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THREE ESSAYS IN INDUSTRIAL ORGANIZATION

By

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ABSTRACT

THREE ESSAYS IN INDUSTRIAL ORGANIZATION

By

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The first chapter develops a simple model of software piracy to analyze the short-run effects of piracy on software usage and the long-run effects on development incentives. I consider two types of costs associated with piracy: the *reproduction cost* that is *constant* across users and the *degradation cost* that is *proportional* to consumers' valuation of the original product. We show that the effects of piracy depend crucially on the nature of piracy costs. Policy implications concerning copyright protection are also discussed.

In the second chapter I analyze a professional sports league's optimal choice of the number of franchises in Salop's (1979) circular city model. I consider two scenarios: (1) the league operates as a fully collusive cartel in which it controls the number of franchises and ticket pricing, and (2) the league operates as a semi-collusive cartel in which it controls only the number of franchises and ticket pricing is left to individual franchises. I compare the outcomes in both scenarios to the socially optimal and free entry outcomes. I extend the analysis to the case where the average quality of each franchise is inversely related to the number of franchises due to diluted talent pool. Finally, I consider the possibility that the league can play relocation game with local or state governments. In particular, I examine the strategic advantage of leaving a few cities vacant, which will be used as a leverage to exploit more consumer surplus.

In the third chapter I develop a simple model of international technology licensing to study the effect of patent protection policy on the licensor's endogenous choice of R&D expenditure and the level of technology transferred. With endowment of two different levels of technologies the licensor may transfer the old technology when the patent protection policy of the host country is not effective. I present the model in which the effectiveness of protection policy depends on the quality gap between technologies and the relative magnitude of the licensee. However, with the licensor's endogenous choice of R&D expenditure, the strong protection policy is shown to have a reverse effect on technology innovation.

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CHAPTER 1

A MODEL OF PIRACY

1. Introduction

As the current controversy surrounding the Napster case testifies, unauthorized reproduction of intellectual property has been a serious but controversial issue for copyright holders, consumers, and policy makers alike, especially with the advent of digital technology. According to a recent study by the Business Software Alliance (2001), for instance, the piracy rate in 2000 is estimated to be 37%, which can be translated into \$11.75 billion dollar losses for software publishers.[1] The piracy rates in the Far East, especially China, Indonesia and Vietnam, represent in each case over 90%. The corresponding rates for Western Europe and North America are 34% and 25%, respectively. Based on these figures, copyright holders claim that piracy is a severe threat to incentives to develop new products, as well as revenue loss from the developed software.

This paper develops a self-selection model of software piracy to analyze the short-run effects of piracy on software usage and the long-run effects on development incentives. The innovation in this paper is to distinguish two types of costs associated with piracy – constant and type-proportional – and to show that the effects of piracy depend crucially on the nature of piracy costs. To comment briefly on the two types of costs, we first assume that piracy entails *reproduction cost*, which is assumed to be

[1] 'Sixth Annual BSA Global Software Piracy Study (May 2001)' conducted by International Planning and Research Corporation (IPRP) for the Business Software Alliance (BSA) and its member companies.

constant across all consumers. The constant reproduction cost can be treated as the price of an illegal copy made by piracy retailers. Even with the assumption that actual reproduction cost is zero, consumers will need to exert efforts to obtain an authorized copy or may have to spend time to find the software, and then to copy or to download it for installation purposes. We assume that these costs are the same across all users or at least *independently* distributed with the valuation of consumers for the product.

The second type of cost we consider is *degradation of product quality* associated with unauthorized copying. The utility loss due to degradation is *proportional* to each consumer's valuation of the software. As examples of degradation of the quality associated with piracy, for instance, an authorized copy of the software is bundled with manuals, installation software, online services, as well as discount on future upgrades. Users who pirate the software, in contrast, may not be able to access the entire complimentary bundle. In addition, some software publishers strategically include web-based functions that require personal identification numbers (PIN). Identical PINs cannot be used on the Web at the same time.[2] With an illegal copy, a consumer thus may be able to use the software off-line, but not able to use online functions, thus experiencing quality degradation.[3] The web-based anti-piracy system is also capable of reducing quality of the software by blocking the users with a pirated copy from receiving upgrades.[4]

As another example of policy relevance, consider the Peer to Peer Piracy Prevention Act (H.R. 5211) which was proposed by Rep. Howard Berman, D-California,

[2] With development of high-speed Internet, the new components of game software are online game services, in which you can play the game with someone through the Internet. With the database for the registration keys the software publisher is able to prohibit the pirated copies with the duplicated key from running on the web.

[3] For TurboTax software, each authorized copy is designed to file tax returns electronically for only one customer. Hence, users with an unauthorized copy are only able to do tax returns except electronic filing.

and is being considered by the House Judiciary subcommittee as a way to protect intellectual property against file-sharing through peer-to-peer (P2P) networks. P2P networks arose as a response to the shutdown of Napster. Unlike Napster, P2P networks do not host files on a central server; instead they list available files on individual PCs and directly connect those computers, which makes the enforcement of copyrights more difficult. The proposed bill would allow the record industry to "hack" into individuals' PCs in search of copyright violations. In our model, this type of copyright enforcement would translate into an increase in the costs of copying that are proportional to user types. Another response by record labels in face of file-sharing, is to upload the so-called "spoof" files – containing little or no music – on P2P networks to confuse downloaders. This practice would increase the expected time of downloading a particular music file and can be considered as an increase in the uniform copy costs.

The purpose of this study is to construct a model of self-selection with heterogeneous consumers who choose among three available options: the purchase of authorized product, the use of an illegal copy with unauthorized reproduction, or no consumption. In such a framework, we conduct a two-step analysis. In the short-run analysis, we investigate how the threat of piracy constrains the pricing behavior of the monopolist. Depending on the relative magnitudes of reproduction and degradation cost, the monopolist is shown to choose the optimal choice of regimes between limit pricing and accommodation to copy. We demonstrate that with the threat of piracy the monopolist's price is lowered, and usage of an authorized copy is *increased* in both

[4] Responding to piracy of Windows XP operating system, Microsoft announces that Windows XP Service Pack 1 (and possibly all future updates) will not install with pirated copies.

regimes with positive welfare implications.[5] This result provides a sharp contrast to the common claims of copyright holders, in which the possibility of piracy reduces demand for a legal copy. We then conduct a comparative statics exercise that analyzes the effects of increased copyright protection. It is shown that the effects could hinge on how it affects the two margins of the piracy costs discussed above. The reason is that the changes in the two margins impact the demand for a legal copy in different ways: the changes in constant production cost shifts the demand curve in a *parallel* fashion whereas the changes in degradation rate induces a *pivot* change in the demand curve.

In the long-run analysis, we extend the model to allow for an endogenous choice of the software quality by producer. The existence of piracy creates inefficiently low quality of the product. Thus, there is potential for increased copyright protection to help mitigate this inefficiency in quality provision and counterbalance the short-run effects. Once again, we demonstrate that the effects of increased copyright protection on the provision of quality depend on how it affects the two margins of the piracy costs.

Earlier papers concerned with the effects of increased copyright protection on social welfare include Novos and Waldman (1984) and Johnson (1985) among others. Novos and Waldman (1984) analyze the effects of increased copyright protection in a model where consumers vary only in terms of their cost of obtaining a copy. They show that there is no tendency for an increase in copyright protection to increase the social welfare loss due to underutilization once the cost of obtaining a copy is taken into account. Our paper, in contrast, allows consumers to vary in terms of their valuations on the quality of software. In addition, we consider two different types of costs associated

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[5] Choi and Thum (2002) provide a similar framework, if we consider purchasing an authorized copy of the software as entering the official economy, and making an illegal copy as operating in the shadow economy.

with piracy and shows that the effects of increased copyright protection hinge on how it affects the two margins of the piracy costs.

Johnson (1985), as in our paper, considers consumers with different tastes, but his model is of horizontal differentiation and the focus is on the product variety issues. More importantly, the major difference between his paper and ours is in the long-run analysis: in Johnson's analysis software supply responses are modeled along the extensive margin (the number of software products created), whereas in our analysis supplier responses are modeled along the intensive margin (the quality of software). In a recent paper, Belleflamme (2002) analyzes pricing decisions of producers of information goods in the presence of copying. He assumes a uniform distribution of consumer types in a model of vertical differentiation and derives similar results as in our paper. Once again, however, his long-run analysis is along the extensive margin as in Johnson (1985).[6]

The remainder of the paper is organized in the following way: Section 2 sets up the basic model and provides a *short-run* analysis in which we investigate how the monopolist's pricing decision is affected by the threat of piracy. We characterize the pattern of self-selection by consumers and the optimal price for the monopolist. In a comparative statics exercise, we show that the effects of increased copyright protection depend crucially on how it affects the two margins of the piracy costs discussed above.

[6]See also Yoon (2002) who considers a similar model in which he derives the optimal level of copyright protection. Yoon (2002) also assumes that the development cost is fixed in his long-run analysis. The only measure for the ex ante efficiency with fixed development cost is whether the monopolist develops the new product or not; the monopolist does not introduce a new product if the development cost can not be recovered due to weak protection level. With this type of ex ante efficiency measure, the optimal protection level is characterized by a step function because the incentive for development can be altered with an infinitesimal change of IPRP. In our model, to have a continuous effect of the increase in IPRP, we assume that the monopolist's long-run incentive is to choose the quality of software. Crampes and Laffont (2002) also analyze the effects of piracy on the pricing policy of a software producer. Their focus, however, is on the consequences of cost randomness in the decision for piracy and on the risk aversion of users.

In Section 3, we extend the model to analyze the *long-run* implications of piracy for software quality. Section 4 contains concluding remarks.

2. The Model of Piracy: A Short-Run Analysis

Before analyzing the more complex effect of an increase in intellectual property rights protection (IPRP) on software usage in the short run and development incentive in the long run, we first develop a simple model of piracy with a monopolistic software publisher. There is a population of consumers whose total number is normalized to unity. Consumers are heterogeneous in their value of using the software. Let v denote a consumer's gross utility of using the software. The distribution of types is given by the *inverse* cumulative distribution function $F(v)$ with continuous density $F'(v) \leq 0$, that is, $F(v)$ denotes the proportion of consumers whose value of the software is *more* than v.

To analyze the *ex post* efficiency effects of piracy, we assume that the software is already developed and the marginal cost of production is zero. The incentives to develop new software are considered in section 3. The copyright holder sets the price of the software p to maximize his revenues. As the consumer's utility v is private information, the copyright holder cannot price discriminate and charges a uniform price p.[7]

Optimal Pricing without Piracy: A Benchmark Case

As a benchmark case, we first consider a situation where the option to pirate copyrighted work is not available, that is, the consumers' only choice is whether to purchase or not. The utility of buying an authorized copy is given by $U_B(v;p) = v - p$. We normalize the consumers' payoffs from not using the software to zero. Then, consumers whose valuation of software is more than p will purchase the software.

The purchase behavior of the consumers implies that the copyright holder maximizes his revenue:

$$\max_{p} \; R(p) = p \cdot F(p).$$

Since the monopolist's price p is uniquely determined by v, we will find it more convenient to treat v as the control variable:

$$\max_{v} \; R(v) = v \cdot F(v).$$

The marginal consumer v^* that maximizes the copyright holder's revenue is implicitly given by the first order condition:

$$F(v^*) + v^* \cdot F'(v^*) = 0. \tag{1}$$

We make the standard assumption that the distribution of types satisfies the monotone hazard rate condition, that is, $-F'/F$ is increasing:

$$-F''F + (F')^2 > 0. \tag{2}$$

This assumption ensures that the copyright holder's objective function is quasi-concave and the second order condition for the maximization problem is satisfied:

$$2F'(v) + vF''(v) < 0.^{8} \tag{3}$$

[7] In a dynamic model, however, the monopolist can price discriminate consumers based on purchase history. See Fudenberg and Tirole (1998) for such an analysis.

[8] Using the first order condition, we can rewrite the second order condition as $2 \cdot F'(v) - F''(v) \cdot F(v) / F'(v) < 0$. The second order condition holds if the distribution F satisfies the monotone hazard rate condition. This condition is a standard assumption in the incentive literature and is satisfied by most widely used distributions; see Fudenberg and Tirole (1991, p. 267).

Then, the number of software users is given by $F(v^*)$. The optimal price of the software for the copyright holder is $p^* = v^*$. Note that the optimal price and the marginal consumer without piracy depends only on the distribution of consumer types $F(\cdot)$.

