \pi_{IB}^1(r) = \pi_I^0(r) + \frac{1}{8} \left[1 - c(r)\right]^2 \left[5 - c(r)\right]$$

Using $\pi_I^{0\prime}(r^0) = 0$, the first-order derivative at $r = r^0$ is given by

$$\pi_{IB}^{0\prime}(r^0) = \pi_{IB}^{1\prime}(r^0) = -\frac{1}{8} c'(r^0) \left[1 - c(r^0)\right] \left[11 - 3c(r^0)\right] \tag{A.2}$$

As (A.2) is positive from $c'(r^0) < 0$, $1 - c(r^0) > 0$ and $11 - 3c(r^0) > 0$, we can conclude that

$$\pi^1_{IB}(r^1) \left\{ \begin{array}{c} > \\ \leq \end{array} \right\} \pi^0_{IB}(r^0), \quad \begin{array}{l} \textit{if } r^1 > r^0 \\ \textit{if } r^1 \leq r^0 \end{array}$$

The condition of $r^1 > r^0$ ($r^1 \leq r^0$) is equivalent to $k > 2$ ($3/2 \leq k \leq 2$) from Proposition 7.

(2) Social welfare: Plugging $\theta = 0$ into (2.11), the social welfare under non-exclusivity and exclusivity is written as

$$W^0(r) = W^1(r) = \frac{1}{2}c(r)\left[1 - c(r)\right] + \frac{3}{8}\left[1 - c(r)\right]^3 - C(r)$$

which can be rewritten as

$$W^0(r) = W^1(r) = \pi^0_I(r) + \frac{1}{2}c(r)\left[1 - c(r)\right] + \frac{1}{8}\left[1 - c(r)\right]^3$$

Using $\pi^{0\prime}_I(r^0) = 0$, the first-order derivative at $r = r^0$ is given by

$$W^{0\prime}(r^0) = W^{1\prime}(r^0) = -\frac{1}{8}c'(r^0)\left[1 + c(r^0)\right]\left[3c(r^0) - 1\right] \tag{A.3}$$

The sign of (A.3) is decided by the sign of $\left[3c(r^0) - 1\right]$ from $c'(r^0) < 0$ and $1 + c(r^0) > 0$. That is, $W^{0\prime}(r^0) = W^{1\prime}(r^0) > 0$ for $0 \leq r^0 < 1/6$ and $W^{0\prime}(r^0) = W^{1\prime}(r^0) \leq 0$ for $1/6 \leq r^0 \leq 1/2$. As $r^1 > r^0$ for $0 \leq r^0 < 1/6$ and $r^1 \leq r^0$ for $1/6 \leq r^0 \leq 1/2$, we can conclude that $W^1(r^1) \geq W^0(r^0)$ for any $0 \leq r^0 \leq 1/2$ (equivalently, for any $k \geq 3/2$ from Proposition 7). ■

Proof of Lemma 6.

(1) Joint payoff: From the first order condition of (2.5) at $\theta = 1$, the equilibrium investment level under exclusivity is given by

$$r^1 = \frac{1}{2(2k - 1)} \tag{A.4}$$

Plugging $\theta = 1$ into (2.9), the joint payoffs under non-exclusivity and exclusivity are written as

$$\begin{aligned}
\pi^0_{IB}(r^0) &= \frac{1}{8}\left[1 - c(r^0)\right]^2 \left[3 + c(r^0)\right] - C(r^0) \\
\pi^1_{IB}(r^1) &= \frac{3}{8}\left[1 - c(r^1)\right]^2 - C(r^1)
\end{aligned}$$

where r^0 and r^1 are given by (2.4) and (A.4) respectively. The comparison of joint payoffs shows $\pi^1_{IB}(r^1) < \pi^0_{IB}(r^0)$ for any $k \geq 3/2$.

(2) Social welfare: Plugging $\theta = 1$ into (2.11), the social welfares under non-exclusivity and exclusivity are written as

$$\begin{aligned}
W^0(r^0) &= \frac{1}{2}c(r^0)\left[1 - c(r^0)\right] + \frac{3}{8}\left[1 - c(r^0)\right]^3 - C(r^0) \\
W^1(r^1) &= \frac{3}{8}\left[1 - c(r^1)\right]^2 - C(r^1)
\end{aligned}$$

The comparison of social welfares shows $W^1(r^1) < W^0(r^0)$ for any $k \geq 3/2$. ■

Proof of Lemma 7.

P1: Let us denote $\pi^1_{IB}(r^1; \theta = 0)$ and $\pi^1_{IB}(r^1; \theta = 1)$ as $\pi^1_{IB}(r^1)$ in (2.9) evaluated at $\theta = 0$ and $\theta = 1$ respectively. Using these notations, equation (2.9) can be rewritten as

$$\pi^1_{IB}(r^1) = \theta \pi^1_{IB}(r^1; \theta = 1) + (1 - \theta)\pi^1_{IB}(r^1; \theta = 0)$$

For $3/2 \leq k \leq 2$, $r^1 \leq r^0$ from Proposition 7. We can also get the following conditions: (i) $\pi^1_{IB}(r^1) < \pi^1_{IB}(r^1; \theta = 0)$ from $\pi^1_{IB}(r^1; \theta = 0) > \pi^1_{IB}(r^1; \theta = 1)$, (ii) $\pi^1_{IB}(r^1; \theta = 0) \leq \pi^0_{IB}(r^0; \theta = 1)$ from Lemma 5 and $r^1 \leq r^0$ and (iii) $\pi^0_{IB}(r^0) = \pi^0_{IB}(r^0; \theta = 1)$ by definition. From these conditions, we obtain $\pi^1_{IB}(r^1) \leq \pi^0_{IB}(r^0)$.

P2: For $\theta \in [0, 1]$, the continuity of $\pi^1_{IB}(\theta, k)$ in θ follows from the continuity of r^1 in θ and π^1_{IB} in r^1. Similarly, the continuity of $W^1(\theta, k)$ in θ follows from the continuity of r^1 in θ and W^1 in r^1.

P3: Consider $k > 2$. The effect of risk of breakdown on the joint payoff can be divided into two channels: (i) the direct effect and (ii) the indirect effect through the impact on investments.

$$\frac{\partial \pi^1_{IB}}{\partial \theta} = \underbrace{\frac{d\pi^1_{IB}}{d\theta}}_{\text{direct effect}} + \underbrace{\pi^{1\prime}_{IB}(r^1) \cdot \frac{\partial r^1}{\partial \theta}}_{\text{indirect effect}}$$

First, the direct effect is negative as the sign of (A.5) is negative.

$$\frac{d\pi^1_{IB}}{d\theta} = -\frac{1}{8}c(r)\left[1 - c(r)\right]^2 \tag{A.5}$$

Second, the indirect effect is decided by the sign of $\pi^{1\prime}_{IB}(r^1)$ and $\partial r^1/\partial\theta$. From (2.9), the joint payoff under exclusivity can be rewritten as

$$\pi^1_{IB}(r) = \pi^1_I(r) + \frac{1}{8}\left[1 - c(r)\right]^2\left[5 + (1-\alpha)(1-\theta)c(r)\right]$$

The first-order derivative $\pi^1_{IB}(r)$ at $r = r^1$ is given by

$$\pi^{1\prime}_{IB}(r^1) = \pi^{1\prime}_I(r^1) - \frac{1}{8}c'(r^1)\left[1 - c(r^1)\right]\left[10 - (1-\alpha)(1-\theta) + 3(1-\alpha)(1-\theta)c(r^1)\right] \tag{A.6}$$

(A.6) is positive from $\pi^{1\prime}_I(r^1) = 0$, $c'_I(r^1) < 0$ and $1 - c_I(r^1) > 0$.

In order to determine the sign of $\partial r^1/\partial\theta$, I will use the first order condition of profit maximization problem under exclusivity which is given by

$$\pi^{1\prime}_I(r^1) \equiv \frac{1}{8}c'(r^1)\left[1 - c(r^1)\right]\left[\alpha(1-\theta) - 4 - 3\alpha(1-\theta)c(r^1)\right] - C'(r^1) = 0$$

By totally differentiating both sides of the above condition,

$$\frac{\partial r^1}{\partial \theta} = -\frac{\alpha c'(r^1)\left[1 - c(r^1)\right]\left[1 - 3c(r^1)\right]}{8\pi^{1\prime\prime}_I(r^1)} \tag{A.7}$$

where $\pi^{1\prime\prime}_I(r^1) < 0$ from the second order condition of profit maximization problem. The sign of (A.7) is negative for $k > 2$, since $c'(r^1) < 0$, $1 - c_I(r^1) > 0$, $1 - 3c(r^1) < 0$ and $\pi_I^{1\prime\prime}(r^1) < 0$.

Therefore, we obtain $\partial\pi_{IB}^1/\partial\theta < 0$ from the negative direct and indirect effects. ■

Proof of Proposition 8. One can show that $\pi_{IB}^1(\theta,k) - \pi_{IB}^0(k) = 0$ has a unique solution (denoted by $\overline{\theta}$) and at least one solution for $W^1(\theta,k) - W^0(k) = 0$ (denoted by $\underline{\theta}$) by using Lemma 5 – Lemma 7, intermediate value theorem and fixed point theorem. From these conditions, $\overline{\theta}$ and $\underline{\theta}$ can be written as

$$\overline{\theta} = \frac{4\{c(r^1)[1-c(r^1)]^2 - c(r^0)[1-c(r^0)]^2\} + 3\{[1-c(r^1)]^3 - [1-c(r^0)]^3\} + C(r^0) - C(r^1)}{c(r^1)[1-c(r^1)]^2}$$

$$\underline{\theta} = \frac{4\{c(r^1)[1-c(r^1)] - c(r^0)[1-c(r^0)]\} + 3\{[1-c(r^1)]^3 - [1-c(r^0)]^3\} + C(r^0) - C(r^1)}{c(r^1)[1-c(r^1)][3+c(r^1)]}$$

where r^0 is given by (2.4) and r^1 denotes the equilibrium investment level under exclusivity. The uniqueness of $\underline{\theta}$ is ensured by the monotonicity of r^0, r^1 in θ and that of $\underline{\theta}$ in r^0, r^1. As $r^1 > r^0$ for $k > 2$, the numerator of $\overline{\theta}$ is larger than that of $\underline{\theta}$ and the denominator of $\overline{\theta}$ is smaller than that of $\underline{\theta}$. This implies $\overline{\theta} > \underline{\theta}$. Therefore,

$$\pi_{IB}^1(r^1)\begin{Bmatrix} > \\ > \\ \leq \end{Bmatrix}\pi_{IB}^0(r^0) \text{ and } W^1(\theta,k)\begin{Bmatrix} > \\ \leq \\ \leq \end{Bmatrix}W^0(k), \quad \begin{matrix} \text{if } 0 \leq \theta < \underline{\theta} \\ \text{if } \underline{\theta} \leq \theta < \overline{\theta} \\ \text{if } \overline{\theta} \leq \theta \leq 1 \end{matrix}$$

which characterizes the profitability and welfare effects of exclusivity depending on the level of risk of breakdown. ■

Proof of Proposition 9. From (2.13) and (2.14), the first-order derivative of $\pi_I^1(r)$ at $r = r^0$ is given by

$$\pi_B^{1\prime}(r^0) = \pi_B^{0\prime}(r^0) + \frac{(1-\theta)(1-\alpha)-3}{8}c'(r^0)\left[1-c(r^0)\right]\left[1-3c(r^0)\right] \tag{A.8}$$

where r^0 denotes the equilibrium investment level under non-exclusivity. Using $\pi_B^{0\prime}(r^0) = 0$,

$c'(r) < 0$ and $0 \leq c(r) \leq 1/2$, the sign of (A.8) is decided by

$$\pi_B^{1\prime}(r^0) \left\{ \begin{array}{c} > \\ \leq \end{array} \right\} 0, \quad \begin{array}{l} \textit{if } 1/6 < r^0 \leq 1/2 \\ \textit{if } 0 \leq r^0 \leq 1/6 \end{array}$$

Since r^0 is strictly decreasing in k and solely determined by k, the condition of $1/6 < r^0 \leq 1/2$ ($0 \leq r^0 \leq 1/6$) is equivalent to $3/2 \leq k < 2$ ($k \geq 2$). ■

BIBLIOGRAPHY

Bibliography

[1] Abito, J.M. and Wright, J. (2008), "Exclusive Dealing with Imperfect Downstream Competition." *International Journal of Industrial Organization*, Vol. 26, pp. 227–246.

[2] Aghion, P. and Bolton, P. (1987), "Contracts as a Barrier to Entry." *American Economic Review*, Vol. 77, pp. 388−401.

[3] Armstrong, M. and Huck, S. (2010) "Behavioral Economics as Applied to Firms: A Primer." *Competition Policy International*, Vol. 6, pp. 3−45.

[4] Bernheim, B. and Whinston, M.D. (1998), "Exclusive Dealing." *Journal of Political Economy*, Vol. 106, pp. 64–103.

[5] Binmore, K., Rubinstein, A. and Wolinsky, A. (1986), "The Nash Bargaining Solution in Economic Modelling." *Rand Journal of Economics*, Vol. 17, pp. 176-188.

[6] Bork,R. (1978), *The Antitrust Paradox: A Policy at War with Itself.* New York: Basic Books.

[7] de Meza, D. and Selvaggi, M. (2007), "Exclusive Contracts Foster Relationship-specific investment." *RAND Journal of Economics*, Vol. 38, pp. 85–97.

[8] Ellison, G. (2006), "Bounded Rationality in Industrial Organization." in Richard Blundell, Whitney Newey, and Torsten Persson (eds.) *Advances in Economics and Econometrics: Theory and Applications*, Ninth World Congress, Cambridge University Press, Cambridge.

[9] Farrell, J. (2005), "Deconstructing Chicago on Exclusive Dealing." *Antitrust Bulletin*, Vol. 50, pp. 465–480.

[10] Fumagalli, C. and Motta, M. (2006), "Exclusive Dealing and Entry, When Buyers Compete." *American Economic Review*, Vol. 96, pp. 785–795.

[11] Fumagalli, C., Motta, M., and Persson, L. (2009), "On the Anticompetitive Effect of Exclusive Dealing when Entry by Merger is Possible." *Journal of Industrial Economics*, Vol. 57, pp. 785–811.

[12] Fumagalli, C., Motta, M., and Rϕnde, T. (2009), "Exclusive Dealing: The Interaction between Foreclosure and Investment Promotion." CEPR Discussion Paper 7240.

[13] Motta, M. (2004), *Competition Policy: Theory and Practice*. Cambridge: Cambridge University Press.

[14] Muthoo, A. (1999), *Bargaining Theory with Applications*. Cambridge: Cambridge University Press.

[15] Posner, R.A. (1976), *Antitrust Law: An Economic Perspective*. Chicago: University of Chicago Press.

[16] Rasmusen, E.B., Ramseyer, J.M., and Wiley, J.S. (1991), "Naked Exclusion." *American Economic Review*, Vol. 81, pp. 1137–1145.

[17] Rey, P. and Tirole, J. (2007), "A Primer on Foreclosure." *Handbook of Industrial Organization*, Vol. 3, pp. 2147−2220.

[18] Segal, I. (1999), "Complexity and Renegotiation: A Foundation for Incomplete Contracts." *Review of Economic Studies*, Vol. 66, pp. 57–82.

[19] Segal, I. and Whinston, M.D. (2000a), "Naked Exclusion: Comment." *American Economic Review*, Vol. 90, pp. 269–309.

[20] Segal, I. and Whinston, M.D. (2000b), "Exclusive Contracts and Protection of Investments." *RAND Journal of Economics*, Vol. 31, pp. 603–633.

[21] Simpson, J. and Wickelgren, A.L., "Naked Exclusion, Efficient Breach, and Downstream Competition." *American Economic Review*, Vol. 97, pp. 1305–1320.

[22] Spier, K. and Whinston, M.D. (1995), "On the Efficiency of Privately Stipulated Damages for Breach of Contract: Entry Barriers, Reliance, and Renegotiation." *RAND Journal of Economics*, Vol. 26, pp. 180–202.

[23] Vasconcelos, L. (2009), "Contractual Signalling, Relationship-Specific Investment and Exclusive Agreements." mimeo, Universidade Nova de Lisboa.

[24] Whinston, M.D. (2006), *Lectures on Antitrust Economics*. Cambridge: MIT Press.

Chapter 3

Dynamic Incentives of Tying in Two-sided Markets

3.1 Introduction

Two-sided markets involve two distinct groups of agents interacting via platforms and each group obtains benefits from interacting with the other group agents. Optimal pricing structure of two-sided markets differs from that of one-sided markets. In two-sided markets, platforms charge subscription fees in order to utilize inter-group externalities. Inter-group externalities intensify the price competition between platforms as a platform should perform well on the other side in order to compete effectively on one side of the market.[1]

This paper explores tying arrangements in two-sided markets. Tying practice is prevalent in two-sided markets. For instance, the media platforms, payment card platforms and software platforms, which have two-sided markets features, often engage in tying arrangements.[2] The main purpose of this paper is to examine how inter-group externalities affect tying incentives through platforms' price and R&D competition.

[1]See Armstrong (2006) for the discussion on the optimal pricing structure in two-sided markets.

[2]See Evans (2003) for the examples of tying practice in two-sided markets.

Evans (2003) provides a general discussion on the antitrust policy in two-sided markets and emphasizes the need for caution in applying a one-sided logic to two-sided markets. He suggests several potential differences in the implications of tying in two-sided markets from one-sided markets: (i) foreclosing a rival firm on one side of the market may prevent the firm from succeeding on the other side and thereby deter entry, (ii) the potential profits on the other side provide additional incentives for tying as the market power on one side may help platforms to gain a market power on the other side and (iii) tying on one side may cause benefits to agents on the other side in the presence of inter-group externalities.[3] The insights imply that, in two-sided markets, we should consider both the potential efficiency-enhancing effect from network benefits and the efficiency-reducing effect from competitive distortions. In this paper, I present a formal model to analyze the relative importance of these contrasting competition effects of tying in two-sided markets.

The motivating example of this paper is Microsoft's tying practice of requiring Windows Operating System users to accept its Windows Media Player software. The European Union alleges that tying practice of Microsoft is anti-competitive since it hurts Microsoft's digital media rivals such as RealNetworks.[4] Microsoft's tying practice has a two-sided markets feature in the sense that platforms intermediate both sides of the market where content providers are located on one side and consumers are located on the other side.

Microsoft's tying case has been studied in both one-sided and two-sided markets frameworks. In the one-sided markets setup, Choi (2004) examines this case from the perspective of leverage theory of tying.[5] He stresses the role of R&D investments which is considered to play a crucial role in the antitrust policy concerning the network industry, in explain-

[3]See also Tirole (2005) for a general discussion on the implications of tying in two-sided markets.

[4]*Microsoft v Commission*, T-201/04 [2007]. See Choi (2010) for a brief summary on this case. "On March 24, 2004, the European Union ruled that Microsoft was guilty of abusing the 'near-monopoly' of its Windows PC operating system and fined it a record 497 million euros ($613 million). The ruling was appealed, but upheld by the Court of First Instance on September 17, 2007 (Footnote 1, p. 607)."

[5]The leverage theory argues that a firm possessing a monopoly power in one market can monopolize another market by tying the products of these two markets.

ing Microsoft's tying incentives to leverage its monopoly power in the Windows Operating System markets to the digital media software markets.[6] My paper reconsiders the leverage theory of tying in the framework of two-sided markets and investigates how tying affects the price and R&D decision of platforms. On the other hand, Choi (2010) analyzes Microsoft's tying case in the two-sided markets framework. His analyses focus on the effects of tying on agents' subscription decision when agents are allowed to multihome (i.e., to subscribe to multiple platforms). However, the paper does not consider the effect of tying on platforms' R&D incentives. My paper attempts to fill the gap between these two papers by considering both R&D incentives and two-sidedness which are important aspects in the investigation on competition effects of Microsoft's tying practice.

I adopt a two-sided Hotelling competition model of Armstrong (2006), and Armstrong and Wright (2007) to analyze the platform competition in two-sided markets. In order to explore the implications of tying, I allow one platform to tie its product with a monopolistic product in another market and also consider R&D competition between platforms. The novel part of my model is to consider the impact of tying on R&D incentives in the two-sided markets model.

My model considers two different platform competition structures regarding agents' subscription decision: i.e., (i) two-sided singlehoming (both group-1 and group-2 agents subscribe to a single platform) and (ii) competitive bottlenecks (group-1 agents singlehome and group-2 agents multihome).[7] Optimal pricing structure depends on the assumption regarding agents' subscription decision which in turn may change the effect of tying on R&D incentives. Therefore, the interaction between R&D competition and price competition (which is affected by agents' subscription decision) plays a central role in determining the competition

[6]The importance of R&D investments in the network industry has been emphasized in several papers. See, for instance, Farrell and Katz (2000), Choi and Stefanadis (2001), Choi (2004), and Gilbert and Riordan (2007).

[7]This paper restricts the analyses to these two platform competition structures, because the other possible case, where all agents on both sides choose to multihome, is not very common. Moreover, there exists no incentive for agents to multihome for nonnegative prices if all agents on the other side multihome. See Armstrong (2006), and Armstrong and Wright (2007) for more details.

effects of tying in two-sided markets.

This paper presents two main findings. First, this study confirms that the main results of leverage theory of tying in one-sided markets also apply to two-sided markets. I show that tying can be a profitable strategy even without foreclosure of rival platform in two-sided markets. The intuition behind this result is as follows. Tying has a tradeoff on tying platform's profit: (i) profit loss from intense price competition and (ii) profit gain from foreclosure of rival's R&D incentives. In the pricing stage, tying acts to commit more aggressive pricing on both sides of the market. In the R&D stage, tying plays a role to commit more aggressive R&D investments on both sides of the market. Numerical analyses confirm that tying is optimal for certain parameter values even without exclusion of rival platform when the profit gain from R&D effect outweighs the profit loss from price competition effect. I also show that the social welfare can be reduced by this tying arrangements through (i) the distortion of R&D incentives, (ii) the increase of transportation costs and (iii) the reduction in the consumption of tying products. I derive the results in both two-sided singlehoming and competition bottlenecks models.

Second, this paper suggests that there exists a potential difference in tying incentives between one-sided and two-sided markets. I show that tying intensifies the price and R&D competition on the non-tying side as well as on the tying side in the two-sided singlehoming model. Inter-group externalities play a role to transfer the impacts on the one side to the other side which may reinforce the potential anti-competitive effects of tying.

Related literature. This paper relates to two strands of literature: (i) the leverage theory of tying and (ii) the platform competition in two-sided markets.