Needless to say, the socially optimal price for the software, once it is developed, is its marginal cost, which is assumed to be zero. Due to monopolistic pricing, consumers whose types are below v^* do not use the software and the deadweight loss is given by $-\int_0^{v^*} x dF(x)$.

Optimal Pricing with Piracy

Now we introduce the possibility of using the software through piracy without purchasing a legal copy. Piracy saves the price of the software for consumers. However, it entails potentially two types of costs. First, the unauthorized copy may not be a perfect substitute for the legal copy and typically entail some degree of quality degradation. In the case of copying with analog technology before the advent of digital technology, for instance, more iteration of additional copying meant lower quality. Even with digital copying, the unauthorized copy may lack technical support or access to other resources offered by the manufacturer. We assume that this cost is proportional to the valuation of the consumer for the original, that is, the valuation of the type v consumer for the unauthorized copy is given by $(1-\alpha)\cdot v$, where α is the parameter for quality degradation. Another interpretation is that α represents the enforcement efforts by the authority. If illegal copiers are caught with the probability of α, in which case the software is confiscated as punishment, the valuation of using an illegal copy would be given by $(1-\alpha)$. In addition, we assume that illegal copying entails reproduction cost of c, which is assumed to be the same across users. Thus, the utility of using an unauthorized copy is given by $U_{UC}(v) = (1-\alpha)\cdot v - c$.[9]

In order to have a meaningful analysis of unauthorized copying, we restrict our attention to the parameter regions in which the piracy constraint is binding, that is,

$$\frac{c}{1-\alpha} < p^* = v^* \qquad (4),$$

where v^* is defined by (1).[10] This condition is satisfied if the degree of quality degradation α and/or the cost of copying c are not too high.

When the piracy condition (4) is binding, the monopolist's problem is complicated by the fact that some consumers are better off copying the software given the monopolist's price of the software. In response to piracy, the monopolist has two choices. One option is to *limit price* the software so that copying is not an attractive option. The other option is to price the software to sell only to the highest types and allow copying for intermediate types of customers.

Limit Pricing Regime without Piracy

With the piracy constraint binding $\left(\frac{c}{1-\alpha} < p^* = v^*\right)$, the limit price should satisfy the following incentive constraint to eliminate the incentives to copy:

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[9] If we let $w = \alpha v + c$, then $U_{UC}(v) = v - w$. Hence, we can denote w as the gross copy cost.

[10] If the possibility to copy the software does not constrain the monopolist's maximization problem, the marginal type of consumer is given by v^* as defined by (1). The marginal type v^* earns zero surplus when he makes a purchase from the monopolist. If he makes an illegal copy instead, his payoff is $U_{UC}(v^*) = (1-\alpha)v^* - c$. If $c/(1-\alpha) < p^* = v^*$, the surplus from making an illegal copy exceeds the one from other options. Thus, possibility to copy the software serves as a binding constraint for the monopolist's revenue maximization problem.

$$U_B(v;p) = v - p \geq (1-\alpha)v - c = U_{UC}(v) \text{ for any } v \geq \frac{c}{1-\alpha} \tag{5}$$

We observe that $U_B(v;p) - U_{UC}(v)$ is increasing in v, which implies that if the constraint above holds for v, then it also holds for any v' such that $v' > v$. Thus, all we need is that the inequality above be satisfied for $v = \frac{c}{1-\alpha}$. This in turn implies that the limit price and the marginal type are given by $p^L = v^L = c/(1-\alpha)$. Notice that the no piracy incentive constraint (5) is always binding under the assumption $\frac{c}{1-\alpha} < p^* = v^*$.

Lemma 1. When the piracy constraint is binding, the optimal limit price that prevents the incentive to copy is given by $p^L = c/(1-\alpha)$. In this case, the monopolist's revenue is given by $R = p^L F(p^L) = \frac{c}{1-\alpha} \cdot F\left(\frac{c}{1-\alpha}\right)$.

Copying Regime ($p > p^L = c/(1-\alpha)$)

If $p > p^L = c/(1-\alpha)$, the no piracy constraint is violated for some v's that are higher than but close to $v^L = c/(1-\alpha)$. Each consumer has two different choices for using the software, which incur two different types of cost. First, when a consumer buys a legal copy from the monopolist, he has to pay the price (p) and enjoys the full quality of the software. However, with choice of making an illegal copy, his cost will be the sum of degradation of quality that is proportional to his own valuation of the software and a constant reproduction cost. We assume at this time that the parameters of IPRP (α for the degradation rate and c for the reproduction cost) are fixed.

When consumers make their usage decision, they choose the one that yields the highest net utility. For a given price of a legal copy ($p > p^L = c/(1-\alpha)$) and the level of IPRP, consumers' optimal choices can be divided as follows:

$$\frac{p-c}{\alpha} \le v \qquad \text{purchase a legal copy}$$

$$\frac{c}{1-\alpha} \le v < \frac{p-c}{\alpha} \qquad \text{make an illegal copy}$$

$$v < \frac{c}{1-\alpha} \qquad \text{no use.}$$

Now the monopolist should take into account that potential consumers have another option to obtain the software. The monopolist, therefore, maximizes

$$Max\ p \cdot F\left(\frac{p-c}{\alpha}\right).$$

Once again, we treat the marginal consumer type $v = \frac{p-c}{\alpha}$ as the control variable:

$$Max\ (\alpha v + c)F(v).$$

The first order condition

$$(\alpha v + c)F'(v) + \alpha F(v) = 0 \qquad (6)$$

determines the marginal type of consumer $\tilde{v}$, who is indifferent from purchasing an authorized copy from the monopolist and making an unauthorized copy.[11] Therefore, with the option of making an illegal copy, consumers with low value $v < c/(1-\alpha)$ do not use the software. Those with intermediate value $c/(1-\alpha) \le v < \tilde{v}$ make illegal copies. Only consumers with high value $v > \tilde{v}$ purchase legal copies from the monopolist [see

[11] Variables under the copying regime are denoted by a tilde ($\tilde{v}$).

figure 1]. We now can compare the monopolist's pricing behavior with and without piracy.

Proposition 1. With the possibility of piracy, the price of the software is lowered, thereby inducing more demand for *legal* copies. Increase in usage of both legal and illegal copies under the copying regime brings higher ex post usage for the software.

Proof. Evaluate (6) at $v*$ which is the marginal consumer when no copying is feasible: $\alpha[F(v^*)+v^*F'(v^*)]+cF'(v^*)=cF'(v^*)<0$. Hence, $v^*>\tilde{v}$.

Under the copying regime, those consumers whose valuation lies between $c/(1-\alpha)$ and $\tilde{v}$ make illegal copies. Therefore, total ex post usage for the software is unambiguously increased with piracy as shown in figure 1. By being just a threat (limit pricing regime) or an actual fact (copying regime), piracy has the same effect on the monopolist's pricing behavior: the price is lower than the one in the benchmark case. A more surprising result is that the usage of *legal* copies increases even in the presence of copying. Thus, the extent to which legal copies are used is *complementary* with the extent of the usage of unauthorized copies.[12] The intuition for this result can be found in the monopolist's pricing behavior in response to the threat of unauthorized copying. If there were no price change, that is, at $p = p^*=v^*$ defined in (1), some of the previous purchasers of the legal copy will switch to the option of copying with the result of a lower number of legal copies being sold. Proposition 1, however, shows that the price

[12] Our result does not assume network effects between authorized and unauthorized copies as in Shy and Thisse (1999).

reduction by the monopolist (from p^* to $\tilde{p} = \alpha\tilde{v} + c$) not only eliminates the incentives to switch for the previous buyers but also expands the base of buyers.

Comparative Statics

We now analyze the effects of marginal increase in the intellectual property rights. As with the previous studies in the literature (Novos and Waldman (1984), Yoon (2002), etc), we model the increase in the intellectual property rights protection as an increase in the cost of piracy ($w = \alpha v + c$, see footnote 9), which makes the option of piracy ($U_{UC}(v) = v - w$) less attractive. It is shown that the effects can have different implications depending on which regime the monopolist is operating under and the type of costs associated with piracy.

Proposition 2. Under the limit pricing regime, both types of an increase in IPRP induces higher software price and less authorized usage.

Proof. Under the limit pricing regime, we have $p^L = c/(1-\alpha)$, and $q^L = F(p^L)$. If we take partial derivatives of p^L and $F(p^L)$ with respect to c and α respectively, we have the following results:

$$\frac{\partial p^L}{\partial c} = \frac{1}{1-\alpha} > 0, \qquad \frac{\partial F(p^L)}{\partial c} = \frac{\partial F(p^L)}{\partial p^L}\frac{\partial p^L}{\partial c} < 0,$$

$$\frac{\partial p^L}{\partial \alpha} = \frac{c}{(1-\alpha)^2} > 0, \text{ and } \frac{\partial F(p^L)}{\partial \alpha} = \frac{\partial F(p^L)}{\partial p^L}\frac{\partial p^L}{\partial \alpha} < 0.$$

The intuition underlying Proposition 2 is straightforward. Due to the possibility of piracy, the monopolist is not able to charge the monopoly price. The maximum price he can charge under limit pricing is $p^L = c/(1-\alpha)$, which depends on the levels of the degradation rate (α) and the reproduction cost (c). The marginal increase in IPRP from either the degradation rate or the reproduction cost provides the monopolist more market power allowing him to charge a higher price.

Proposition 3. Under the copying regime, as expected, the monopoly price increases with the strengthening of IPRP. The effects of an increase in IPRP on the usage of software, however, are ambiguous depending on the types of costs associated with piracy. Higher degradation rate induces *less* authorized usage whereas higher reproduction cost induces *more* authorized usage [see table 1].

Proof. Total differentiation of the first-order condition with respect to c:

$$[2\alpha F'(\tilde{v}) + \alpha \tilde{v} F''(\tilde{v}) + cF''(v)]dv = -F'(\tilde{v})dc\,.$$

$$\frac{d\tilde{v}}{dc} = \frac{-F'(\tilde{v})}{|H|} < 0$$

where $|H| = 2\alpha F'(\tilde{v}) + \alpha \tilde{v} F''(\tilde{v}) + cF''(v) < 0$ by the second-order condition.

Total differentiation of the first-order condition with respect to α :

$$[2\alpha F'(\tilde{v}) + \alpha \tilde{v} F''(\tilde{v}) + cF''(v)]dv = -(F(\tilde{v}) + \hat{v} F'(\tilde{v}))d\alpha\,.$$

$$\frac{d\tilde{v}}{d\alpha} = \frac{-(F(\tilde{v}) + \tilde{v} F'(\tilde{v}))}{|H|} = \frac{1}{|H|}\frac{cF'(\tilde{v})}{\alpha} > 0\,.$$

With higher reproduction cost, all consumers face the same increase in the gross copy cost, which is equivalent to an outward *parallel* shift in demand for legal copies. With an increased demand, the monopolist responds with a price hike. The price increase, however, does not completely offset the initial demand increase with the result of increased sales. In contrast, if an increase in IPRP is derived from higher degradation rate, we observe a *pivot* change in demand that affects the *slope* of the demand curve for legal copies. Due to proportional increase in the gross copy cost, higher valuation consumers are more adversely affected by an increase in the degradation cost. A steeper demand curve means that elasticity of consumers is lower with more market power. Thus, the monopolist is more interested in serving only the high valuation consumers.

Welfare Effects of Increase in IPRP in the Short Run

We are now in position to examine the effects of an increase in IPRP on social welfare. When the monopolist's optimal choice is limit pricing, it is straightforward to show the effect of an increase in IPRP on social welfare. As either the degradation or the reproduction cost increases, making an illegal copy becomes less attractive. In response to this, the monopolist is able to charge a higher price and fewer consumers use a legal copy. The increased profit margin is only a monetary transfer from consumers to the monopolist. Social welfare is reduced as a result of less authorized usage.

Proposition 4. Under the limit pricing regime, both types of increase in IPRP induces lower social welfare.

Proof. With limit pricing, the social welfare is identical to the gross consumer surplus from authorized usage:

$$SW(p^L) = -\int_{v^L}^{\infty} v \cdot F'(v)dv = v^L F(v^L) + \int_{v^L}^{\infty} F(v)dv .$$

This implies that

$$\frac{\partial SW}{\partial c} = \frac{c}{(1-\alpha)^2} F'\left(\frac{c}{1-\alpha}\right) < 0 \text{ and } \frac{\partial SW}{\partial \alpha} = \frac{c^2}{(1-\alpha)^3} F'\left(\frac{c}{1-\alpha}\right) < 0 .$$

If the monopolist's optimal choice is accommodation of piracy, the welfare effects of an increase in IPRP depend on the types of costs associated with piracy.