This study explores the implications of leverage theory of tying in two-sided markets. More specifically, this paper examines whether the leverage theory of tying in Whinston (1990) and Choi (2004) applies to the two-sided markets model. The literature on the leverage theory of tying concerns that a firm with a monopoly power in one market can monopolize another market using a monopoly power in the first market.[8] Whinston (1990) shows that when the tied good market structure is oligopoly and the scale economies are present, tying can be optimal by inducing the rival firm to exit from the product market. Choi (2004) extends the model to consider R&D incentives and shows that tying in the primary market can be used as a leverage to gain profits in the tied good market by foreclosing rival's R&D investments. Moreover, he finds that tying can be privately optimal even without exclusion of rival firm from the product market. I extend the analysis of Choi (2004) to two-sided markets and examine the effects of tying on the price and R&D competition in the presence of inter-group externalities.[9]

In the same vein, Choi and Stefanadis (2001) extend the leverage theory to analyze the implications of tying on R&D incentives. They show that when the monopolistic incumbent faces a threat of entry in system markets, tying makes the prospects of successful entry less certain and discourages rivals from investing in innovation. Carlton and Waldman (2002) also analyze how tying between complementary products can be used to preserve a monopoly power by focusing on the entry costs and network externalities.

This paper is also related to the literature on the two-sided platform competition (e.g., Armstrong, 2006; Armstrong and Wright, 2007; Rochet and Tirole, 2003, 2006). The main focus of the literature is the optimal pricing structure in the presence of inter-group externalities. In the two-sided singlehoming model, platforms charge lower price for the group which causes larger benefits to the other group and/or which is more competitive side of the market. In the competitive bottlenecks model, platforms may charge lower price for singlehoming agents (more competitive side) and higher price for multihoming agents (less competitive side). My paper adopts the two-sided platform competition model to analyze the competition effects of tying when the tying platform is able to invest in cost-reducing

[8]In addition to the leverage theory of tying, the efficiency rationale and price discrimination device are the other veins to explain the incentives of tying. See Motta (2004) for details.

[9]As in Choi (2004), I analyze the effects of tying between independent products instead of complementary products in order to avoid a multiple equilibria problem. The intuition behind the main results applies to the complementary products (Choi, 2004; Choi, Lee and Stefanadis, 2003).

R&D. I analyze how the optimal pricing structure in two-sided markets interacts with R&D effects.

Recently, several authors have analyzed tying arrangements in the two-sided markets model (e.g., Rochet and Tirole, 2008; Amelio and Jullien, 2007; Choi, 2010). They find that tying in two-sided markets may be welfare-enhancing through (i) rebalancing interchange fees (Rochet and Tirole, 2008), (ii) relaxing nonnegative price constraints (Amelio and Jullien, 2007) and (iii) increasing multihoming subscription (Choi, 2010).[10] None of these articles consider the effects of tying on competing platforms' R&D incentives which is the main focus of my paper. Contrary to these articles, I find that tying can be socially inefficient through distorting platforms' R&D incentives.

The rest of this paper proceeds as follows. Section 2 describes the basic model of this paper. Section 3 and 4 examine the implications of tying on the price competition and innovation incentives in different platform competition models: (i) two-sided singlehoming model (Section 3) and competitive bottlenecks model (Section 4). Section 5 summarizes and concludes.

3.2 The Model

In this section, I explain the basic setup of the model which will be used throughout the paper. I consider both two-sided singlehoming and competitive bottlenecks models which extend the two-sided Hotelling competition model of Armstrong (2006), and Armstrong and Wright (2007). The additional assumptions or setups needed in each model will be introduced as needed in each subsequent section.

Demand structure. Two symmetric platforms (A and B) compete in a standard Hotelling specification − they are located at either end of a unit interval on both sides of the market.

[10]Rochet and Tirole (2008) analyze the implications of "honor-all-cards" rule of Visa and MasterCard which forces merchants who accept their credit cards also to accept their debit cards. In 2003, Visa and MasterCard agreed to abandon this rule in the US.

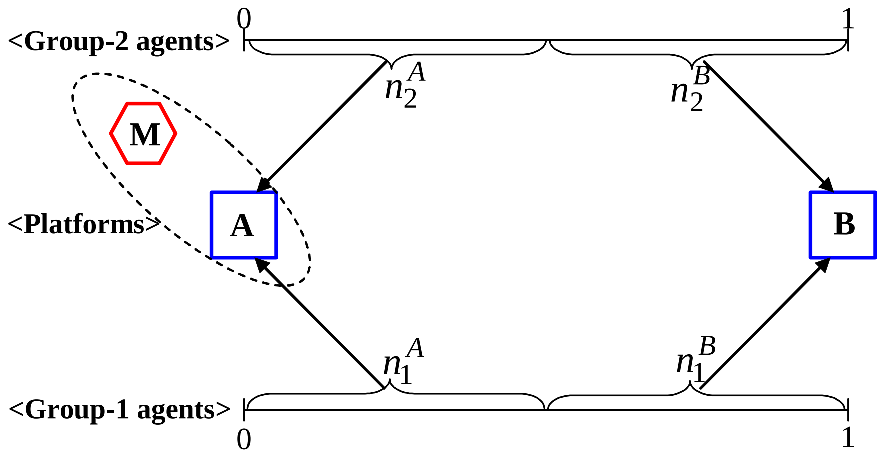

Figure 3.1: Platform competition in the two-sided singlehoming model

Platform A is able to tie its product with a monopolistic product M.[11] Two agent groups (1 and 2), representing consumers and content providers, are uniformly distributed along the unit interval and each agent has a unit demand. The measure of group-i agents who join platform H is denoted by n_i^H ($i = 1, 2$ and $H = A, B$) and the total measure of each group agents is normalized to 1. Only group-1 agents value product M as v_M and platform A's marginal cost of product M is c_M. Thus, platform A's monopoly surplus from product M is defined as $s_M \equiv v_M - c_M$. Figure 3.1 summarizes the platform competition structure in the two-sided singlehoming model which will be analyzed in Section 3.

I consider two cases of agents' subscription decision: i.e., (i) two-sided singlehoming (both group-1 and group-2 agents subscribe to a single platform) and (ii) competitive bottlenecks (group-1 agents singlehome and group-2 agents subscribe to both platforms). In each case, the parameter values are assumed to satisfy the conditions of two-sided singlehoming or competitive bottlenecks.[12]

[11]In Microsoft's tying case, platform A, platform B and product M can be regarded as Windows Media Player, Real Player, and Windows Operating System, respectively.

[12]See Assumption 5 (Section 3) and Assumption 6 (Section 4) for the specific conditions on the parameter values in each case.

Cost structure. I assume a symmetric cost structure for platform A and B in which each platform incurs a per-agent cost c_i for each group. Platforms are able to invest in R&D on both sides of the market. Let I_i^H denote the cost reduction on the group-i agent side ($i = 1, 2$) by platform H ($H = A, B$). After R&D investment decision is made, the cost of platform H is given by $c_i - I_i^H$ on the group-i agent side.

Additionally, I suppose several simplifying assumptions. First, the possibility of R&D investments in product M is ignored in order to focus on the effect of tying on R&D incentives in the tied good market. Second, each platform can reduce the unit production cost by I with incurring the investment cost $C(I)$ where $C'(I) > 0$ and $C''(I) > 0$. I assume $C(I) = \frac{k}{2}I^2$ where k measures the R&D cost efficiency (i.e., larger k implies more inefficient in cost-reducing R&D investments). Finally, I assume that each product cannot be sold separately under tying.[13]

Timing. The timing of the game is as follows.

- Stage 1: Platform A decides whether or not to tie its product with product M.
- Stage 2: Platform A and B simultaneously determine their own R&D investment levels.
- Stage 3: Platform A and B simultaneously determine their own prices.
- Stage 4: Group-1 and group-2 agents make a subscription decision.

3.3 Two-sided Singlehoming

This section considers the case where agents on both sides of the market subscribe to a single platform. The analyses focus on the effects of tying on the price and R&D decision of competing platforms.

In the two-sided singlehoming model, the utility of group-i agent located at $x_i \in [0, 1]$

[13] This can be justified by assuming a technological tying from the costly investments in the product design and production process.

from platform H is written as

$$u_i^H = v_i^0 - p_i^H - t_i x_i + \alpha_i n_j^H \tag{3.1}$$

where $i, j = 1, 2$ $(i \neq j)$ and $H = A, B$.[14] v_i^0 denotes the fixed benefit from subscribing to each platform which is assumed to be sufficiently large such that all agents are willing to join at least one platform in equilibrium. p_i^H denotes the subscription fee from joining each platform and t_i, α_i represent group-i agent's transportation costs and inter-group benefits from interacting with each group-j agent. I also assume the following restrictions on the parameter values throughout this section.

Assumption 5 (Two-sided singlehoming conditions) *Parameter values satisfy the following conditions.*

(5.1) $t_1 > \alpha_1, \ \ t_2 > \alpha_2$

(5.2) $4t_1t_2 > (\alpha_1 + \alpha_2)^2$

(5.3) $c_1 + t_1 \geq \alpha_2, \ \ c_2 + t_2 \geq \alpha_1$

Assumption 5 ensures that both group-1 and group-2 agents choose singlehoming and the nonnegative price constraints are not binding in equilibrium. Specifically, Assumption (5.1) ensures that agents on both sides never choose to multihome at nonnegative prices. The unique and nonnegative equilibrium prices are ensured by Assumption (5.2) and (5.3).[15]

I use a backward induction to find a subgame perfect equilibrium.

3.3.1 Price decision

The price decision of each platform depends on the tying decision of platform A.

[14]Throughout the paper, I use the superscript H, K to denote each platform and the subscript i, j to denote each group agent. I will also use a tilde ($\tilde{}$) to denote the variables corresponding to the tying case.

[15]See Proposition 1 of Armstrong and Wright (2007) for details.

No tying. Suppose that platform A does not engage in tying. In this case, each market can be analyzed independently. Platform A can extract the whole consumer surplus (s_M) from product M, but platforms compete for subscribers on both sides of the tied good market.

From (1), combined with $n_i^H + n_i^K = 1$, the demand of each group agent must satisfy the following condition.

$$v_i^0 - p_i^H - t_i n_i^H + \alpha_i n_j^H = v_i^0 - p_i^K - t_i(1 - n_i^H) + \alpha_i(1 - n_j^H)$$

where $i, j = 1, 2$ ($i \neq j$) and $H, K = A, B$ ($H \neq K$). Consequently, the number of group-i agents subscribing to platform H is given by

$$n_i^H = \frac{1}{2} + \frac{\alpha_i(p_j^K - p_j^H) + t_j(p_i^K - p_i^H)}{2\,(t_1 t_2 - \alpha_1 \alpha_2)}$$

where $i, j = 1, 2$ ($i \neq j$) and $H, K = A, B$ ($H \neq K$).

The first order condition of each platform's maximization problem is given by

$$p_i^H = \frac{1}{2}\left\{p_i^K + c_i - I_i^H + t_i - \frac{\alpha_j}{t_j}\left[\alpha_i - c_j + I_j^H + \left(1 + \frac{\alpha_i}{\alpha_j}\right)p_j^H - \frac{\alpha_i}{\alpha_j}p_j^K\right]\right\} \tag{3.2}$$

where $i, j = 1, 2$ ($i \neq j$) and $H, K = A, B$ ($H \neq K$). The symmetric equilibrium price is reduced to

$$p_i = c_i - I_i + t_i - \frac{\alpha_j}{t_j}\left(\alpha_i - c_j + I_j + p_j\right) \tag{3.3}$$

where $p_i \equiv p_i^A = p_i^B$, $p_j \equiv p_j^A = p_j^B$, $I_i \equiv I_i^A = I_i^B$, $I_j \equiv I_j^A = I_j^B$ and $i, j = 1, 2$ ($i \neq j$). Due to inter-group externalities, subscription fees are adjusted downward to represent the marginal external benefit from attracting an extra group-1 agent which is measured by the last term in (3.3).[16] In the general case, the equilibrium prices are determined as in Appendix A.