Proposition 5. Under the copying regime, the effects on social welfare of increase in IPRP depend on the types of costs associated with piracy. Social welfare decreases with an increase in the degradation rate (α). However, the effects of an increase in the reproduction cost (c) on social welfare are ambiguous.

Proof. The social welfare can be derived from the sum of the monopolist's revenue and the consumer's surplus:

$$\begin{aligned} SW(\tilde{p}) &= R(\tilde{p}) + CS(\tilde{p}) \\ &= (\alpha\tilde{v} + c)F(\tilde{v}) - \int_{\tilde{v}}^{\infty}(v - \alpha\tilde{v} - c)F'(v)dv - \int_{\frac{c}{1-\alpha}}^{\tilde{v}}[(1-\alpha)v - c]F'(v)dv \\ &= \tilde{v}F(\tilde{v}) + \int_{\tilde{v}}^{\infty}F(v)dv - \int_{\frac{c}{1-\alpha}}^{\tilde{v}}[(1-\alpha)v - c]F'(v)dv . \end{aligned}$$

We examine the effect of an increase of IPRP on social welfare as

$$\frac{\partial SW(\tilde{p})}{\partial \alpha} = \underbrace{[\tilde{v} - ((1-\alpha)\tilde{v} - c)]F'(\tilde{v})\frac{\partial \tilde{v}}{\partial \alpha}}_{\text{demand switch }(-)} + \underbrace{\int_{\frac{c}{1-\alpha}}^{\tilde{v}} vF'(v)dv}_{\text{copy cost increase }(-)} < 0$$

$$\frac{\partial SW(\tilde{p})}{\partial c} = \underbrace{[\tilde{v} - ((1-\alpha)\tilde{v} - c)]F'(\tilde{v})\frac{\partial \tilde{v}}{\partial c}}_{\text{demand switch }(+)} + \underbrace{\int_{\frac{c}{1-\alpha}}^{\tilde{v}} F'(v)dv}_{\text{copy cost increase }(-)} \begin{matrix} < 0 \\ > 0 \end{matrix}$$

As can be seen from the expressions above, we can separate two different channels through which an increase in IPRP affects social welfare. The second term in each equation is always negative and represents social welfare loss due to increase in consumers gross copy cost caused by an increase in IPRP for consumers who continue to copy. The first term of each equation represents the demand switch effect between legal and illegal copies, which induces welfare gain or loss depending on the direction of demand switches. It decreases social welfare in case of an increase in the degradation rate (α), since the marginal consumers ($\tilde{v}$) who were indifferent between the legal and illegal copies now switch to illegal copies that are produced inefficiently and suffer from degradation. Taken together, both the demand switch effect and increased gross copy cost affects social welfare adversely with an increase in the degradation rate (α). In case of an increase in the reproduction cost (c), however, the demand switch effect is *positive* since it induces marginal consumers to switch to legal copies as we have demonstrated earlier. Therefore, the overall effect on social welfare is ambiguous and depends on the relative magnitude of the two countervailing effects [see figure 2].[13]

Uniform Distribution Example

We now illustrate our results using a simple uniform distribution that generates a linear demand curve for the monopolist. This example also allows a closed-form solution for welfare analysis. Let us assume that consumers' evaluations for the software are uniformly distributed over the unit interval as $v_i \in U[0, 1]$. In the benchmark case without piracy, it easy to verify that the marginal consumer is determined by $v^* = p^* = 1/2$.[14]

We now turn to the monopolist's optimal pricing problem when the piracy constraint is binding, that is, $c \leq (1-\alpha)/2$. The first option for the monopolist is to accommodate piracy in which the monopolist sets a higher price and tolerates copying. In this case, the monopolist's objective becomes:

$$Max\ p\left(1-\frac{p-c}{\alpha}\right).$$

Once again, we treat the marginal consumer type $v = \dfrac{p-c}{\alpha}$ as the control variable:

[13] As can be seen from Figure 2, there is a third effect (total usage change) coming from marginal consumers $c/(1-\alpha)$ who are indifferent between copying and no consumption. However, these consumers have zero surplus and the effect on social surplus is of second-order and does not show up in the equations.

[14] This would be the case if $(1-\alpha)/2 < c \leq 1-\alpha$. To see this, if we substitute $v^* = p^* = 1/2$ into the no piracy condition $p < c/(1-\alpha)$, the condition is not binding at the monopoly price if we have $(1-\alpha)/2 < c$. If $c > 1-\alpha$, the gross copy cost exceeds the valuation for the software, which is not a meaningful case to consider.

$$Max\ (\alpha v + c)(1 - v).$$

The first order condition

$$\alpha(1 - v) - (\alpha v + c) = 0$$

yields $\tilde{v} = \frac{1}{2} - \frac{c}{2\alpha}$ and $\tilde{p} = \frac{(\alpha + c)}{2}$, which confirms Proposition 1.

The second option is for the monopolist to eliminate piracy by setting the price sufficiently low. Since the monopolist should reduce the price until the piracy constraint is binding, $(1-\alpha)v - c = v - p$, the optimal price and revenues are $p^L = c/(1-\alpha)$, and $\pi^L = p^L(1-p^L)$. By comparing profits from each regime, we can conclude that the monopolist's optimal choice is to accommodate piracy if $0 < c \le \alpha(1-\alpha)/1+\alpha$ and to limit price if $\alpha(1-\alpha)/(1+\alpha) < c \le (1-\alpha)/2$. We can illustrate the monopolist's optimal regime change depending on the relative magnitude of IPRP parameters as in figure 3.

With liner demand and closed form solutions the effect of increased copyright protection can be shown more clearly in the uniform distribution example. Under the limit pricing regime, we can verify that both types of increase in IPRP induces higher software price and less usage. With the optimal choice of price $p^L = \left(\frac{c}{1-\alpha}\right)$ and quantity ($q^L = 1 - p^L$) under the limit pricing, we can calculate as follows:

$$\frac{\partial p^L}{\partial c} = \frac{1}{1-\alpha} > 0, \qquad \frac{\partial q^L}{\partial c} = \frac{-1}{1-\alpha} < 0,$$

$$\frac{\partial p^L}{\partial \alpha} = \frac{c}{(1-\alpha)^2} > 0, \text{ and } \qquad \frac{\partial q^L}{\partial \alpha} = \frac{-c}{(1-\alpha)^2} < 0.$$

Under the copying regime, it is observed that the effects of an increase in IPRP depend on the types of costs associated with piracy [see figure 4]. As we expect, an increase in both types of costs trigger a higher price but ambiguous effect on demand switch. These effects are clearly shown as

$$\frac{\partial p}{\partial c} = \frac{1}{2} > 0, \quad \frac{\partial q}{\partial c} = \frac{1}{2\alpha} > 0, \quad \frac{\partial p}{\partial \alpha} = \frac{1}{2} > 0, \text{ and } \frac{\partial q}{\partial \alpha} = \frac{-2c}{4\alpha^2} < 0.$$

For the last part of the short-run analysis, we examine welfare effects of an increase in IPRP. If $\alpha(1-\alpha)/(1+\alpha) < c \leq (1-\alpha)/2$, we identify that the monopolist prefer to eliminate piracy by lowering the price; in other words, the possibility of piracy enforce the monopolist to set a lower price at $p^L = c/(1-\alpha)$. It is straightforward to show the effect of an increase of IPRP on social welfare. Consumer surplus and the monopolist's revenue under the limit pricing are computed as follows: $CS^L = \int_{\frac{c}{1-\alpha}}^{1} (x - \frac{c}{1-\alpha})dx$, and $\pi^L = p^L(1-p^L)$. Defining social welfare as

$SW^L = CS^L + \pi^L = \dfrac{1-2\alpha+\alpha^2-c^2}{2(\alpha-1)^2}$ we observe that

$$\frac{\partial SW^L}{\partial c} = \frac{-c}{(\alpha-1)^2} < 0, \text{ and } \frac{\partial SW^L}{\partial \alpha} = \frac{c^2}{(\alpha-1)^3} < 0.$$

If $0 < c \leq \alpha(1-\alpha)/1+\alpha$, the monopolist is in the copying regime and the welfare effects of an increase in IPRP depend on the types of costs associated with piracy. The consumer surplus and the monopolist's revenue in the copying regime are given by

$$CS(\tilde{p}) = \int_{\frac{c}{1-\alpha}}^{\frac{p-c}{\alpha}} ((1-\alpha)x - c)dx + \int_{\frac{p-c}{\alpha}}^{1} (x-p)dx, \text{ and } \tilde{\pi} = \tilde{p}(1 - \frac{\tilde{p}-c}{\alpha}).$$

We then calculate social welfare as $SW(\tilde{p}) = CS(\tilde{p}) + \tilde{\pi} = \frac{1}{2} - \frac{\alpha}{8} - \frac{c}{4} + \frac{c^2}{2(1-\alpha)} + \frac{3c^2}{8\alpha}$.

With positive demand switch and negative total usage change, the effect of an increase in IPRP with higher reproduction cost is uncertain. However, with negative demand switch and negative total usage change we are able to pin down the effect of an increase in IPRP with higher degradation rate. These results can be illustrated by the following two partial derivatives [see figure 5].

$$\left.\frac{\partial SW}{\partial \alpha}\right|_{c \text{ is fixed}} = -\frac{1}{8} + \frac{c^2}{2(1-\alpha)^2} - \frac{3c^2}{8\alpha^2} < 0, \text{ and}$$

$$\left.\frac{\partial SW}{\partial c}\right|_{\alpha \text{ is fixed}} = -\frac{1}{4} + \frac{c}{1-\alpha} + \frac{3c}{4\alpha}.$$ [15]

To determine the sign of $\frac{\partial SW}{\partial c}$, let $\hat{c}$ be the critical value, which satisfies $\frac{\partial SW}{\partial c} = 0$ and we have $\hat{c} = \frac{\alpha(1-\alpha)}{3+\alpha}$. Hence, if $c < \hat{c}$, we have $\frac{\partial SW}{\partial c} < 0$. Otherwise, we observe $\frac{\partial SW}{\partial c} > 0$.

[15] Since we have parameter region for the copy regime such as $c \le \frac{\alpha(1-\alpha)}{1+\alpha}$, we can verify that $\frac{\partial SW}{\partial \alpha} < 0$.

3. Copyright Protection and Incentives to Create

Up to now, we have analyzed the effects of an increase in copyright protection on pricing and the incentives to pirate once the software has been produced. In this section, we analyze the long-term effects of an increase in IPRP on the incentive to create. To analyze this issue, we introduce the cost of creating the software and endogenize the quality of the software. Let θ measure the quality of software that is created at cost $C(\theta)$ (with $C'(\theta) > 0, C''(\theta) > 0$). The quality of the good enters positively into the utility of consumers; the utility of consumer of type v is $\theta \cdot v$.

We consider now the long-term effects of piracy in which the monopolist decides not only on the pricing of the software but also on the quality of the software. We continue to assume that the marginal cost of software is fixed at zero regardless of the quality of the software once it has been developed.

Software Quality without Piracy: A Benchmark Case

Before analyzing the monopolist's quality provision with the possibility of piracy, we start with the benchmark case, in which consumers face a monopolistic software publisher but do not have the opportunity to make an illegal copy. Hence, the consumers' only decision is whether to purchase or not. Since the consumers' payoff from not using the software is zero, consumers with non-negative net utilities purchase an official copy: $\theta \cdot v - p \geq 0$. Given the purchase decision of consumers, the copyright holder selects a price and a level of quality that maximize his profit:[16]

$$\max_{v,\theta} \ \pi \equiv \theta \cdot v \cdot F(v) - C(\theta).$$

The first order conditions

$$\frac{\partial \pi}{\partial v} = \theta \cdot F(v) + \theta \cdot v \cdot F'(v) = 0 \tag{7}$$

$$\frac{\partial \pi}{\partial \theta} = v \cdot F(v) - C'(\theta) = 0 \tag{8}$$

determines the marginal consumer v^* and the monopolist's optimal level of quality θ^*.

Proposition 6. Given the number of software users $F(v^*)$, the quality of the software is sub-optimally low.

Proof. Given the number of software users $F(v^*)$, i.e. all consumers of type $v \geq v^*$ buying the software, the socially optimal quality of the software can be found by solving

$$\max_{\theta} \; - \int_{v^*}^{\infty} \theta \cdot v \cdot F'(v) dv - C(\theta).$$

The first order condition

$$- \int_{v^*}^{\infty} v \cdot F'(v) dv - C'(\theta^{opt}) = 0$$

determines the socially optimal level of quality θ^{opt}. Integration by parts of the first term on the left hand side shows $- \int_{v^*}^{\infty} v \cdot F'(v) dv \geq v^* \cdot F(v^*)$. This implies that $C'(\theta^{opt}) \geq C'(\theta^*)$ as we have $v^* \cdot F(v^*) = C'(\theta^*)$ from (8). Therefore, the level of the software quality provided by the monopolist is sub-optimally low: $\theta^{opt} \geq \theta^*$.

[16] Again, we use v as a control instead of p.

The intuition for this result is the following. The choice of θ^* by the monopolist is determined by the marginal type v^*. An increase in the benefit for the marginal consumer is captured via higher price of the software by the copyright holder. The effect on the inframarginal consumers is irrelevant for the monopolist as he cannot price discriminate among consumers. In contrast, the second-best level θ^{opt} is determined by the aggregate (or average) benefits for all consumers with values $[v^*, \infty)$. As the *average* consumer's marginal valuation for the software quality is higher than the one for the *marginal* consumer, the second-best level of quality of the software exceeds the one provided by the monopolist.[17]

Software Quality with Piracy

Now we turn to the monopolist's choice of the software quality when he faces piracy: how does the potential threat or actual piracy affect the monopolist's choice of the software quality? To answer this question, we use the previous optimal pricing framework with the monopolist's choice of the software quality. We still assume there are two different types of cost associated with piracy: the constant reproduction cost and the proportional degradation rate. The degradation rate now affects the valuation of the type v consumer for the unauthorized copy as $(1-\alpha)\cdot\theta\cdot v$. Thus, the utility of using an unauthorized copy is given by $U_{UC}(v) = (1-\alpha)\cdot\theta\cdot v - c$.

In order to have a meaningful analysis of unauthorized copying, we have the same restriction to the parameter regions, in which the piracy constraint is binding, that is,

[17] This point is closely related to a monopolist's choice on product quality; see Spence (1975) and Tirole (1988, pp. 100-102).

$$\frac{c}{1-\alpha} < p^* = \theta^* v^* \qquad (9),$$

where θ^* and v^* are defined by (7) and (8). This condition is satisfied if the degree of quality degradation (α) and/or the cost of copying (c) are not too high. Therefore, with the binding constraint (9), the monopolist practices either limit pricing or accommodation to piracy.

Software Quality under the Limit Pricing Regime

With the piracy constraint (9) binding, the monopolist faces the following constrained profit maximization problem:

$$Max\ \pi^L = p^L F(\frac{p^L}{\theta}) - C(\theta)$$

Subject to

$$(1-\alpha)\theta v - c \le \theta v - p$$

Since the constraint is always binding under the assumption $\frac{c}{1-\alpha} < p^* = \theta^* v^*$, the optimal price $p^L = \frac{c}{1-\alpha}$, and profit is $\pi^L = \left(\frac{c}{1-\alpha}\right)\cdot F\left(\frac{c}{(1-\alpha)\theta}\right) - C(\theta)$.

The monopolist now determines the optimal choice of the software quality with the optimal limit price as following:

$$\underset{\theta}{Max}\,\pi^L = \left(\frac{c}{1-\alpha}\right)\cdot F\left(\frac{c}{(1-\alpha)\theta}\right) - C(\theta).$$

The first order condition

$$\frac{\partial \pi^L}{\partial \theta} = -\frac{c^2}{(1-\alpha)^2\theta^2} F'\left(\frac{c}{(1-\alpha)\theta}\right) - C'(\theta) = 0 \qquad (10)$$

determines the monopolist's optimal choice of software quality.

Proposition 7. Under the limit pricing regime, the monopolist chooses a lower level of quality than the one without piracy.

Proof. Let us evaluate the first order condition (10) at θ^* which is the level of quality without piracy.

$$\left.\frac{\partial \pi^L}{\partial \theta}\right|_{\theta^*} = -\frac{c^2}{(1-\alpha)^2(\theta^*)^2}F'\left(\frac{c}{(1-\alpha)\theta^*}\right) - C'(\theta^*)$$

We know that

$$-\frac{c^2}{(1-\alpha)^2(\theta^*)^2}\cdot F'\left(\frac{c}{(1-\alpha)\theta^*}\right) < \frac{c}{(1-\alpha)\ \theta^*}\cdot F\left(\frac{c}{(1-\alpha)\theta^*}\right) < v^* F(v^*)$$

The inequalities above follow from the fact that $vF(v)$ is a concave function which is maximized at v^* and our assumption that $\frac{c}{1-\alpha} < p^* = \theta^* v^*$. Thus, we have

$$\left.\frac{\partial \pi^L}{\partial \theta}\right|_{\theta^*} < v^* F(v^*) - C'(\theta^*) = 0,$$ which implies that $\theta^L < \theta^*$.

Software Quality under the Copying Regime

Under the copying regime consumers compare the payoffs from buying an authorized copy $[\theta \cdot v - p]$ or making an unauthorized copy $[(1-\alpha)\cdot\theta\cdot v - c]$. Given the purchase behavior of consumers, the monopolist maximizes his profit:

$$\max_{v,\theta}\ \tilde{\pi} = (\alpha\cdot\theta\cdot v + c)F(v) - C(\theta).$$

The first order conditions

$$\frac{\partial \tilde{\pi}}{\partial v} = (\alpha\theta\ v + c)F'(v) + \alpha\theta F(v) = 0 \tag{11}$$

$$\frac{\partial \tilde{\pi}}{\partial \theta} = \alpha\, vF(v) - C'(\theta) = 0 \tag{12}$$

again determine the marginal consumer $\tilde{v}$ and the software quality $\tilde{\theta}$.

Proposition 8. Under the copying regime the existence of piracy leads to a further underprovision of the software quality but more authorized usage.

Proof. Evaluating (11) at $v = v^*$ yields $(\alpha\theta\ v^* + c)F'(v^*) + \alpha\theta F(v^*) = cF'(v^*) < 0$. Hence we have $\tilde{v} < v^*$. Also, evaluating (12) at $v = v^*$ yields $-v^* F(v^*)(1-\alpha) < 0$ and therefore $\tilde{\theta} < \theta^*$.

The intuition underlying this result is the following. The choice of $\tilde{\theta}$ by the monopolist is determined by the marginal type $\tilde{v}$. At the development stage of the software the monopolist expects that the marginal consumer is not v^* but $\tilde{v}$ when there is piracy. Given this anticipation, the optimal choice of the software quality should be lower than the one from the benchmark case. As seen from Proposition 6, the software quality provision by the monopolist is already sub-optimally low $(\theta^* < \theta^{opt})$ even without the threat of piracy. The existence of piracy aggravates this inefficient provision of the software quality in both regimes. Our result thus lends theoretical support for the claim that piracy reduces the incentives to develop new software.

Comparative Statics

We now turn to analysis of the effects of marginal increase in IPRP on the monopolist's development incentive.

Proposition 9. Under the limit price regime, an increase in IPRP on both margins induce higher software quality and less authorized usage.

Proof. We can rewrite (10) as $c^2 F'(v) + (1-\alpha)^2 \theta^2 C'(\theta) = 0$. By totally differentiating the first-order condition, we have

$$2cF'(v)dc + (1-\alpha)^2 \theta^2 C''(\theta) d\theta + (1-\alpha)^2 2\theta C'(\theta) d\theta = 0.$$

$$\frac{d\theta}{dc} = -\frac{2cF'(v)}{(1-\alpha)^2 \theta [\theta C''(\theta) + 2C'(\theta)]} > 0.$$

By totally differentiating the first-order condition, we have

$$-2(1-\alpha)\theta^2 C'(\theta) d\alpha + (1-\alpha)^2 \theta^2 C''(\theta) d\theta + (1-\alpha)^2 2\theta C'(\theta) d\theta = 0$$

$$\frac{d\theta}{d\alpha} = -\frac{2(1-\alpha)\theta^2 C'(\theta)}{(1-\alpha)^2 \theta [\theta C''(\theta) + 2C'(\theta)]} > 0.$$

Also we can easily verify that

$$\frac{dv}{dc} = \frac{d\left(\frac{c}{(1-\alpha)\theta}\right)}{dc} = \frac{1}{(1-\alpha)\theta} > 0, \text{ and}$$

$$\frac{dv}{d\alpha} = \frac{d\left(\frac{c}{(1-\alpha)\theta}\right)}{d\alpha} = \frac{c}{(1-\alpha)^2 \theta} > 0.$$

The intuition underlying Proposition 9 is straightforward. In the limit pricing regime, the monopolist lowers his price until the constraint $(1-\alpha)\theta v - c \leq \theta v - p$ is binding to eliminate piracy. The maximum price he can charge under limit pricing is $p^L = c/(1-\alpha)$, which depends on the relative level of the degradation rate (α) and the reproduction cost (c). Increases in IPRP from either the degradation rate or the reproduction cost induce less authorized usage, which is equivalent to higher valuation from the marginal consumer v^L. This induces the monopolist to provide a higher quality.

Proposition 10. Under the copying regime the effects of increase in IPRP depend on the types of costs associated with piracy. Higher degradation rate induces higher quality and less legal usage. In contrast, higher reproduction cost results in lower quality and more authorized usage.

Proof. See Appendix A.

Table 2 summarizes our results. Since the monopolist's quality provision is determined by the marginal consumer's valuation for the software, the effects of increase in IPRP depend on the change of the marginal consumer, which is different according to types of costs associated with piracy. With higher reproduction cost, all consumers face the same increase in the gross copy cost, which is equivalent to overall demand increase for the monopolist. Hence, the monopolist benefits from higher demand by charging a higher price, yet increasing sales at the same time. Facing the marginal consumer's lower valuation, the monopolist has less incentive to provide higher quality. In contrast, if an increase in IPRP is derived from higher degradation rate, we observe proportional increase in the gross copy cost and comparatively more market power for the monopolist. With increase in market power, the monopolist charges a higher price by focusing on high valuation consumers. Responding to the marginal consumer's higher valuation, the monopolist has more incentive to supply higher quality. In the Appendix, we demonstrate our results by using an example with uniform distribution and quadratic cost function.

4. Concluding Remarks

In this paper, we develop a simple model of piracy to analyze implications of increased intellectual property rights on the short-run and long-run resource allocations. In a model of self-selection with heterogeneous users, we show that the consumers' option to use illegal copies constrains the copyright holder's ability to charge a monopoly price. Consequently, the possibility of piracy leads to more usage of legal copies. In this sense, the presence of unauthorized copies acts as a complement to the usage of legal copies rather than a substitute.

To analyze the effects of an increase in IPRP more precisely, we consider two types of costs associated with piracy; the type-independent *reproduction cost* and the type-dependent *degradation cost*. We provide a theoretical framework to show that the effects of piracy depend crucially on the nature of piracy costs. In particular, strengthening IPRP in the form of an increase in the degradation cost supports the conventional wisdom on IPRP. It reduces social welfare in the short-run by providing the monopolist with more market power, which results in both negative demand switch and total usage change. In the long-run, the monopolist facing a higher marginal consumer type has more incentive to provide higher quality. Thus, there is a trade-off between short-run and long-run efficiency. In contrast, an increase in the reproduction cost, induces more authorized usage of the software in the short-run. Even though an increase in IPRP with higher reproduction cost reduces the total usage of the software, more consumers obtain the software from the monopolist with more efficient technology. Therefore, an increase in the reproduction cost may increase or decrease social welfare in the short run. Moreover, due to the marginal consumer's lower valuation for the software, the monopolist has less incentive to provide higher quality in the long-run. Thus, we cannot rule out the case where an increase IPRP reduces social welfare both in the short-run and long-run. The results in the paper thus suggest that any policy implementation of IPRP should pay more attention to how the policy change will affect the two margins of piracy costs, not just the overall piracy costs.