[16] See Section 4 of Armstrong (2006) for details.

Tying. Now consider the case where platform A ties its product with product M. Tying prevents group-1 agents from purchasing product M separately. Accordingly, group-1 agents' choice is essentially between consuming the bundled product by subscribing to platform A and consuming the unbundled product by subscribing to platform B with foregoing the consumption of product M. In this case, the equilibria are no longer symmetric.

The demand of each group agent must satisfy the following conditions.

$$\begin{aligned} v_M + v_1^0 - \tilde{P}_1 - t_1\tilde{n}_1^A + \alpha_1\tilde{n}_2^A &= v_1^0 - \tilde{p}_1^B - t_1(1-\tilde{n}_1^A) + \alpha_1(1-\tilde{n}_2^A) \\ v_2^0 - \tilde{p}_2^A - t_2\tilde{n}_2^A + \alpha_2\tilde{n}_1^A &= v_2^0 - \tilde{p}_2^B - t_2(1-\tilde{n}_2^A) + \alpha_2(1-\tilde{n}_1^A) \end{aligned}$$

where $\tilde{P}_1$ denotes the price for the bundled product. Consequently, the number of group-1 and group-2 agents subscribing to platform A are given by

$$\begin{aligned} \tilde{n}_1^A &= \frac{1}{2} + \frac{\alpha_1(\tilde{p}_2^B - \tilde{p}_2^A) + t_2(\tilde{p}_1^B - \tilde{P}_1 + v_M)}{2(t_1t_2 - \alpha_1\alpha_2)} \\ \tilde{n}_2^A &= \frac{1}{2} + \frac{\alpha_2(\tilde{p}_1^B - \tilde{P}_1 + v_M) + t_1(\tilde{p}_2^B - \tilde{p}_2^A)}{2(t_1t_2 - \alpha_1\alpha_2)} \end{aligned}$$

Note that the number of group-i agents subscribing to platform B can be derived from $\tilde{n}_i^B = 1 - \tilde{n}_i^A$.

Define a fictitious price $\tilde{p}_1^A \equiv \tilde{P}_1 - v_M$ which measures the implicit subscription fee for platform A separated from the price of bundled product. The first order conditions of each platform's maximization problem are given by

$$\begin{aligned} \tilde{p}_1^A &= \frac{1}{2}\left\{\tilde{p}_1^B + c_1 - \tilde{I}_1^A - s_M + t_1 - \frac{\alpha_2}{t_2}\left[\alpha_1 - c_2 + \tilde{I}_2^A + \left(1+\frac{\alpha_1}{\alpha_2}\right)\tilde{p}_2^A - \frac{\alpha_1}{\alpha_2}\tilde{p}_2^B\right]\right\}, \\ \tilde{p}_2^A &= \frac{1}{2}\left\{\tilde{p}_2^B + c_2 + t_2 - \frac{\alpha_1}{t_1}\left[\alpha_2 - c_1 + \tilde{I}_2^A + s_M + \left(1+\frac{\alpha_2}{\alpha_1}\right)\tilde{p}_1^A - \frac{\alpha_2}{\alpha_1}\tilde{p}_1^B\right]\right\}, \\ \tilde{p}_i^B &= \frac{1}{2}\left\{\tilde{p}_i^A + c_i - \tilde{I}_i^B + t_i - \frac{\alpha_j}{t_j}\left[\alpha_i - c_j + \tilde{I}_j^B + \left(1+\frac{\alpha_i}{\alpha_j}\right)\tilde{p}_j^B - \frac{\alpha_i}{\alpha_j}\tilde{p}_j^A\right]\right\}. \end{aligned} \tag{3.4}$$

where $i, j = 1, 2$ $(i \neq j)$. Comparing (3.2) and (3.4), we can observe that tying intensifies the price competition on both sides of the market. Tying shifts platform A's reaction curves for both group-1 and group-2 agents inward because platform A behaves as if its costs on the group-i side were $c_i - \tilde{I}_i^A - s_M$ with tying. The intuition of this result is the following. With tying, platform A can realize the monopoly surplus (s_M) only with the sale of bundled product. Because of inter-group externalities, tying on the group-1 side makes platforms to determine their prices more aggressively on the group-2 side as well as the group-1 side. The equilibrium prices in the tying case are determined as in Appendix B.

3.3.2 R&D decision

In the R&D stage, each platform maximizes its own profit given price decision. Graphically, the equilibrium R&D investments are decided at the intersection of each platform's reaction curves. The effect of tying on R&D incentives is determined by the change of reaction curves from tying arrangements. Proposition 10 characterizes the effect of tying on R&D incentives.

Proposition 10 *In the two-sided singlehoming model, tying raises tying platform's R&D investments but reduces rival platform's R&D investments on both sides of the market (i.e., $\tilde{I}_i^{A*} > I_i^{A*}$ and $\tilde{I}_i^{B*} < I_i^{B*}$, $i = 1, 2$).*

Proof. Suppose that reaction curves have negative slopes and satisfy stability conditions.[17] The reaction curves under no tying and tying can be defined as $\partial\pi^H/\partial I_i^H - C'(I_i^H) = 0$ and $\partial\tilde{\pi}^H/\partial\tilde{I}_i^H - C'(\tilde{I}_i^H) = 0$ ($i = 1, 2$ and $H = A, B$). For any given $I_i^H = \tilde{I}_i^H$, the differences

[17]Given the second order conditions of maximization problems, the negative slope and stability conditions are written as $\frac{\partial^2\pi^H}{\partial I_i^H \partial I_i^K} < 0$ and $\left(C''(I_i^H) - \frac{\partial^2\pi^H}{\partial {I_i^H}^2}\right)\left(C''(I_i^K) - \frac{\partial^2\pi^K}{\partial {I_i^K}^2}\right) > \left|\frac{\partial^2\pi^H}{\partial I_i^H \partial I_i^K}\right| \left|\frac{\partial^2\pi^K}{\partial I_i^K \partial I_i^H}\right|$, $i = 1, 2$ and $H, K = A, B$ $(H \neq K)$.

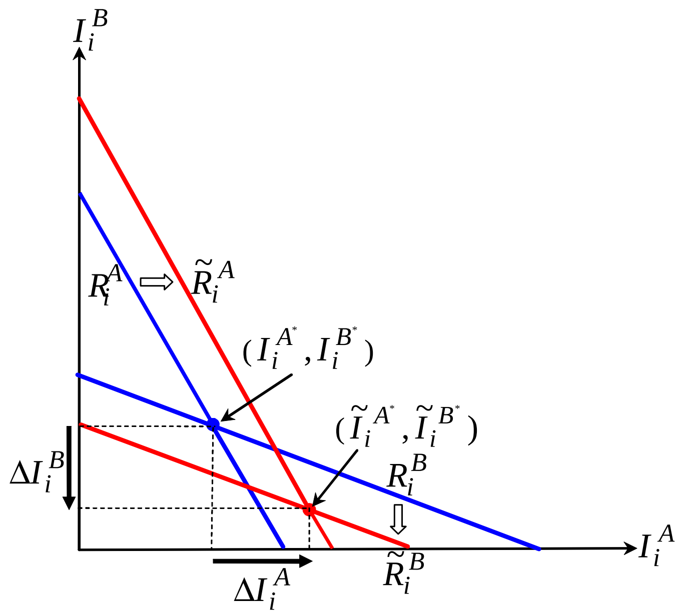

Figure 3.2: Effects of tying on R&D investments

between reaction curves under tying and no tying are given by

$$\begin{aligned}
\frac{\partial \tilde{\pi}^A}{\partial \tilde{I}_1^A} - \frac{\partial \pi^A}{\partial I_1^A} &= -\left(\frac{\partial \tilde{\pi}^B}{\partial \tilde{I}_1^B} - \frac{\partial \pi^B}{\partial I_1^B}\right) = \frac{6t_2\left[\Phi^2 + 4(\alpha_1 - \alpha_2)^4\right]}{\Phi} s_M, \\
\frac{\partial \tilde{\pi}^A}{\partial \tilde{I}_2^A} - \frac{\partial \pi^A}{\partial I_2^A} &= -\left(\frac{\partial \tilde{\pi}^B}{\partial \tilde{I}_2^B} - \frac{\partial \pi^B}{\partial I_2^B}\right) = \frac{3(\alpha_1 + \alpha_2)\left[\Phi^2 + 4(\alpha_1 - \alpha_2)^4\right]}{\Phi} s_M. \quad (3.5)
\end{aligned}$$

where $\Phi \equiv 2(\alpha_1 - \alpha_2)^2 + 9(t_1 t_2 - \alpha_1 \alpha_2)$. Both equations in (3.5) are positive under Assumption (5.1).[18] This implies that tying shifts platform A's reaction curves outward and platform B's reaction curves inward on both sides of the market. Figure 3.2 shows that $\tilde{I}_i^{A^*} > I_i^{A^*}$ and $\tilde{I}_i^{B^*} < I_i^{B^*}$ $(i = 1, 2)$.[19] ■

The intuition behind this result is as follows. Tying allows the tying platform to capture a larger market share on both sides of the market as the platform determines its price more

[18] Both the numerator and the denominator of (3.5) are positive if $t_1 t_2 - \alpha_1 \alpha_2 > 0$ (Assumption (5.1)).

[19] In Figure 3.2, the shifts of reaction curves are parallel because the difference between the slopes of reaction curves under tying and no tying does not rely on R&D investment levels.

aggressively on both sides of the market with tying. This implies that the cost reduction from R&D investments translates into a larger profit with tying through the larger market share effect. That is, tying plays a role as a commitment to more aggressive R&D investments and raises tying platform's R&D investments. Tying also reduces rival's R&D investments from the substitutability of R&D investments.[20] Note that this result only depends on Assumption (5.1) with a few regular conditions such as the negative slope and stability conditions of reaction curves. This implies that tying distorts R&D incentives of competing platforms for any parameter values satisfying the two-sided singlehoming conditions.

In addition, the effect of tying on R&D investments might be asymmetric between the tying side and non-tying side. Lemma 8 explores the relative size of R&D effects on both sides of the market.

Lemma 8 *For the parameter values satisfying Assumption 5,*

$$\left|\frac{\partial\tilde{\pi}^H}{\partial\tilde{I}_1^H}-\frac{\partial\pi^H}{\partial I_1^H}\right|\left\{\begin{array}{c} > \\ \leq \end{array}\right\}\left|\frac{\partial\tilde{\pi}^H}{\partial\tilde{I}_2^H}-\frac{\partial\pi^H}{\partial I_2^H}\right| \qquad \begin{array}{l} \text{if } t_2 > \dfrac{\alpha_1+\alpha_2}{2} \\ \text{otherwise.} \end{array}$$

Proof. From (3.5),

$$\left|\frac{\partial\tilde{\pi}^H}{\partial\tilde{I}_1^H}-\frac{\partial\pi^H}{\partial I_1^H}\right|-\left|\frac{\partial\tilde{\pi}^H}{\partial\tilde{I}_2^H}-\frac{\partial\pi^H}{\partial I_2^H}\right|=\frac{3\left[t_2-2\left(\alpha_1+\alpha_2\right)\right]\left[\Phi^2+4\left(\alpha_1-\alpha_2\right)^4\right]}{\Phi}s_M$$

and so

$$\left|\frac{\partial\tilde{\pi}^H}{\partial\tilde{I}_1^H}-\frac{\partial\pi^H}{\partial I_1^H}\right|-\left|\frac{\partial\tilde{\pi}^H}{\partial\tilde{I}_2^H}-\frac{\partial\pi^H}{\partial I_2^H}\right|>0 \text{ iff } t_2>\frac{\alpha_1+\alpha_2}{2}.$$

■

Lemma 8 shows that the relative size of R&D effects of tying depends on the product differentiation on the non-tying side (t_2) and inter-group externalities (α_1, α_2). Tying may have larger R&D effects on the tying side than on the non-tying side if t_2 is larger than

[20]See Bulow, Geanakoplos and Klemperer (1985) and Tirole (1988) for the strategic substitutes of R&D investments.