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Appendix A: Proof of Proposition 10

By totally differentiating (11) and (12), we have

$$\begin{bmatrix} \frac{\partial^2 \pi}{\partial v^2} & \frac{\partial^2 \pi}{\partial v \partial \theta} \\ \frac{\partial^2 \pi}{\partial \theta \partial v} & \frac{\partial^2 \pi}{\partial \theta^2} \end{bmatrix} \begin{bmatrix} \frac{dv}{dc} \\ \frac{d\theta}{dc} \end{bmatrix} = \begin{bmatrix} -\frac{\partial^2 \pi}{\partial v \partial c} \\ -\frac{\partial^2 \pi}{\partial \theta \partial c} \end{bmatrix}.$$

By using Cramer's rule, we have

$$\frac{dv}{dc} = \frac{1}{|H|} \begin{vmatrix} -\frac{\partial^2 \pi}{\partial v \partial c} & \frac{\partial^2 \pi}{\partial v \partial \theta} \\ -\frac{\partial^2 \pi}{\partial \theta \partial c} & \frac{\partial^2 \pi}{\partial \theta^2} \end{vmatrix}, \text{ and } \frac{d\theta}{dc} = \frac{1}{|H|} \begin{vmatrix} \frac{\partial^2 \pi}{\partial v^2} & -\frac{\partial^2 \pi}{\partial v \partial c} \\ \frac{\partial^2 \pi}{\partial \theta \partial v} & -\frac{\partial^2 \pi}{\partial \theta \partial c} \end{vmatrix}.$$

where $|H| = \frac{\partial^2 \pi}{\partial v^2} \cdot \frac{\partial^2 \pi}{\partial \theta^2} - \left(\frac{\partial^2 \pi}{\partial v \partial \theta} \right)^2$ is the determinant of the Hessian matrix with $|H| > 0$

by the second-order condition for maximization.

$$\frac{dv}{dc} = \frac{1}{|H|} (F'(v) C''(\theta)) < 0.$$[18]

$$\frac{d\theta}{dc} = \frac{1}{|H|} \left(-\frac{c(F'(v))^2}{\theta} \right) < 0.$$[19]

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[18] It can be easily verified that $\frac{\partial^2 \pi}{\partial v \partial c} = F'(v) < 0$, $\frac{\partial^2 \pi}{\partial \theta^2} = -C''(\theta) < 0$, $\frac{\partial^2 \pi}{\partial \theta \partial c} = 0$, and

$$\frac{\partial^2 \pi}{\partial v \partial \theta} = \alpha\, v F'(v) + \alpha\, F(v) = -\frac{cF'(v)}{\theta} > 0.$$

By totally differentiating the first-order conditions, we have

$$\begin{bmatrix} \frac{\partial^2 \pi}{\partial v^2} & \frac{\partial^2 \pi}{\partial v \partial \theta} \\ \frac{\partial^2 \pi}{\partial \theta \partial v} & \frac{\partial^2 \pi}{\partial \theta^2} \end{bmatrix} \begin{bmatrix} \frac{dv}{d\alpha} \\ \frac{d\theta}{d\alpha} \end{bmatrix} = \begin{bmatrix} -\frac{\partial^2 \pi}{\partial v \partial \alpha} \\ -\frac{\partial^2 \pi}{\partial \theta \partial \alpha} \end{bmatrix}.$$

By using Cramer's rule, we have

$$\frac{dv}{d\alpha} = \frac{1}{|H|} \begin{vmatrix} -\frac{\partial^2 \pi}{\partial v \partial \alpha} & \frac{\partial^2 \pi}{\partial v \partial \theta} \\ -\frac{\partial^2 \pi}{\partial \theta \partial \alpha} & \frac{\partial^2 \pi}{\partial \theta^2} \end{vmatrix}, \text{ and } \frac{d\theta}{d\alpha} = \frac{1}{|H|} \begin{vmatrix} \frac{\partial^2 \pi}{\partial v^2} & -\frac{\partial^2 \pi}{\partial v \partial \alpha} \\ \frac{\partial^2 \pi}{\partial \theta \partial v} & -\frac{\partial^2 \pi}{\partial \theta \partial \alpha} \end{vmatrix}.$$

$$\frac{dv}{d\alpha} = -\frac{1}{|H|} F'(v) \left[\frac{c}{\alpha} C''(\theta) + \frac{cv}{\theta} F(v) \right] > 0.$$ [20]

$$\frac{d\theta}{d\alpha} = \frac{1}{|H|} \left[\frac{\partial^2 \pi}{\partial v^2} (-vF(v)) + \frac{c^2}{\alpha^2 \theta} \{F'(v)\}^2 \right] > 0.$$ [21]

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[19] It can be also easily verified that, $\frac{\partial^2 \pi}{\partial v^2} < 0$, $\frac{\partial^2 \pi}{\partial \theta \partial c} = 0$, $\frac{\partial^2 \pi}{\partial v \partial c} = F'(v) < 0$, and $\frac{\partial^2 \pi}{\partial \theta \partial v} = \alpha vF'(v) + \alpha F(v) = -\frac{cF'(v)}{\theta} > 0$.

[20] We have $\frac{\partial^2 \pi}{\partial v \partial \alpha} = \frac{-cF'(v)}{\alpha} > 0$, $\frac{\partial^2 \pi}{\partial \theta^2} = -C''(\theta) < 0$ $\frac{\partial^2 \pi}{\partial \theta \partial \alpha} = vF(v) > 0$, and $\frac{\partial^2 \pi}{\partial v \partial \theta} = \alpha vF'(v) + \alpha F(v) = -\frac{cF'(v)}{\theta} > 0$.

[21] We have $\frac{\partial^2 \pi}{\partial v^2} < 0$, $\frac{\partial^2 \pi}{\partial \theta \partial \alpha} = vF(v) > 0$, $\frac{\partial^2 \pi}{\partial v \partial \alpha} = \frac{-cF'(v)}{\alpha} > 0$, and $\frac{\partial^2 \pi}{\partial \theta \partial v} = vF'(v) + F(v) = -\frac{cF'(v)}{\alpha \theta} > 0$.

Appendix B: Uniform Distribution Example of the Software Quality

We now assume consumers' valuation for the software is uniformly distributed as $v_i \in U[0, 1]$. To make our analysis more tractable, we also suppose that the monopolist's cost of quality provision is given by $C(\theta) = \frac{k}{2}\theta^2$, where k is a cost parameter.

With uniform distribution we can easily verify Proposition 6 that the monopolist's optimal choice of the quality provision under the benchmark case is suboptimally low. Since the consumers' only decision is whether to purchase or not, the monopolist has the marginal consumer whose valuation $v^* = p/\theta$. Given this arrangement, the monopolist maximizes his profit:

$$\underset{v,\theta}{Max}\, \pi = \theta v(1-v) - \frac{k}{2}\theta^2 .$$

The first order conditions

$$\frac{\partial \pi}{\partial v} = \theta - 2\theta v = 0 \tag{A1}$$

$$\frac{\partial \pi}{\partial \theta} = v(1-v) - k\theta = 0 \tag{A2}$$

determine $v^* = \frac{1}{2}$ and $\theta^* = \frac{1}{4k}$.

Socially optimal level of quality can be derived by maximizing the aggregate valuation of consumers between $[1/2, 1]$, which is $Max \int_{1/2}^{1} \theta v dv - \frac{k}{2}\theta^2$. We have $\theta^{opt} = \frac{3}{8k}$, which is $\theta^{opt} \geq \theta^*$.

Now we turn to the monopolist's optimal choice of software quality with piracy. The monopolist's choice depends on how he responds to the threat of piracy. With two margins of IPRP [degradation rate (α) and copy cost (c)] the monopolist has two different strategies to choose.[22] First, we observe that the monopolist maximizes the constrained profit under the limit pricing regime as following:

$$Max\ \pi^L = p^L\left(1-\frac{p^L}{\theta}\right)-\frac{k}{2}\theta^2$$

subject to

$$(1-\alpha)\theta v - c \le \theta v - p$$

The optimal price $p^L = \frac{c}{1-\alpha}$, and profit is $\pi^L = \left(\frac{c}{1-\alpha}\right)\left(1-\frac{c}{(1-\alpha)\theta}\right)-\frac{k}{2}\theta^2$. The monopolist then chooses his optimal choice of quality by

$$\underset{\theta}{Max}\,\pi^L = \left(\frac{c}{1-\alpha}\right)\left(1-\frac{c}{(1-\alpha)\theta}\right)-\frac{k}{2}\theta^2.$$

The first order condition

$$\frac{\partial\pi}{\partial\theta} = \frac{c^2}{(1-\alpha)^2\theta^2} - k\theta = 0 \qquad \text{(A3)}$$

determines the optimal level of software quality for the monopolist. If we valuate the first-order condition at $\theta^* = \frac{1}{4k}$, we can verify that under the limit pricing regime, the monopolist chooses lower level of quality as the one without piracy.[23]

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[22] The consumers' optimal behaviors are the same as the short run case.

[23] With our assumption $\frac{c}{1-\alpha} < p^* = \theta^* v^* = \frac{1}{8k}$, we can verify the sign of (A3) at $\theta^* = \frac{1}{4k}$ as

$$16k^2\left(\frac{c^2}{(1-\alpha)^2}\right)-\frac{1}{4} = 16k^2\left(\frac{c}{1+\alpha}+\frac{1}{8k}\right)\left(\frac{c}{1+\alpha}-\frac{1}{8k}\right)<0.$$

For the last case where the monopolist chooses to allow piracy, the marginal consumer who is indifferent between buying and copying is given by $v = \dfrac{p-c}{\alpha\theta}$. With facing demand of $1 - \dfrac{p-c}{\alpha\theta}$, the monopolist's profit maximization problem is

$$Max\ (\alpha\theta\, v + c)(1-v) - \frac{k}{2}\theta^2.$$

The first order conditions

$$\frac{\partial \pi}{\partial v} = \alpha\theta(1-v) - (\alpha\theta v + c) = 0 \tag{A4}$$

$$\frac{\partial \pi}{\partial \theta} = \alpha\, v(1-v) - k\theta = 0 \tag{A5}$$

determine $\tilde{v} = \dfrac{\alpha\theta - c}{2\alpha\theta} = \dfrac{1}{2} - \dfrac{c}{2\alpha\theta}$, which is $\tilde{v} < v^*$. Also, if we evaluate $\tilde{\theta} = \dfrac{\alpha v(1-v)}{k}$ at $v^* = \dfrac{1}{2}$, we can verify $\tilde{\theta} = \dfrac{\alpha}{4k} < \theta^*$.

The effect of increased copyright protection on development incentives can be shown more clearly in the uniform distribution example. By totally differentiating (A3) we can show both types of increase in IPRP induces higher software quality and less authorized usage as the following:

$$\frac{d\theta}{dc} = \frac{2ck}{6(1-\alpha)^2\theta^2} > 0,\ \frac{dv}{dc} = \frac{d(\frac{c}{(1-\alpha)\theta})}{dc} = \frac{1}{(1-\alpha)\theta} > 0,$$

$$\frac{d\theta}{d\alpha} = \frac{2\theta)}{3(1-\alpha)} > 0, \text{ and } \frac{dv}{d\alpha} = \frac{d(\frac{c}{(1-\alpha)\theta})}{d\alpha} = \frac{c}{(1-\alpha)^2\theta} > 0.$$

Moreover, we can easily verify the effects of increase in IPRP under the copying regime: higher quality and less official usage with increased degradation rate, and lower quality and more authorized usage with increased reproduction cost. By totally differentiating (A4), (A5) and using Cramer's Rule we can present a simplified version of proposition 10 as follows:

$$\frac{dv}{dc} = \frac{1}{|H|}[-\frac{2}{k}] < 0, \quad \frac{d\theta}{dc} = -\frac{1}{|H|}[\alpha(1-2v)] < 0,$$

$$\frac{dv}{d\alpha} = \frac{1}{|H|}(1-2v)\left[\frac{2\theta}{k} + \alpha\, v(1-v)\right] > 0, \text{ and}$$

$$\frac{d\theta}{d\alpha} = \frac{1}{|H|}\alpha\,\theta[2v(1-v) + (1-2v)^2] > 0.$$

Table 1.

Comparative Statics Results in the Short Run

	Benchmark	**Limit Pricing**	**Copying Regime**
The monopolist's optimal choice	v^* p^*	v^L $(v^* > v^L)$ p^L $(p^L < p^*)$	$\tilde{v}$ $(v^* > \tilde{v})$ $\tilde{p}$ $(\tilde{p} < p^*)$
An increase in the reproduction cost	*N/C*	$\frac{\partial v^L}{\partial c} > 0$ and $\frac{\partial p^L}{\partial c} > 0$	$\frac{\partial \tilde{v}}{\partial c} < 0$ and $\frac{\partial \tilde{p}}{\partial c} > 0$
An increase in the degradation rate	*N/C*	$\frac{\partial v^L}{\partial \alpha} > 0$ and $\frac{\partial p^L}{\partial \alpha} > 0$	$\frac{\partial \tilde{v}}{\partial \alpha} > 0$ and $\frac{\partial \tilde{p}}{\partial \alpha} > 0$

Table 2.