$(\alpha_1 + \alpha_2)/2$. However, the relative size of effects can be reversed for a sufficiently small t_2 compared to α_1 and α_2. The result is intuitive in the sense that platforms may have incentives to compete aggressively for R&D investments on the non-tying side for a relatively large inter-group externalities (α_1, α_2) given the product differentiation on that side (t_2).

This lemma is closely related to the optimal pricing structure. In the two-sided single-homing model, platforms target one group more aggressively than the other if the group causes larger benefits to the other group and/or is more competitive side of the market. From the interaction between the price and R&D game, the intense price competition reinforces the R&D competition. Thus, R&D effect is likely to be smaller on the non-tying side than on the tying side for a small inter-group externalities (small inter-group benefits) or for a large product differentiation on the non-tying side (less competition on the non-tying side).

With symmetric parameter values, R&D effects are determined unambiguously as R&D effect is always larger on the tying side than on the non-tying side.

Corollary 1 *For $\alpha_1 = \alpha_2$ and $t_1 = t_2$,*

$$\left| \frac{\partial \tilde{\pi}^H}{\partial \tilde{I}_1^H} - \frac{\partial \pi^H}{\partial I_1^H} \right| > \left| \frac{\partial \tilde{\pi}^H}{\partial \tilde{I}_2^H} - \frac{\partial \pi^H}{\partial I_2^H} \right|$$

This corollary follows from Lemma 8 since $t_2 > (\alpha_1 + \alpha_2)/2$ holds for $\alpha_1 = \alpha_2$ under Assumption (5.1).

The analyses in this subsection show that tying forecloses rival's R&D investments even without exclusion of rival platform. This implies that the anti-competitive effect of tying may occur through two different channels: i.e., (i) exclusion of rival platform and (ii) distortion of R&D incentives. In the following subsection, I explore if tying can be profitable for the tying platform even without exclusion of rival platform from the product market (i.e., the analysis focuses on the second channel).

3.3.3 Tying decision

This subsection examines the profitability of tying. Specifically, I assume the symmetric parameter values and a specific investment cost function to explore if there exist parameter specifications such that tying is profitable for the tying platform. Suppose $\alpha_1 = \alpha_2 = \alpha$, $t_1 = t_2 = 1$ and $\alpha < 1$ which satisfy Assumption 1. I further assume $C(I) = \frac{k}{2}I^2$ to obtain a closed form solution for the optimal R&D investment levels.

The symmetric equilibrium R&D investments without tying are given by $I_i^{H^*} = \frac{1}{3k}$ where $i = 1, 2$ and $H = A, B$. On the other hand, the equilibrium R&D investments with tying are given by

$$\begin{aligned}
\tilde{I}_1^{A*} &= \frac{1}{3k} + \frac{(9k-2)}{9k\left[9k(1-\alpha^2)-2\right]-2(9k-2)}s_M \\
\tilde{I}_1^{B*} &= \frac{1}{3k} - \frac{(9k-2)}{9k\left[9k(1-\alpha^2)-2\right]-2(9k-2)}s_M \\
\tilde{I}_2^{A*} &= \frac{1}{3k} + \frac{9k\alpha}{9k\left[9k(1-\alpha^2)-2\right]-2(9k-2)}s_M \\
\tilde{I}_2^{B*} &= \frac{1}{3k} - \frac{9k\alpha}{9k\left[9k(1-\alpha^2)-2\right]-2(9k-2)}s_M
\end{aligned}$$

The profitability condition is given by[21]

$$s_M > \frac{2\left[9k(1-\alpha)-2\right]\left[9k(1+\alpha)-2\right]^2\left[18k(1-\alpha)-5\right]}{3k\left[(9k-1)(9k-2)^2-243k^2(3k-1)\alpha^2\right]} \tag{3.6}$$

For a graphical analysis, I additionally assume the stability condition of reaction curves and no exit condition to focus on the case where tying does not induce the rival platform to exit. With a stability condition, the cost efficiency parameter (k) should satisfy Proposition

[21] Platform A's profit change from tying is given by

$$\Delta\Psi^A = \frac{-324k^2(1-\alpha^2)+18k(9+\alpha)}{6\{9k\left[9k(1-\alpha^2)-2\right]-2(9k-2)\}}s_M + \frac{k(9k-1)(9k-2)^2-243k^3(3k-1)\alpha^2}{2\{9k\left[9k(1-\alpha^2)-2\right]-2(9k-2)\}^2}{s_M}^2$$

where $\Delta\Psi^A \equiv \tilde{\Psi}^A - \Psi^A$, $\Psi^A \equiv \pi^A - C(I_1^A) - C(I_2^A) + s_M$, $\tilde{\Psi}^A \equiv \tilde{\pi}^A - C(\tilde{I}_1^A) - C(\tilde{I}_2^A)$. Thus, tying is profitable if $\Delta\Psi^A > 0$.

1, which is given by[22]

$$k > \frac{2}{9(1-\alpha)} \tag{3.7}$$

In addition, no exit condition (i.e., $0 < \tilde{n}_i^A < 1$) is given by[23]

$$0 < s_M < \frac{\left[9k\left(1-\alpha^2\right)-2\right]-2(9k-2)}{3k(9k-2)} \tag{3.8}$$

Graphically, tying is profitable without exclusion of rival platform for the parameter values of k, s_M satisfying (3.6)−(3.8). Figure 3.3 illustrates the tying incentives for $\alpha = 0.5$.[24] The shaded area represent the parameter values in which tying is profitable without exclusion of rival platform. The main insights for the general case can be obtained from this figure. Proposition 11 characterizes the profitability of tying.

Proposition 11 *Suppose $\alpha_1 = \alpha_2 = \alpha$, $t_1 = t_2 = 1$ and $0 < \alpha < 1$. In the two-sided singlehoming model, there exist the investment cost efficiency (k) and the monopoly surplus (s_M) such that tying is profitable for the tying platform even without exclusion of rival platform.*

Proof. Denote $\underline{k}$ and $\overline{k}$ to represent two intersection points of the profitability and no exit conditions. One can show that the set of (k, s_M) satisfying (3.6)−(3.8) is not empty, because (k, s_M) with $k \in (\underline{k}, \overline{k})$ and $s_M \in (0, \bar{s}_M)$ satisfy (3.6)−(3.8) where $\underline{k} = 2/\left[9(1-\alpha)\right]$, $\overline{k} > \underline{k}$ and $\bar{s}_M = \left\{\left[9\overline{k}\left(1-\alpha^2\right)-2\right]-2(9\overline{k}-2)\right\}/\left\{3\overline{k}(9\overline{k}-2)\right\} > 0$. Therefore, there exist (k, s_M) such that the conditions (3.6)−(3.8) are satisfied for any $0 < \alpha < 1$. ■

[22]The condition is derived from the comparison of equilibrium investment levels. For $0 < \alpha < 1$, this condition is stricter than the stability condition itself which is given by $k > \frac{2}{9}\left(1-\alpha^2\right)$. The stability condition is derived from $\frac{\partial^2 \pi^H}{\partial {I_i^H}^2} = \frac{1}{9}(1-\alpha^2)$ and $C''(I_i^H) = k$. In addition, the negative slope condition is satisfied since $\frac{\partial^2 \pi^H}{\partial I_i^H \partial I_i^K} = -\frac{1}{9}(1-\alpha^2) < 0$ for $\alpha < 1$ (see Footnote 17 for details).

[23]Only $\tilde{n}_1^A < 1$ is binding under the condition (3.7).

[24]For $\alpha = 0.5$, the conditions (3.6)−(3.8) are given by $s_M > \frac{(9k-4)(9k-5)(27k-4)^2}{12k(9k-1)(9k-2)^2-729k^2(3k-1)}$, $k > \frac{4}{9}$ and $0 < s_M < \frac{3(27k-8)}{4k(9k-2)} - \frac{2}{3k}$.

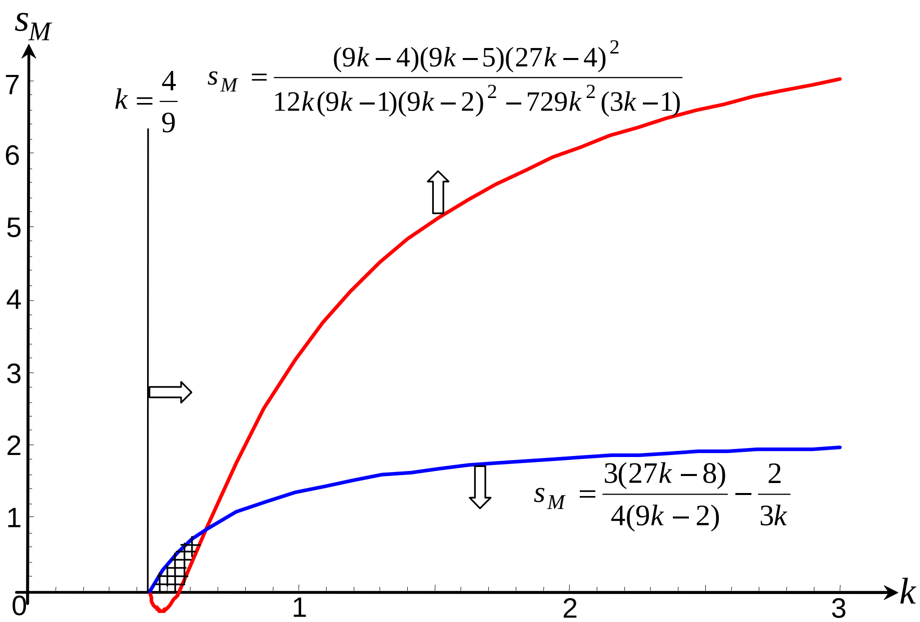

Figure 3.3: Tying incentives in the two-sided singlehoming model (α =0.5)

This result shows that tying can be a profitable strategy for the tying platform even without exclusion of rival platform for certain parameter configurations. The intuition behind this result is as follows. In a dynamic model with R&D competition, tying has a tradeoff on tying platform's profit: (i) profit loss from intense price competition and (ii) profit gain from foreclosure of rival's R&D investments. Proposition 11 confirms that there always exist certain parameter configurations such that the profit gain from tying outweighs the profit loss. More specifically, tying is more likely to be profitable for a small k (i.e., more efficient in R&D investments) or a large s_M (i.e., larger monopoly surplus). Intuitively, the platform, which is more efficient in investments or has larger monopoly surplus, can easily obtain profits from tying.

3.3.4 Welfare analysis

Welfare effects of tying may have important policy implications. In the two-sided singlehoming model, tying may have potential welfare effects through two different channels: i.e., (i) exclusion of rival platform and (ii) distortion of R&D investments. As the first channel leads to the welfare reduction obviously, I focus on the second channel to discuss the potential welfare implications of tying without exclusion of rival platform.

In my model, there are several channels through which tying affects the social welfare. First, tying causes the asymmetry in R&D incentives and results in socially suboptimal R&D investments (tying platform invests too much and rival platform invests too little). Second, tying increases transportation costs as it induces the asymmetry in market shares. Third, some group-1 agents must forego the consumption of product M under tying. All three channels lead to welfare reduction in my model.

Proposition 12 *In the two-sided singlehoming model, tying reduces the social welfare even without exclusion of rival platform.*

Proof. See Appendix C. ■

The result implies that tying may have anti-competitive effects even without exclusion of rival platform from the product market. Proposition 11 and 12 confirm that the main results of Choi (2004) in one-sided markets carry over to the two-sided singlehoming model and provide a new rationale for the regulation on Microsoft's tying practice in the media software markets. In two-sided markets, tying practice may have anti-competitive effects through the foreclosure of rival's R&D investments as well as the exclusion of rival platform from the product market. Moreover, as the foreclosure of R&D investments occurs on both sides of the market in two-sided markets, the anti-competitive effect may be reinforced via inter-group externalities.

Welfare implications of this paper are significantly different from the existing literature. The existing literature on tying in two-sided markets has focused on the welfare-enhancing effect of tying from inter-group externalities (Amelio and Jullien, 2007; Rochet and Tirole, 2008; Choi, 2010). In contrast, my model stresses the welfare-reducing effect from the distortion of R&D incentives. Their papers and mine are complementary in the sense that my paper presents the potential welfare-reducing effect of tying which has not been considered in the other papers.

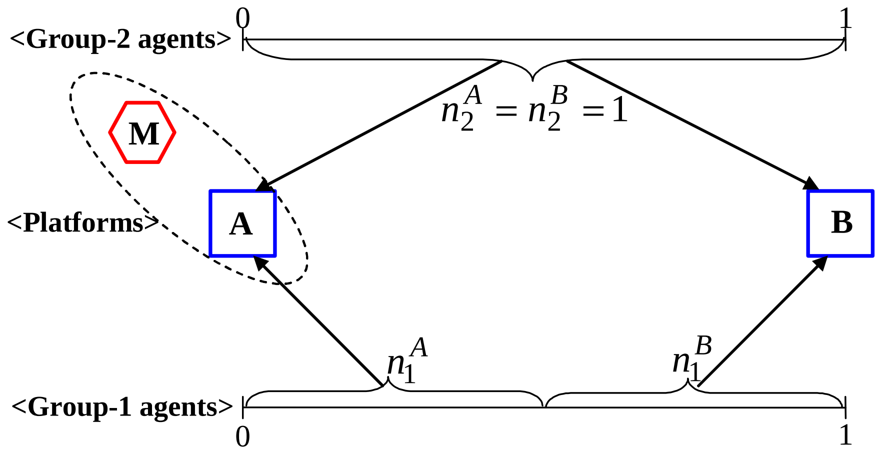

Figure 3.4: Platform competition in the competitive bottlenecks model

3.4 Competitive Bottlenecks

This section analyzes the effects of tying in the competitive bottlenecks model. The model of Section 3 is modified to allow group-2 agents to subscribe to both platforms (multihome). Figure 3.4 summarizes the platform competition structure in the competitive bottlenecks model.

The analyses on tying in the competitive bottlenecks model are meaningful in several respects. First, there are several examples which are well characterized by the competitive bottlenecks model.[25] Moreover, the optimal pricing structure in this model differs from the two-sided singlehoming model. In the competitive bottlenecks model, platforms compete more aggressively on the singlehoming side and leave zero surplus on the multihoming side. Platforms behave as though they do not compete directly for the multihoming side, instead compete indirectly by attracting the singlehoming side to subscribe. This section explores how the difference in pricing structure affects the impacts of tying on R&D incentives, profitability and social welfare.

The model in this section follows Section 4.2 in Armstrong and Wright (2007) in which

[25] Armstrong (2006) presents several examples of the competitive bottlenecks framework, such as mobile telecommunications networks, newspapers, shopping malls, supermarkets and airline reservation system.

only one side cares about the platform performance on the other side (i.e., $\alpha_1 = 0$).[26] The utility of group-1 agent located at $x_1 \in [0,1]$ from the platform H is written as

$$u_1^H = v_1^0 - p_1^H - t_1 x_1 \tag{3.9}$$

where $H = A, B$. v_1^0 is sufficiently large such that all group-1 agents are willing to subscribe at least one platform in equilibrium and v_2^0 is assumed at 0. Furthermore, I assume the following restrictions on the parameter values throughout this section.

Assumption 6 (Competitive bottlenecks conditions) *Parameter values satisfy the following conditions.*

(6.1) $\alpha_2 > \alpha_1 = 0, \;\; t_1 > t_2 = 0$

(6.2) $c_2 \leq \min\{t_1/2, \;\alpha_2/4\}$

(6.3) $c_1 + t_1 \geq \alpha_2$

In the unique and symmetric equilibrium, group-1 agents choose singlehoming and group-2 agents choose multihoming under Assumption 6. Specifically, Assumption (6.1) ensures the uniqueness of equilibrium.[27] Platforms serve group-2 agents in equilibrium with nonnegative profits under Assumption (6.2). Finally, Assumption (6.3) guarantees the nonnegative equilibrium prices.

Additionally, I assume that cost-reducing R&D investments are feasible only on the group-1 side. In the competitive bottlenecks model, platforms have no incentive to engage in R&D competition on the group-2 side because all group-2 agents have already subscribed to both platforms. After R&D decision is made, platform H's cost on the group-1 side is given by $c_1 - I_1^H$ but the cost on the group-2 side remains at c_2.

[26] Armstrong and Wright (2007) pointed out that many of insights in more general models can be seen in this simplified setup.

[27] The assumption is adopted to focus on the unique equilibrium without concerning about the equilibrium selection among multiple equilibria.

3.4.1 Price decision

No tying. Without tying, platform A can extract the whole consumer surplus (s_M) from product M. From the multihoming assumption, the numbers of group-2 agents subscribing to platform A and B are both equal to 1 (i.e., $n_1^A = n_1^B = 1$). From (3.9), combined with $n_1^B = 1 - n_1^A$, the demand of group-1 agents must satisfy the following condition.

$$v_1^0 - p_1^H - t_1 n_1^H = v_1^0 - p_1^K - t_1 \left(1 - n_1^H\right)$$

where $H, K = A, B$ $(H \neq K)$. The number of group-1 agents subscribing to platform H is given by

$$n_1^H = \frac{1}{2} + \frac{p_1^K - p_1^H}{2t_1}$$

where $H, K = A, B$ $(H \neq K)$. I also assume that if group-2 agents subscribe to a platform if they are indifferent between subscribing and unsubscribing to the platform. In this case, it is optimal for platforms to charge the maximum willingness to pay for group-2 agents. Thus, each platform charges $p_2^H = \alpha_2 n_1^H$ for group-2 agents.

The first order condition of each platform's maximization problem is given by

$$p_1^H = \frac{1}{2}(p_1^K + c_1 - I_1^H + t_1 - \alpha_2) \tag{3.10}$$

where $H, K = A, B$ $(H \neq K)$. The symmetric equilibrium price for group-1 agents is reduced to

$$p_1 = c_1 - I_1 + t_1 - \alpha_2 \tag{3.11}$$

where $p_1 \equiv p_1^A = p_1^B$ and $I_1 \equiv I_1^A = I_1^B$. The interpretation for the equilibrium price is similar to the two-sided singlehoming model (Section 3). Platforms have incentives to adjust subscription fees downward to utilize the external benefit from attracting an extra group-1 agent. In the competitive bottlenecks model, the marginal external benefit from an extra group-1 agent is equal to α_2 as the price for group-2 agents is determined at $p_2^H = \alpha_2 n_1^H$.

Tying. With tying, group-1 agents' choice is essentially between consuming the bundled product by subscribing to platform A and consuming the unbundled product by subscribing to platform B with foregoing the consumption of product M. While all group-2 agents subscribe to both platforms (i.e., $\tilde{n}_2^A = \tilde{n}_2^B = 1$), the demand of group-1 agents must satisfy the following condition.

$$v_M + v_1^0 - \tilde{P}_1 - t_1\tilde{n}_1^A = v_1^0 - \tilde{p}_1^B - t_1(1 - \tilde{n}_1^A)$$

where $\tilde{P}_1$ denotes the price for the bundled product. The number of group-1 agents subscribing to platform A is written as

$$\tilde{n}_1^A = \frac{1}{2} + \frac{v_M + \tilde{p}_1^B - \tilde{P}_1}{2t_1}$$

The number of group-1 agents subscribing to platform B can be derived from $\tilde{n}_i^B = 1 - \tilde{n}_i^A$.

Let us define $\tilde{p}_1^A \equiv \tilde{P}_1 - v_M$ which measures the implicit subscription fee for platform A separated from the price of bundled product. The first order conditions of each platform's maximization problem are given by

$$\tilde{p}_1^A = \frac{1}{2}\left(\tilde{p}_1^B + c_1 - \tilde{I}_1^A - s_M + t_1 - \alpha_2\right); \quad \tilde{p}_1^B = \frac{1}{2}\left(\tilde{p}_1^A + c_1 - \tilde{I}_1^B + t_1 - \alpha_2\right) \qquad (3.12)$$

Comparing (3.10) and (3.12), platform A behaves as if its cost on the group-1 side were $c_1 - \tilde{I}_1^A - s_M$ under tying. This implies that tying shifts platform A's reaction curve inward on the group-1 side. Solving (3.12), the equilibrium prices for group-1 agents are given by

$$\tilde{p}_1^A = c_1 + t_1 - \alpha_2 - \frac{2\tilde{I}_1^A + \tilde{I}_1^B + 2s_M}{3}; \quad \tilde{p}_1^B = c_1 + t_1 - \alpha_2 - \frac{\tilde{I}_1^A + 2\tilde{I}_1^B + s_M}{3} \qquad (3.13)$$

3.4.2 R&D decision

No tying. The maximization problem of each platform is written as

$$\max_{I_1^H} \pi^H - C(I_1^H) = \left(t_1 - \alpha_2 + \frac{I_1^H - I_1^K}{3}\right)\left(\frac{1}{2} + \frac{I_1^H - I_1^K}{6t_1}\right) + \alpha_2\left(\frac{1}{2} + \frac{I_1^H - I_1^K}{6t_1}\right)$$
$$-c_2 - C(I_1^H)$$

where $H, K = A, B$ $(H \neq K)$. The equilibrium investments are decided by

$$\frac{1}{3} + \frac{I_1^H - I_1^K}{9t_1} = C'(I_1^H) \tag{3.14}$$

where $H, K = A, B$ $(H \neq K)$. I assume that reaction curves satisfy the negative slope and stability conditions. In a symmetric equilibrium ($I_1^* \equiv I_1^{A^*} = I_1^{B^*}$), the negative slope condition is satisfied from the second order conditions of maximization problem and the stability condition is given by $C''(I_1^H) > \frac{2}{9}t_1$.