Comparative Statics Results in the Long Run

	Benchmark	**Limit Pricing**	**Copying Regime**
The monopolist's optimal choice	$v*$ $p*$ $\theta*$	v^L $(v* > v^L)$ p^L $(p^L < p*)$ θ^L $(\theta^L < \theta*)$	$\tilde{v}$ $(v* > \tilde{v})$ $\tilde{p}$ $(\tilde{p} < p*)$ $\tilde{\theta}$ $(\tilde{\theta} < \theta*)$
An increase in the reproduction cost	*N/C*	$\frac{\partial v^L}{\partial c} > 0$ and $\frac{d\theta^L}{dc} > 0$	$\frac{\partial \tilde{v}}{\partial c} < 0$ and $\frac{d\tilde{\theta}}{dc} < 0$
An increase in the degradation rate	*N/C*	$\frac{\partial v^L}{\partial \alpha} > 0$ and $\frac{d\theta^L}{d\alpha} > 0$	$\frac{\partial \tilde{v}}{\partial \alpha} > 0$ and $\frac{d\tilde{\theta}}{d\alpha} > 0$

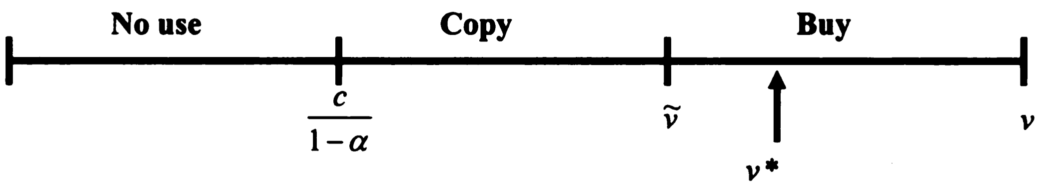
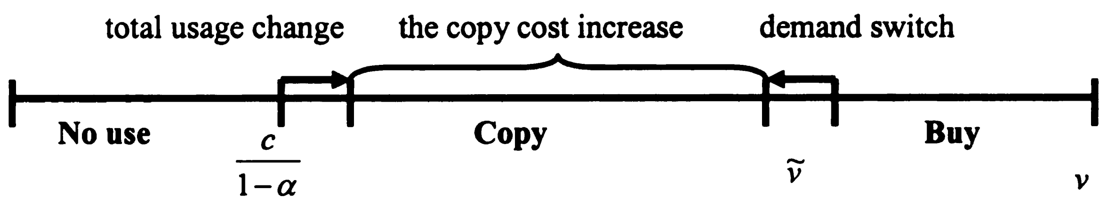
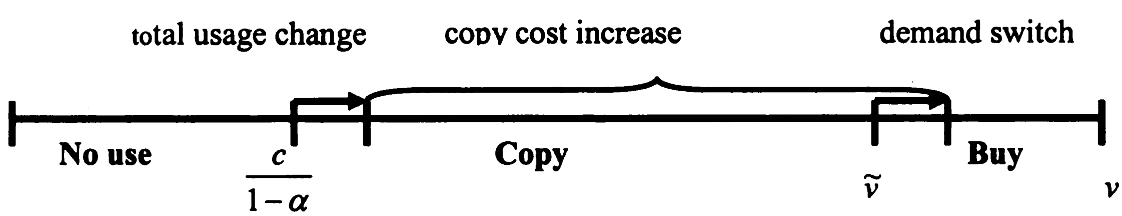


Figure 1. Consumers' Choice under Copying Regime



(a) Welfare effect of higher reproduction cost



(b) Welfare effect of higher degradation rate

Figure 2. Welfare Effect of the Two Margins of Piracy Costs

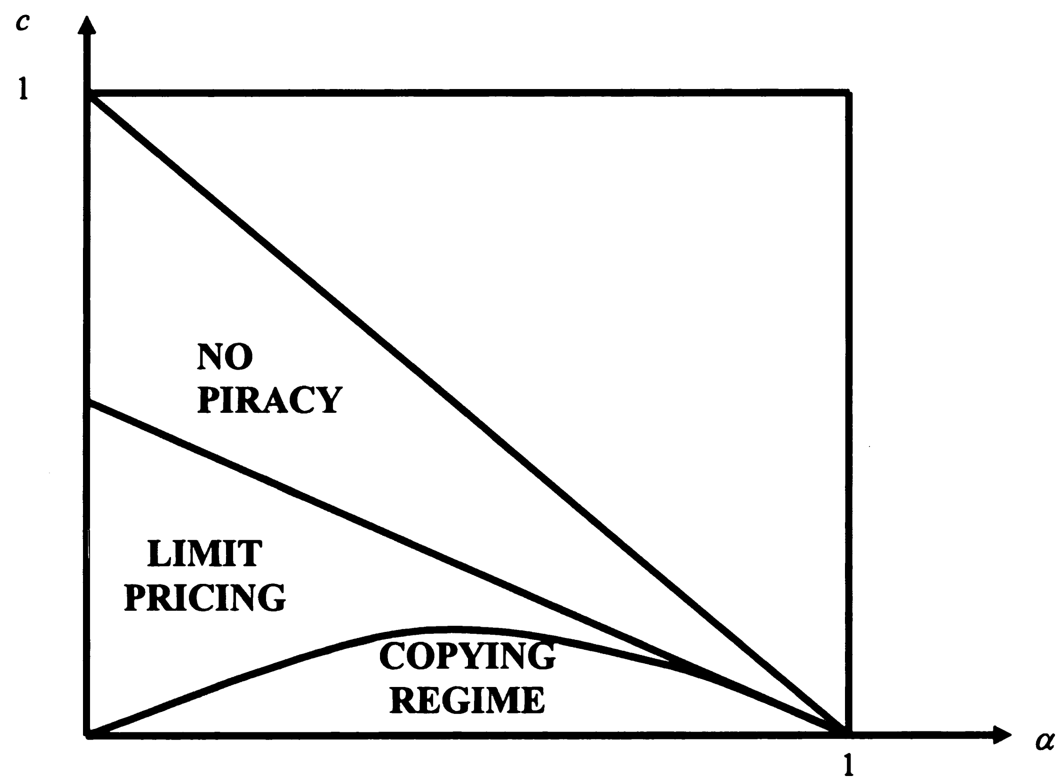
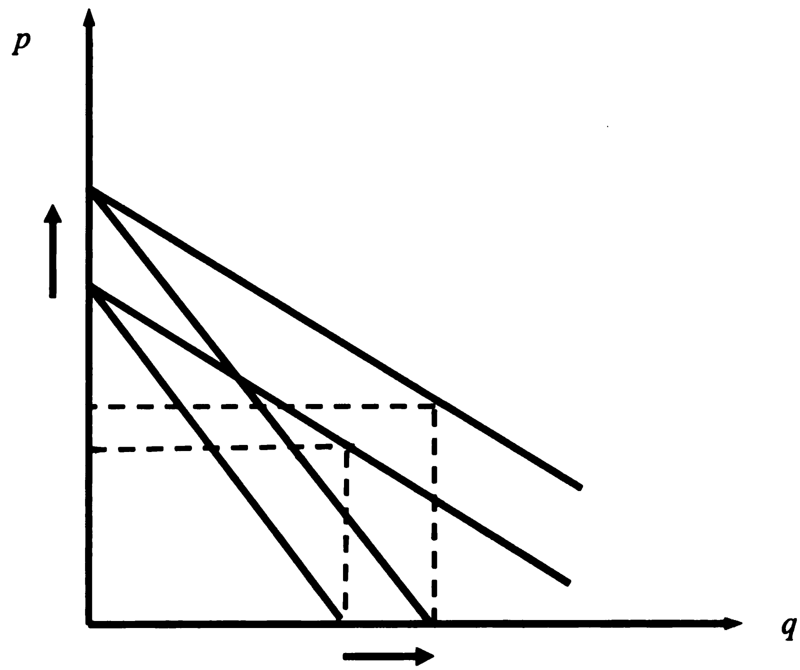
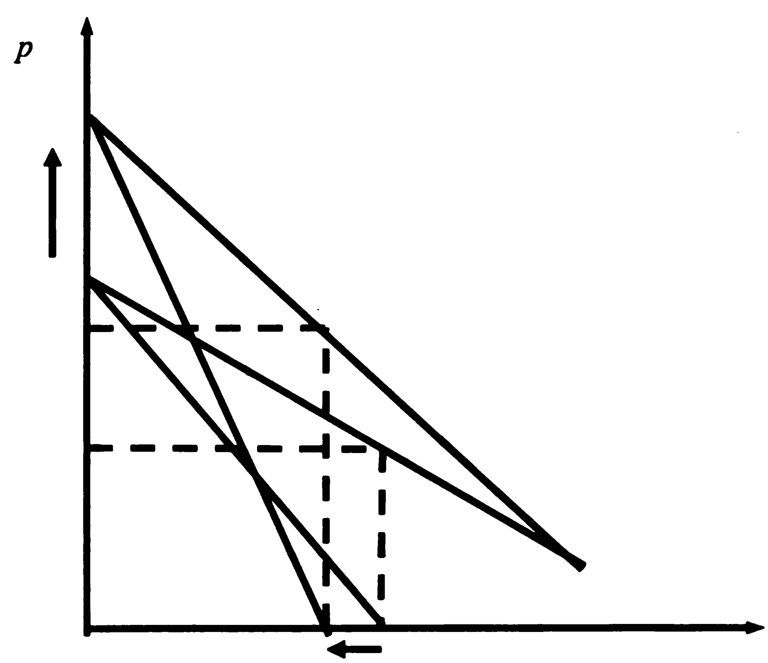


Figure 3. The Monopolist's Optimal Choice

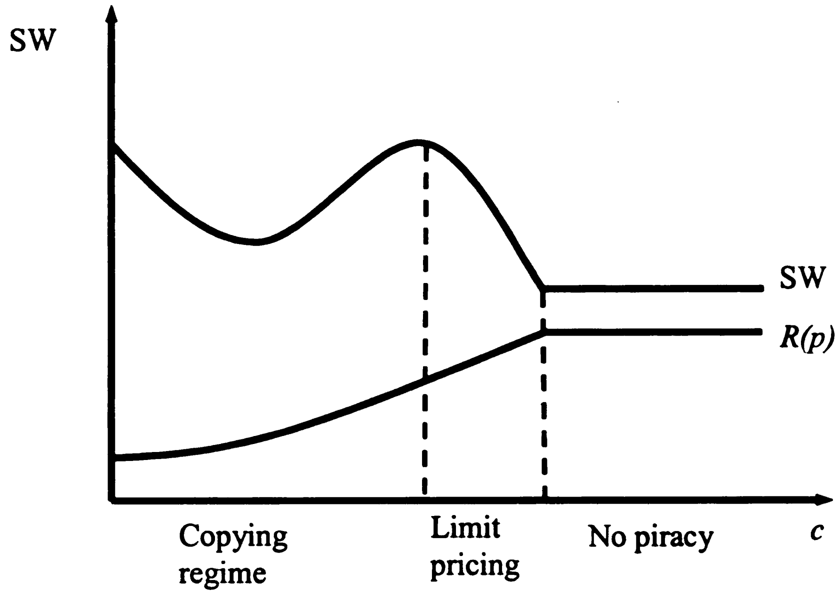


(a) The effect of reproduction cost increase

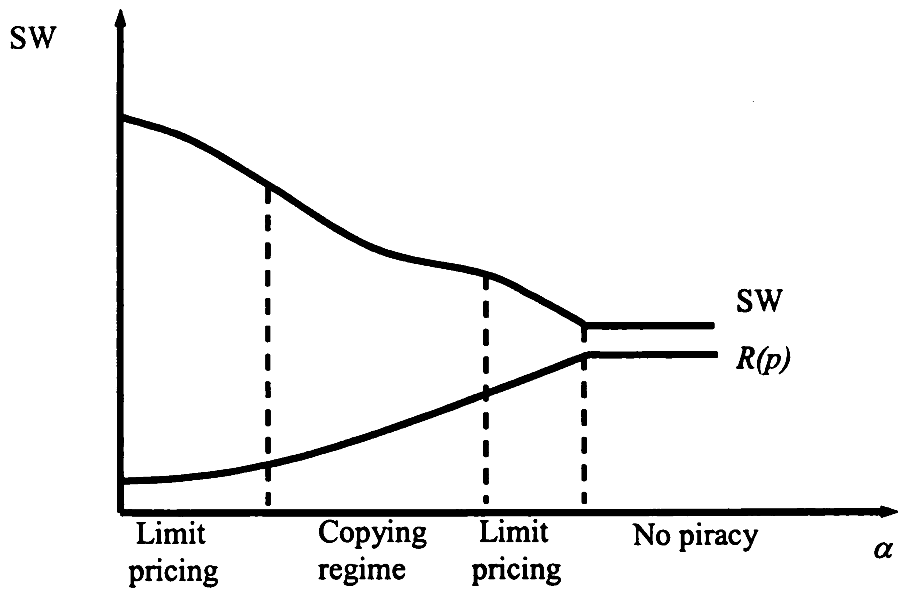


(b) The effect of the degradation rate increase

Figure 4. The Effects of an increase in IPRP with Linear Demand



(a) The effect of increase in the reproduction cost



(b) The effect of increase in the degradation rate

Figure 5. Welfare Effects in Uniform Distribution Example

CHAPTER 2

THE OPTIMAL NUMBER OF FRANCHISES WITH APPLICATION TO PROFESSIONAL SPORTS LEAGUES

1. Introduction

In recent years many issues about professional sport leagues have drawn economists' attention; the professional player's labor market, revenue sharing, relocation of franchises and public finance of stadiums and increasing ticket prices.[24] These peculiar phenomena are originated from the characteristics of professional sports industry. One of the most important aspects of the professional sport leagues is their monopoly, or cartel status. For decades, since player movement was restricted by the reserve clause, the leagues enjoyed absolute control over players. Even the control over the labor market has weakened, the leagues have developed more extraordinary control over the rest of professional sport leagues.[25] As the salary of players has been increased, the leagues are looking for another sources of revenues. They played strategic games with local governments about relocation of teams unless the local government provides subsidy for a new stadium or renovation for old stadiums. They increased ticket prices from new stadiums or renovation of old stadiums with public finance.