Tying. The maximization problem of each platform is written as

$$\max_{\tilde{I}_1^H} \tilde{\pi}^H - C(\tilde{I}_1^H) = \left(t_1 - \alpha_2 + \frac{\tilde{I}_1^H - \tilde{I}_1^K + s_M}{3}\right)\left(\frac{1}{2} + \frac{\tilde{I}_1^H - \tilde{I}_1^K + s_M}{6t_1}\right)$$
$$+ \alpha_2\left(\frac{1}{2} + \frac{\tilde{I}_1^H - \tilde{I}_1^K + s_M}{6t_1}\right) - c_2 - C(\tilde{I}_1^H)$$

where $H, K = A, B$ $(H \neq K)$. The equilibrium investments are decided by

$$\frac{1}{3} + \frac{\tilde{I}_1^A - \tilde{I}_1^B + s_M}{9t_1} = C'(\tilde{I}_1^A); \quad \frac{1}{3} + \frac{\tilde{I}_1^B - \tilde{I}_1^A - s_M}{9t_1} = C'(\tilde{I}_1^B) \tag{3.15}$$

Thus, the equilibrium R&D investment levels are decided at the intersection of platform A and B's reaction curves. Comparing (3.14) and (3.15), we can observe that tying shifts platform A's reaction curve outward but platform B's reaction curve inward on the group-1 side. Therefore, tying raises platform A's R&D investments but reduces platform B's investments (see Figure 3.2 for a graphical illustration).

Proposition 13 *In the competitive bottlenecks model, tying raises tying platform's R&D investments but reduces rival platform's R&D investments on the group-1 side (i.e.,* $\tilde{I}_1^{A^*} > I_1^{A^*}$ *and* $\tilde{I}_1^{B^*} < I_1^{B^*}$*).*

The proof and intuition for this proposition are similar to Proposition 10. Tying forecloses R&D investments of rival platform because it acts as a commitment to more aggressive R&D investments.

3.4.3 Tying decision

Suppose $\alpha_1 = \alpha_2 = \alpha$, $t_1 = 1$, $t_2 = 0$ and $\alpha < 1$ which satisfy Assumption 6. In addition, R&D investment cost function is assumed as $C(I) = \frac{k}{2}I^2$.

Without tying, the symmetric equilibrium R&D investments are decided by $I_1^* = \frac{1}{3k}$ from (3.14). With tying, the equilibrium R&D investments are decided by (3.15) and they are given by

$$\tilde{I}_1^{A^*} = \frac{1}{3k} + \frac{1}{9k-2}s_M; \quad \tilde{I}_1^{B^*} = \frac{1}{3k} - \frac{1}{9k-2}s_M$$

Graphically, tying is optimal for the tying platform for parameter values (k, s_M) satisfying the profitability, stability and no exit conditions, which are respectively given by[28]

$$s_M > \frac{2\,(9k-2)\,(18k-5)}{3k\,(9k-1)}; \quad k > \frac{2}{9}; \quad 0 < s_M < 3 - \frac{2}{3k} \tag{3.16}$$

In Figure 3.5, the shaded area represent the parameter values satisfying the conditions in (3.16). For any $0 < \alpha < 1$, there exist parameter values (k, s_M) where tying is profitable for the tying platform even without exclusion of rival platform.

[28]Platform A's profit change from tying is given by $\Delta\Psi^A = \frac{5-18k}{3(9k-2)}s_M + \frac{k(9k-1)}{2(9k-2)^2}{s_M}^2$, where $\Delta\Psi^A \equiv \tilde{\Psi}^A - \Psi^A$, $\Psi^A \equiv \pi^A - C(I_1^A) + s_M$, $\tilde{\Psi}^A \equiv \tilde{\pi}^A - C(\tilde{I}_1^A)$. Tying is profitable if $\Delta\Psi^A > 0$.

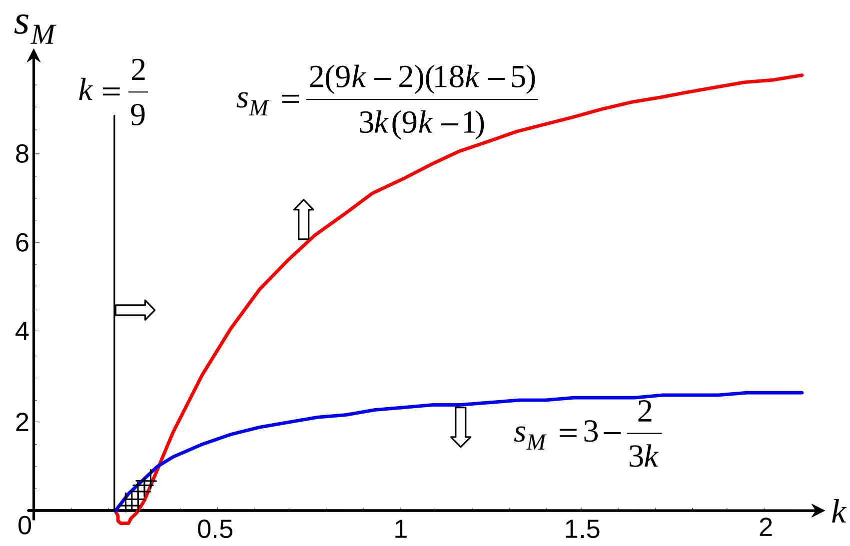

Figure 3.5: Tying incentives in the competitive bottlenecks model

Proposition 14 *Suppose* $\alpha_1 = \alpha_2 = \alpha$, $t_1 = 1$, $t_2 = 0$ *and* $0 < \alpha < 1$. *In the competitive bottlenecks model, there exist the investment cost efficiency* (k) *and the monopoly surplus* (s_M) *such that tying is profitable for the tying platform.*

Proposition 14 implies that the one-sided leverage theory of tying translates into the competitive bottlenecks model. In other words, tying can be used as a tool to leverage monopoly power in one market to gain profits in the tied product markets through the distortion of R&D investments.

3.4.4 Welfare analysis

Welfare implications in the two-sided singlehoming model also apply to the competitive bottlenecks model. Tying can be socially inefficient through (i) the distortion of R&D incentives, (ii) the increase of transportation costs and (iii) the reduction in the consumption of product M.

Proposition 15 *In the competitive bottlenecks model, tying reduces the social welfare even without exclusion of rival platform.*

Proof. See Appendix C. ∎

3.5 Concluding Remarks

This paper studies the effects of tying on the price and R&D competition when there exist inter-group externalities between agents on both sides of the market. My paper contributes to the literature by extending the leverage theory of tying to two-sided markets. The paper formalizes the mechanism how tying affects the interaction between the price and R&D competition in two-sided markets. In the two-sided Hotelling model, tying with a monopolistic product leads to the distortion of R&D incentives as well as the exclusion of rival platform. Moreover, this tying practice can be profitable and welfare-reducing through foreclosing rival's R&D investments even without exclusion of rival platform. The analyses of this paper are relevant to Microsoft's tying case and implies that tying between Windows Operating System and Windows Media Player may have anti-competitive effects through distorting platforms' R&D incentives.

In my paper, agents' homing decision has been given exogenously. I assume the parameter values to satisfy the two-sided singlehoming or competitive bottlenecks conditions in each model. However, agents' homing decision itself can be also affected by tying decision. Considering the endogenous homing decision complicates the analysis considerably, but it may be more realistic in some tying cases in two-sided markets. For example, tying on the consumer side may raise sellers' multihoming incentives (see Choi (2010) for a model of endogenous homing decision).

APPENDIX

Appendix

A. Equilibrium prices without tying in the two-sided singlehoming model

$$\begin{aligned}
p_i^{H*} = & [-2\,{\alpha_i}^2\alpha_j - 5\alpha_i\,{\alpha_j}^2 - 2\,{\alpha_j}^3 + 2\,{\alpha_i}^2 t_i + 5\alpha_i\alpha_j t_i + 2\,{\alpha_j}^2 t_i + 9\alpha_j t_i t_j - 9\,{t_i}^2 t_j \\
& +2\,{\alpha_i}^2 c_i + 5\alpha_i\alpha_j c_i + 2\,{\alpha_j}^2 c_i - 9t_i t_j c_i - 2\,{\alpha_i}^2 I_i^H - 3\alpha_i\alpha_j I_i^H - {\alpha_j}^2 I_i^H \\
& +6t_i t_j I_i^H - {\alpha_j}^2 I_i^K - 2\alpha_i\alpha_j I_i^K + 3t_i t_j I_i^K - t_i(\alpha_i - \alpha_j)(I_j^H - I_j^K)] \\
& /(2\,{\alpha_1}^2 + 5\alpha_1\alpha_2 + 2\,{\alpha_2}^2 - 9t_1 t_2), \\
& \text{where } i, j = 1, 2\ (i \neq j)\ \textit{and}\ H, K = A, B\ (H \neq K).
\end{aligned}$$

B. Equilibrium prices with tying in the two-sided singlehoming model

$$\begin{aligned}
\tilde{p}_1^{A*} = & [-2\,{\alpha_1}^2\alpha_2 - 5\alpha_1\,{\alpha_2}^2 - 2\,{\alpha_2}^3 + 2\,{\alpha_1}^2 t_1 + 5\alpha_1\alpha_2 t_1 + 2\,{\alpha_2}^2 t_1 + 9\alpha_2 t_1 t_2 \\
& -9\,{t_1}^2 t_2 + 2\,{\alpha_1}^2 c_1 + 5\alpha_1\alpha_2 c_1 + 2\,{\alpha_2}^2 c_1 - 9t_1 t_2 c_1 \\
& -\{(\alpha_1 + \alpha_2)(2\alpha_1 + \alpha_2) - 6t_1 t_2\} s_M - (\alpha_1 + \alpha_2)(2\alpha_1 + \alpha_2)\tilde{I}_1^A + 6t_1 t_2 \tilde{I}_1^A \\
& - {\alpha_2}^2\,\tilde{I}_1^B - 2\alpha_1\alpha_2 \tilde{I}_1^B + 3t_1 t_2 \tilde{I}_1^B - t_1(\alpha_1 - \alpha_2)(\tilde{I}_2^A - \tilde{I}_2^B)] \\
& /(2\,{\alpha_1}^2 + 5\alpha_1\alpha_2 + 2\,{\alpha_2}^2 - 9t_1 t_2), \\
\tilde{p}_1^{B*} = & [-2\,{\alpha_1}^2\alpha_2 - 5\alpha_1\,{\alpha_2}^2 - 2\,{\alpha_2}^3 + 2\,{\alpha_1}^2 t_1 + 5\alpha_1\alpha_2 t_1 + 2\,{\alpha_2}^2 t_1 + 9\alpha_2 t_1 t_2 \\
& -9\,{t_1}^2 t_2 + 2\,{\alpha_1}^2 c_1 + 5\alpha_1\alpha_2 c_1 + 2\,{\alpha_2}^2 c_1 - 9t_1 t_2 c_1 \\
& -\{\alpha_2(2\alpha_1 + \alpha_2) - 3t_1 t_2\} s_M - 2\alpha_1\alpha_2 \tilde{I}_1^A - {\alpha_2}^2\,\tilde{I}_1^A + 3t_1 t_2 \tilde{I}_1^A \\
& -(\alpha_1 + \alpha_2)(2\alpha_1 + \alpha_2)\tilde{I}_1^B + 6t_1 t_2 \tilde{I}_1^B + t_1(\alpha_1 - \alpha_2)(I_2^A - I_2^B)] \\
& /(2\,{\alpha_1}^2 + 5\alpha_1\alpha_2 + 2\,{\alpha_2}^2 - 9t_1 t_2), \\
\tilde{p}_2^{H*} = & [-2\,{\alpha_1}^3 - 5\,{\alpha_1}^2\alpha_2 - 2\alpha_1\,{\alpha_2}^2 + 2\,{\alpha_1}^2 t_2 + 5\alpha_1\alpha_2 t_2 + 2\,{\alpha_2}^2 t_2 + 9\alpha_1 t_1 t_2 \\
& -9t_1\,{t_2}^2 + 2\,{\alpha_1}^2 c_2 + 5\alpha_1\alpha_2 c_2 + 2\,{\alpha_2}^2 c_2 - 9t_1 t_2 c_2 \\
& +t_2(\alpha_1 - \alpha_2)(I_2^H - I_2^K + s_M) - {\alpha_1}^2\,\tilde{I}_2^H - 3\alpha_1\alpha_2 \tilde{I}_2^H - 2\,{\alpha_2}^2\,\tilde{I}_2^H + 6t_1 t_2 \tilde{I}_2^H \\
& - {\alpha_1}^2\,\tilde{I}_2^K - 2\alpha_1\alpha_2 \tilde{I}_2^K + 3t_1 t_2 \tilde{I}_2^K] \\
& /(2\,{\alpha_1}^2 + 5\alpha_1\alpha_2 + 2\,{\alpha_2}^2 - 9t_1 t_2), \text{ where } H, K = A, B\ (H \neq K).
\end{aligned}$$