This paper constructs a model regarding a league cartel's optimal choice of the number of franchises and ticket pricing. The innovation in this paper is to distinguish

[24] See Cairns et al (1986), Fort and Quirk (1995), Kahn (2000), Vrooman (2000) for excellent survey in the sport literature.
[25] Starting in 1970s, athletes in the four major sports began to gain some degree of freedom of movement by introducing some form of free agency. After serving a team for a certain period, a player can be a free agent, in which he can sell his services to the highest bidder and, as a result, salaries have been increased. However, even with free agency there remain residual restrictions on player movement and open bidding,

two types of cartel associated with its control over franchises' ticket pricing and to show the optimal number of franchises depends crucially on the nature of a cartel. To comment briefly on the two types of cartel, we first assume there is a *cartel with full collusion* in which it has absolute control over the number of franchises as well as ticket pricing. For example, we can think of an exclusive territorial franchise that is assigned to the owner of each member team in the league.[26] In this case a cartel with full collusion is able to determine the number of franchises and enforce franchises not to undercut the ticket price. The second type of cartel we consider is *semi-collusive cartel* in which it controls only the number of franchises and ticket pricing is independently determined by each franchise in non-cooperative behavior. In the first stage the league cartel selects the number of franchises with consideration there exists trade-off between reduction of distance cost and increase in fixed cost. On the other hand, if the league cartel is not able to prevent franchises to cut their ticket below the collusive level, any franchise has an incentive to deviate. As one of franchises undercuts ticket price given the rest still stick to the collusive price, the franchise's profit will increase by taking customers away from his neighboring franchises. It is because demand of each franchise is limited by the league cartel to maximize joint profits. Since the franchise sells his ticket at lower price to inframarginal consumers to increase ticket sales, for the league cartel it will reduce joint profit. However, the semi-collusive league cartel is capable of choosing the optimal number of franchises. It should be the case in which the league cartel increases the

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such as initial assignments of players to particular teams and required years of service to reach free-agent status.

[26] In the NFL, for example, a team's territory is that contained within a seventy-five-mile radius of the team's home field.

distance between franchises by choosing smaller number of teams until each franchise becomes a local monopoly.[27]

The purpose of this study is to analyze the cartel's optimal choice of the number of franchises with adaptation of a' la Salop's (1979) circular city model. In such a framework, we conduct two-step analyses. In the first part of analysis, we investigate how the degree of control over franchises determines the league cartel's optimal choice. Depending on the degree of control, the league is shown to choose different number of franchises, and we compare the outcomes to the socially optimal and free entry ones.

The second part of analysis examines the league's strategic advantage of leaving a few cities vacant, which will be used as a leverage to exploit more consumer surplus. To serve this purpose, we construct a model with finite number of separated markets. In each market a franchise operates as a local monopolist and does not compete with one another to attract consumers from neighboring franchises. With a bidding mechanism designed to maximize the league's joint profit, the optimal choice of the number of franchise is shown that the league does not provide franchises to cover the entire markets and rather leaves a few cities vacant, which can be used as a leverage to receive subsidy from state and local governments. Leaving a few cities without a franchise team makes the vacant cities want to bid for a team.[28] In fact, it explains one of the most important issues in professional sports league; why do local and state governments pay for stadiums while franchises receive all or almost all of revenues? Beside the fact that the league already uses the most basic aspect of monopoly, which is to restrict the quantity supplied

[27] In the case of Korea Baseball Organization (KBO) the ticket price was set by the league until 2002. However, in the beginning of 2003 season, each franchise is able to determine own ticket price schedule.

to increase ticket price, now the league is able to extract more consumer surplus from not serving the entire markets. By doing this, the league makes teams enable to extract subsidies from communities that might otherwise enjoy considerable surplus from a hosting a franchise even they charge monopoly price.

Previous papers concerned with the optimal choice of number of franchises in professional sports leagues include Vrooman (1997b) and Fort and Quirk (1995) among others. Vrooman (1997b) analyzes the optimal size of a league explicitly on analogy of Buchanan's (1965) theory of clubs. He shows that if each franchise has an interest in maximizing league's total revenue, franchises should expend to the point in which average revenue of franchises is maximized. Also, the optimal number of franchises is smaller than the socially optimal choice, which maximizes total franchises revenue. Our paper, in contrast, allows two different types of cartel according to the control over franchises and compares the outcomes in both scenarios to the socially optimal and free entry outcomes.[29]

Fort and Quirk (1995) also provide historic evidence of the league's expansion choice with the threat of entry of a new league. However, there is no theoretical framework to explain the mechanism of the expansion choice or the optimal choice of the league. Our paper, in contrast, is able to provide a theoretical framework by adopting Salop's circular city model.

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[28] In the case of Major League Baseball, the vacant cities would be Washington D.C., Las Vegas, Sacramento and Portland, Oregon even these cities have enough demand for a Major League Baseball team.

[29] Cyrenne (2001), as in our paper, compare the non-cooperative outcome to the socially optimal outcomes. However, he compares the optimal number of games in a season, not the optimal number of franchises according to the consumers' both the absolute and relative quality of game.

The remainder of this paper is organized as follows. Section 2 sets up the basic model and analyzes the two-stage game of the complete and intermediate league cartel, in which the optimal number of franchises is determined. I compare it with the socially optimal number of franchise and one from the free entry case. In section 3, I provide a model in which it analyzes the mechanism of relocation game of the league. Section 4 contains concluding remarks. In appendix, I extend the analysis to the case where the average quality of each franchise is inversely related to the number of franchises due to diluted talent pool.

2. The Optimal Number of Franchises

To examine the league cartel's entry decision with differentiated product, we use the circular city model a\` la Salop (1979). Fans are located uniformly on a circle with a perimeter equal to 1. Teams are located equidistant from each other, that is, if there are n franchises, the distance from one team to the next one is $1/n$. The location of fans in the circular city model represents their fan royalties for an ideal team, suffering disutility from choosing a variant that differs from their ideal. Fans want to buy one unit of the good, such as a seasonal ticket, and have a cost per unit of distance t. Their reservation value for the ticket of their ideal team is given by v. They will buy a ticket from the team that offers the lowest generalized cost (ticket price + transportation cost) if it does not exceed their reservation value. To analyze the issue of the number of franchises, we assume that there is a fixed cost F when a franchise decides to enter the league. In addition, each franchise faces an identical marginal cost c of serving consumers.

Therefore, franchise i's profit is $(p_i - c)q_i - F$ if it enters and sells to q_i consumers at the price of p_i, and 0 otherwise.

To facilitate the analysis below, we first consider the optimal pricing problem for a local monopoly that does not face any competition as a benchmark. If a monopolistic franchise charges a price of p, the marginal consumers who are indifferent between buying a ticket and not buying are located at the distance $x = (v - p)/t$ away from the franchise. Thus, the demand for the local monopoly is given by $2x = 2(v - p)/t$. This implies that the monopoly franchise i sets ticket price as $p^m = \frac{v+c}{2}$. The demand for monopoly is given by $q^m = \frac{v-c}{t}$ and its profit is $\pi^m = \frac{(v-c)^2}{2t} - F$. To have a meaningful analysis, we need to make the following assumption to ensure that the local monopoly is profitable.

Assumption 1. $v - c > \sqrt{2tF}$

We now analyze two cases depending on the degree of the sports league's control over the conduct of franchises.

Cartel with Full Collusion

Consider a situation where the cartel has complete control over franchises, that is, the cartel chooses the number of franchises in the first stage and franchises coordinate their prices to maximize their joint profits in the second stage. For analytical simplicity, we ignore the integer constraint and treat the number of franchises (n) as a continuous variable. With the assumption of continuous n and assumption 1, it is obvious that the whole market will be covered in the case of full collusion.

Lemma 1. A critical consumer who is indifferent between purchasing from team i and purchasing i's closest neighbor does not get any consumer surplus.

Proof. Suppose not. Then, the cartel can increase the prices of *both* franchises by the amount of the critical consumer's surplus and can increase the total profit since there will be no change in the amount of demand for both franchises.

With the help of Lemma 1, we can easily calculate the optimal number of franchises for the fully collusive case. We proceed by backward induction. In the second stage without a threat of price cut by its neighbor franchises, each franchise charges the maximum price given the market shares. Since franchise i sets price such that an indifferent consumer $\tilde{x}_i^c = \dfrac{v - p_i^c}{t}$ is located at the end of his territory, price and demand for franchise i is

$$p_i^c = v - \frac{t}{2n^c} \text{ and } q_i^c = 2\tilde{x}_i^c = \frac{1}{n^c}.$$

Profit of franchise i is given by $\pi_i^c = (p_i^c - c)q_i^c - F = (v - \dfrac{t}{2n^c} - c)\dfrac{1}{n^c} - F$. Once franchises choose their collusive price in the second stage, the cartel select the optimal number of franchises. The fully collusive cartel chooses n^c such that

$$\underset{n^c}{Max}\ n^c \pi_i^c = n^c[(v - \frac{t}{2n^c} - c)\frac{1}{n^c} - F]. \tag{1}$$

Thus, the optimal number of franchises for the league with full collusion is $n^c = \sqrt{\dfrac{t}{2F}}$.

Semi-Collusive Cartel without Price Control

We now consider a *semi-collusive* league cartel that does not have a complete control over franchises' pricing behavior. It is only capable of choosing the optimal number of franchises in the first stage. By considering the second stage first, given the number of franchises n^{sc}, each franchise faces demand of $q_i^{sc} = \frac{1}{t}(p_j^{sc} + \frac{t}{n^{ic}} - p_i^{sc})$ and profit of franchise i is given by

$$\pi_i^{sc} = (p_i^{sc} - c)q_i^{sc} - F = (p_i^{sc} - c)\frac{1}{t}(p_j^{sc} + \frac{t}{n^{sc}} - p_i^{sc}) - F.^{30} \tag{2}$$

Therefore, each franchise sets his price as $p^{sc} = c + \frac{t}{n^{sc}}$. In the first stage, the semi-collusive league cartel should choose the optimal of franchises n^{sc} so that it maximizes its joint profit, where the joint profit is given by $\Pi^{sc} = n\pi_i^{sc} = \frac{1}{n^{sc}} - n^{sc}F$. The first order condition with respect to n^{sc}, however, is negative for all positive n^{sc}, implying that reducing the number of franchises increases the joint profit. There are two reasons for this; it alleviates price competition among franchises and reduces the aggregate fixed cost. It means that the semi-collusive league cartel is able to increase the joint profit by reducing the number of franchises. We thus conclude that the semi-collusive league cartel increases distance between franchises by choosing smaller number of teams until

[30] n^{sc} denotes the number of franchises in an intermediate league cartel case.

each franchise becomes local monopoly. More precisely, the semi-collusive league cartel chooses the optimal number of cartel as $\frac{1}{n^{sc}} = q^m = \frac{v-c}{t}$; the optimal number of franchises for the semi-collusive league cartel is $n^{sc} = \frac{t}{v-c}$.[31]

Under assumption 1, we have $n^c = \sqrt{\frac{t}{2F}} = \frac{t}{\sqrt{2tF}} > \frac{t}{v-c} = n^{sc}$. Thus, we have the following proposition.