C. Proofs omitted in the text

Proof of Proposition 12. Denote group-i agents' consumer surplus of as $s_i \equiv v_i - c_i$. The social welfare without tying can be written as

$$\begin{aligned} W &= s_M + s_1 + s_2 + \underbrace{[I_1^{A^*} n_1^{A^*} + I_1^{B^*}\left(1 - n_1^{A^*}\right) + I_2^{A^*} n_2^{A^*} + I_2^{B^*}\left(1 - n_2^{A^*}\right) - \frac{k}{2}\left(I_1^{A^*\,2} + I_1^{B^*\,2} + I_2^{A^*\,2} + I_2^{B^*\,2}\right)]}_{\equiv DR} \\ &\quad \underbrace{- \left[\int_0^{n_1^{A^*}} t_1 x dx + \int_{n_1^{A^*}}^1 t_1 x dx + \int_0^{n_2^{A^*}} t_2 x dx + \int_{n_2^{A^*}}^1 t_2 x dx\right]}_{\equiv TC} \end{aligned}$$

The social welfare with tying can be written as

$$\begin{aligned} \tilde{W} &= s_M \tilde{n}_1^{A^*} + s_1 + s_2 + \underbrace{[\tilde{I}_1^{A^*} \tilde{n}_1^{A^*} + \tilde{I}_1^{B^*}\left(1 - \tilde{n}_1^{A^*}\right) + \tilde{I}_2^{A^*} \tilde{n}_2^{A^*} + \tilde{I}_2^{B^*}\left(1 - \tilde{n}_2^{A^*}\right) - \frac{k}{2}(\tilde{I}_1^{A^*\,2} + \tilde{I}_1^{B^*\,2} + \tilde{I}_2^{A^*\,2} + \tilde{I}_2^{B^*\,2})]}_{\equiv \widetilde{DR}} \\ &\quad \underbrace{- \left(\int_0^{\tilde{n}_1^{A^*}} t_1 x dx + \int_{\tilde{n}_1^{A^*}}^1 t_1 x dx + \int_0^{\tilde{n}_2^{A^*}} t_2 x dx + \int_{\tilde{n}_2^{A^*}}^1 t_2 x dx\right)}_{\equiv \widetilde{TC}} \end{aligned}$$

The social welfare change from tying can be decided by

$$\Delta W \equiv \tilde{W} - W = s_M(\tilde{n}_1^{A^*} - 1) + \left[(\widetilde{DR} - \widetilde{TC}) - (DR - TC)\right]$$

(i) $\widetilde{DR} - \widetilde{TC} < DR - TC$: The following maximization problem can be considered to compare $(\widetilde{DR}-\widetilde{TC})$ and $(DR-TC)$ from $I_i^{H^*}+I_i^{K^*}=2/3k$ with $I_i^{H^*}=1/3k$.

$$
\begin{aligned}
\max_{\theta, I_1^A, I_1^B} \Theta &= I_1^A(\frac{1}{2}+\theta_1)+I_1^B(\frac{1}{2}-\theta_1)+I_2^A(\frac{1}{2}+\theta_2)+I_2^B(\frac{1}{2}-\theta_2) \\
&-\frac{k}{2}({I_1^A}^2+{I_1^B}^2+{I_2^A}^2+{I_2^B}^2) \\
&-\left(\int_0^{\frac{1}{2}+\theta_1} t_1 x dx+\int_{\frac{1}{2}+\theta_1}^1 t_1 x dx+\int_0^{\frac{1}{2}+\theta_2} t_2 x dx+\int_{\frac{1}{2}+\theta_2}^1 t_2 x dx\right) \\
&\text{subject to } I_1^A+I_1^B=I_2^A+I_2^B=\frac{2}{3k}.
\end{aligned}
$$

Θ is maximized at $\theta_i=0$, $I_i^H=1/3k$ which implies $\widetilde{DR}-\widetilde{TC}<DR-TC$.

(ii) $s_M(\tilde{n}_1^{A^*}-1)<0$ from $\tilde{n}_1^{A^*}<1$.

Therefore, $\Delta W<0$ follows from (i) and (ii). ■

Proof of Proposition 15. The social welfare without tying can be written as

$$
\begin{aligned}
W &= s_M+s_1+s_2+\underbrace{\left[I_1^{A^*}n_1^{A^*}+I_1^{B^*}\left(1-n_1^{A^*}\right)-\frac{k}{2}({I_1^{A^*}}^2+{I_1^{B^*}}^2)\right]}_{\equiv DR} \\
&-\underbrace{\left(\int_0^{n_1^{A^*}} t_1 x dx+\int_{n_1^{A^*}}^1 t_1 x dx\right)}_{\equiv TC}
\end{aligned}
$$

The social welfare with tying can be written as

$$
\begin{aligned}
\tilde{W} &= s_M\tilde{n}_1^{A^*}+s_1+s_2+\underbrace{\left[\tilde{I}_1^{A^*}\tilde{n}_1^{A^*}+\tilde{I}_1^{B^*}\left(1-\tilde{n}_1^{A^*}\right)-\frac{k}{2}({\tilde{I}_1^{A^*}}^2+{\tilde{I}_1^{B^*}}^2)\right]}_{\equiv\widetilde{DR}} \\
&-\underbrace{\left(\int_0^{\tilde{n}_1^{A^*}} t_1 x dx+\int_{\tilde{n}_1^{A^*}}^1 t_1 x dx\right)}_{\equiv\widetilde{TC}}
\end{aligned}
$$

The social welfare change from tying can be decided by

$$\Delta W \equiv \tilde{W} - W = s_M(\tilde{n}_1^{A^*} - 1) + \Big[(\widetilde{DR} - \widetilde{TC}) - (DR - TC)\Big]$$

(i) $\widetilde{DR} - \widetilde{TC} < DR - TC$: The following maximization problem can be considered to compare $(\widetilde{DR} - \widetilde{TC})$ and $(DR - TC)$ from $I_1^{A^*} + I_1^{B^*} = \tilde{I}_1^{A^*} + \tilde{I}_1^{B^*} = 2/3k$ with $I_1^{A^*} = I_1^{B^*} = 1/3k$ and $\tilde{I}_1^{A^*} = 1/3k + s_M/(9k-2)$, $\tilde{I}_1^{B^*} = 1/3k - s_M/(9k-2)$.

$$\max_{\theta, I_1^A, I_1^B} \Theta = I_1^A(\frac{1}{2} + \theta) + I_1^B(\frac{1}{2} - \theta) - \frac{k}{2}({I_1^A}^2 + {I_1^A}^2) - \left(\int_0^{\frac{1}{2}+\theta} t_1 x dx + \int_{\frac{1}{2}+\theta}^1 t_1 x dx\right)$$
$$\text{subject to } I_1^A + I_1^B = \frac{2}{3k}.$$

Θ is maximized at $\theta = 0$, $I_1^A = I_1^B = 1/3k$ which implies $\widetilde{DR} - \widetilde{TC} < DR - TC$.

(ii) $s_M(\tilde{n}_1^{A^*} - 1) < 0$ from $\tilde{n}_1^{A^*} < 1$.

Therefore, $\Delta W < 0$ follows from (i) and (ii). ■

BIBLIOGRAPHY

Bibliography

[1] Amelio, A. and Jullien, B. (2007), "Tying and Freebies in Two-Sided Markets." IEDI Working Papers 445.

[2] Armstrong, M. (2006), "Competition in Two-Sided Markets." *RAND Journal of Economics*, Vol. 37, pp. 668−691.

[3] Armstrong, M. and Wright, J. (2007), "Two-Sided Markets, Competitive Bottlenecks and Exclusive Contracts." *Economic Theory*, Vol. 32, pp. 353−380.

[4] Bulow, J. I., Geanakoplos, J. D. and Klemperer, P. D. (1985), "Multimarket Oligopoly: Strategic Substitutes and Complements." *Journal of Political Economy*, Vol. 93, pp. 488−511.

[5] Carlton, D.W. and Waldman, M. (2002), "The Strategic Use of Tying to Preserve and Create Market Power in Evolving Industries." *RAND Journal of Economics*, Vol. 33, pp. 194−220.

[6] Choi, J.P. (2004), "Tying and Innovation: A Dynamic Analysis of Tying Arrangements." *Economic Journal*, Vol. 114, pp. 83−101.

[7] Choi, J.P. (2010) "Tying in Two-Sided Markets with Multi-Homing", *Journal of Industrial Economics*, Vol. 58, pp. 607−626.

[8] Choi, J.P., and Stefanadis, C. (2001), "Tying, Investment, and the Dynamic Leverage Theory." *RAND Journal of Economics*, Vol. 32, pp. 52−71.

[9] Choi, J.P., Lee, G. and Stefanadis, C. (2003), "The effects of Integration on R&D Incentives in System Markets." *Netnomics*, Vol. 5, pp. 21−32.

[10] Evans, D. (2003), "The Antitrust Economics of Multi-Sided Platform Markets." *Yale Journal on Regulation*, Vol. 20, pp. 328−382.

[11] Farrell, J. and Katz, M.L. (2000), "Innovation, Rent Extraction, and Integration in System Markets." *Journal of Industrial Economics*, Vol. 48, pp. 413−432.

[12] Gilbert, R.J. and Riordan, M.H. (2007), "Product Improvement and Technological Tying in a Winner-Take-All Market." *Journal of Industrial Economics*, Vol. 55, pp. 113−139.

[13] Motta, M. (2004), *Competition Policy: Theory and Practice*. Cambridge: Cambridge University Press.

[14] Rey, P. and Tirole, J. (2007), "A Primer on Foreclosure." *Handbook of Industrial Organization*, Vol. 3, pp. 2147−2220.

[15] Rochet, J.-C. and Tirole, J. (2003), "Platform Competition in Two-Sided Markets." *Journal of European Economic Association*, Vol. 1, pp. 990−1029.

[16] Rochet, J.-C. and Tirole, J. (2006), "Two-Sided Markets: A Progress Report." *RAND Journal of Economics*, Vol. 37, pp. 645−667.

[17] Rochet, J.-C. and Tirole, J. (2008), "Tying in Two-Sided Markets and the Honor All Cards Rule." *International Journal of Industrial Organization*, Vol. 26, pp. 1333−1347.

[18] Tirole, J. (1988), *The Theory of Industrial Organization*. Cambridge: MIT Press.

[19] Tirole, J. (2005), "The Analysis of Tying Cases: A Primer." *Competition Policy International*, Vol. 1, pp. 1−25.

[20] Whinston, M.D. (1990), "Tying, Foreclosure, and Exclusion." *American Economic Review*, Vol. 80, pp. 837−859.