Proposition 1. Without control over franchises' ticket pricing, the semi-collusive league cartel provides a smaller number of franchises than the fully collusive cartel with price control ($n^{sc} < n^c$).

The intuition for Proposition 1 can be explained in the following way. Each franchise's pricing decision is constrained by either the *competition margin* or the *reservation value margin*. That is, the marginal consumers for each franchise are those who are indifferent between purchasing from it or purchasing from its neighbor (competitive margin binding) or those who are indifferent between purchasing from it or not purchasing (reservation margin binding). When the market is covered and the cartel has no control over individual franchises' pricing decision, the binding constraint is the competitive margin. In such a case, reducing the number of franchises relaxes price competition and saves on fixed costs without affecting the reservation value margin. The semi-collusive cartel will reduce the number of franchises until the competition margin is

[31] In this case the semi-collusive league cartel fill the market without market gap. With the assumption of continuous *n*, it is never optimal to leave a gap in the market. However, in section 3, we consider the case where the league strategically leaves some markets vacant to play a strategic game with local governments.

not binding. With the optimal number of firms (n^{sc}), the competition margin is not binding and the only constraint is the reservation value margin, which implies that every franchise is local monopoly under the semi-collusive regime. Under the fully collusive cartel regime, the league is never bound by the competition margin and does not need to reduce the number of franchises to relax competition between franchises.

Free entry

Now we consider free entry case in which there is no entry barrier except fixed cost. It makes any potential franchise enters the league whenever his profit is greater than fixed cost. Two-stage game is considered. In the first stage potential franchises simultaneously choose whether or not to enter. As in Salop's model, we assume that franchises do not choose their locations, but they are located the same distance form each other. By backward induction, each franchise sets ticket price to maximize its profit given distance between franchises. Suppose that franchise i chooses ticket price as p_i^f and there exists a fan who is indifferent between buying a ticket form franchise i and buying a ticket from its neighbor franchise j if $v - t\tilde{x} - p_i = v - t(\frac{1}{n^f} - \tilde{x}) - p_j$. In this case franchise i's demand is $q_i^f = 2\tilde{x}_i^f = \frac{1}{n^f}$ and he sets ticket price to maximize its profit $\pi_i^f = (p_i^f - c)q_i^f - F = (p_i^f - c)\frac{1}{t}(p_j^f + \frac{t}{n^f} - p_i^f) - F$. Therefore, each franchise sets price as $p_i^f = c + \frac{t}{n^f}$. In the first stage, potential franchises enter the league until $\pi_i^f = (p_i^f - c)\frac{1}{n^f} - F = 0$. The equilibrium number of franchises with free entry is $n^f = \sqrt{\frac{t}{F}}$.

Social Optimum

When there are n^s franchises at distance of $\frac{1}{n^s}$ apart from its neighbor franchise and they all sell products at price of p^s, total surplus generated by franchise i is

$$s(n^s) = 2\int_0^{\frac{1}{2n^s}} (v - p_i^s - tx)dx + \frac{p_i^s}{n^s} - \frac{c}{n^s} - F = \frac{v}{n^s} - \frac{p_i^s}{n^s} - t(\frac{1}{2n^s})^2 + \frac{p_i^s}{n^s} - \frac{c}{n^s} - F \qquad (3)$$

From the above total surplus of one franchise, we have the total surplus in a n^s-franchise league as $S(n^s) = n^s s(n^s) = v - \frac{t}{4n^s} - c - n^s F$. Maximization with respect to n^s yields the socially optimal number of franchises $n^s = \sqrt{\frac{t}{4F}}$.

Comparison

We now compare the optimal number of franchises under different regimes to the socially optimal one and the one that prevails under free entry condition.

Proposition 2. With complete control over pricing behavior of franchises, the league provides a larger number of franchises than the socially optimal one, but a smaller number of franchises than free entry one ($n^s < n^c < n^f$).

Proof. A simple comparison of expressions for $n^s = \sqrt{\frac{t}{4F}}$, $n^c = \sqrt{\frac{t}{2F}}$, and $n^f = \sqrt{\frac{t}{F}}$.

The discrepancy in choices between the fully collusive league cartel and the social planner can be explained by Spence's (1975) intuition for the monopolistic provision of quality, if we interpret the number of franchises as quality since more franchises imply better match between preferences of consumers and franchise locations. As Spence (1975, 1976) has pointed out, the fully collusive cartel's incentive to establish an additional franchise is related to the marginal increase in gross utility for the *marginal* consumer whereas the social planner's incentive depends on the marginal increase in gross utility for the *average*. In our model, the marginal consumers gain more than the average consumer in gross utilities as the number of franchises increases. More specifically, by increasing the number of franchises by Δn, the marginal consumer's transportation cost decreases by $\frac{d(t/2n)}{dn} = -\frac{t}{2n^2}$. The average transportation cost is given by $\frac{\int_0^{t/2n} tx dx}{(1/2n)} = \frac{t}{4n}$, which implies that the average consumer's transportation cost decreases by $\frac{d(t/4n)}{dn} = -\frac{t}{4n^2}$. Thus, the marginal impact of increasing the number of franchises on gross utility is greater for the marginal consumer than the average consumer. As a result, the fully collusive cartel supplies more franchises than the socially optimal level.

When the cartel is semi-collusive and does not have control over franchises' pricing, we know that it establishes less number of firms than the fully collusive cartel to eliminate price competition among franchises. However, the number of franchises can be either larger or smaller than the socially optimal choice [see figure 2].

Proposition 3. The comparison between the number of franchises under semi-collusive cartel (n^{SC}) and socially optimal one (n^{S}) depends on parameter values. If $v-c>\sqrt{4tF}$, $n^{S}>n^{SC}$. Otherwise, $n^{S}<n^{SC}$.

Proof. A simple comparison of expressions for n^{S} and n^{SC} proves the proposition.

A corollary of Proposition 3 is that if $v-c<\sqrt{4tF}$, it would be welfare improving not to allow price coordination for the league since $n^{S}<n^{SC}<n^{C}$; such a policy would induce the cartel to choose the number of franchises more aligned with the socially optimal one. If $v-c>\sqrt{4tF}$, however, such a policy would overshoot the target (n^{S}) and its welfare implication is ambiguous.

3. Franchise Relocation Game

In this section, we extend the analysis to consider the possibility that the league can play a relocation game with local or state governments. In particular, we examine the strategic advantage of leaving a few cities vacant, which will be used as a leverage to exploit more consumer surplus. To this end, we depart from the circular model and assume that there are N separate potential markets where franchises can be located. Each franchise operates as a local monopolist in each market and does not compete with one another to attract consumers from other markets. As before, we assume that consumers with reservation value of v are uniformly distributed around each franchise in each market. We assume that the length of each market is assumed to be more than $q^m = \frac{v-c}{t}$, which means that the size of each market does not constrain the monopolist's pricing behavior.

Identical Markets

We consider the case where every market is identical in terms of consumers' reservation value v. With each firm being local monopoly in each market, there is no distinction between the full and semi-collusive cartels. If the league sets up franchises in every market, the joint profit is given by

$$N\pi^m = N\left[\frac{(v-c)^2}{2t} - F\right]. \tag{4}$$

Now consider the possibility that the league vacates some markets with a strategic motive to extract consumer surplus by playing a relocation game with local government officials. We assume that a local government maximizes consumer surplus of citizens in its jurisdiction. Note that the consumer surplus in each market due to the existence of franchise is given by $CS = 2\int_0^{\frac{v-c}{2t}} (\frac{v-c}{2} - tx)dx = \frac{(v-c)^2}{4t}$. This implies that a local government without any franchise is willing to provide a subsidy of up to $\frac{(v-c)^2}{4t}$ to attract a franchise located elsewhere. Since it takes only one vacant market to extract such a subsidy, the optimal strategy for playing a relocation game is to install (N–1) franchises. In such a case, the cartel's joint profit is given by

$$(N-1)[\pi^m + CS] = (N-1)\left[\frac{(v-c)^2}{2t} - F + \frac{(v-c)^2}{4t}\right] \tag{5}$$

A comparison of equations (4) and (5) yields the following proposition.

Proposition 4. With identical markets with $N \geq 3$, the cartel's optimal strategy is to leave one market without franchise to extract consumer surplus as a subsidy in the rest of the markets.

Asymmetric Markets

We now consider the case where markets are asymmetric in terms of consumers' reservation value v_i. Without loss of generality, we assume that v_i is decreasing in *i*. In this case, it is possible that the league's optimal strategy is to leave more than one market without franchises since the subsidy the league can collect will depend on consumer surplus in the vacant market with the highest v_i. More precisely, when there are *m* (< *N*) franchises, the joint profit is given by

$$\left(\sum_{i=1}^{m}\pi_i^m\right) + m(CS_i) = \left(\sum_{i=1}^{m}\frac{(v_i-c)^2}{2t} - F\right) + m\left[\frac{(v_{m+1}-c)^2}{4t}\right]. \tag{6}$$

Proposition 5. With asymmetric markets, the cartel's optimal number of franchises n^* is given by

$$n^* = \underset{m \le N}{\arg\max} \left(\sum_{i=1}^{m} \pi_i^m \right) + m(CS_i) = \left(\sum_{i=1}^{m} \frac{(v_i - c)^2}{2t} - F \right) + m\left[\frac{(v_{m+1} - c)^2}{4t} \right], \text{ where}$$

v_{m+1} is taken to be c when $m = N$.

4. Concluding Remarks

In this paper we develop a simple model of the choice of league cartel about the number of franchises. I examine the optimal choice of the league cartel with various degree of control over franchises' ticket pricing, the socially optimal, and the free entry case based on Salop's circular city model. I conclude that the semi-collusive league cartel provides a smaller number of franchises than the fully collusive cartel. Since the semi-collusive league cartel cannot control ticket prices, it has to choose a smaller number of franchises to eliminate price competition. Second, the fully collusive league cartel chooses a larger number of teams compare to the socially optimal one. The league cartel's choice is based on the consideration between the surplus of the marginal fan and the fixed cost. On the other hand, the social planner's choice is based on the average surplus of fans. Therefore, the league cartel oversupplies variety of team to maximize its joint profits.

In the last part of this analysis, we examine the league's decision of the number of franchises when relocation game is considered. In this case the league's choice of the optimal number of franchises will be smaller than one with covering entire market. The main force behind this scheme is the league is able to use vacant cities as leverage to extract more consumer surplus. In addition to the fact that consumers with a franchise face a higher ticket price with a local monopoly, consumer's who has low valuation for a team cannot enjoy the benefit from hosting a team in their hometown when we consider asymmetric markets.

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Appendix C: The Optimal Number of Franchises With Endogenous Quality

In this section, we extend the basic analysis in section 2 by allowing that fans' reservation value is determined by the average quality of franchises, which is endogenously determined by the number of teams in the league. More specifically, we imagine a situation where franchises use inputs whose supplies are fixed in the economy. For instance, the talent pools for athletes and prime locations for stores are limited in supply. If we assume that the best athletes play for the league, increasing the number of franchises would dilute the talent pool and reduce the average quality of franchises.

To model such a situation, suppose that each franchise's roster needs α players to play a game. This implies that the top αn players will play in the league if there are n franchises. Let us assume that the athletic talent/skill in the economy is distributed with a cumulative distribution $G(s)$ with a support of $[\underline{s}, \bar{s}]$, where s denotes skill level. We normalize the population in the economy at 1. Then, all athletics with the skill level higher than s* will play for the league, where s* is defined by $G(s^*) = 1 - \alpha n$. We further assume that athletes are randomly assigned to a team and the average quality of a franchise is given by $v = E[s|s \geq s^*] = \int_{s^*}^{\bar{s}} sdG/\alpha n$, where $G(s^*) = 1 - \alpha n$. Since the critical skill level s^* is decreasing in n, a higher number of franchises imply a lower average quality of franchises.

To derive a closed form solution, we simplify the analysis by assuming a uniform distribution of athletic talent/skill. More specifically, we assume that s is uniformly distributed on [0, 1]. Then, the average quality of franchise is given by $v = \frac{1}{\alpha n} \int_{1-\alpha n}^{1} sds$.

Therefore, if we have n franchises in the league, the average quality of a franchise is $v(n) = 1 - \frac{\alpha n}{2}$.[32]

Quality of Franchise with Fully Collusive Cartel

With consideration of quality of franchises, the league cartel with full collusion chooses the optimal number of franchises in the first stage, which automatically determines the average quality of franchises. The second stage follows to maximize their joint profits by colluding ticket prices. By backward induction, in the second stage each franchise maximizes its profit given the market share and the average quality. It is because the cartel league already chooses n^c franchises, which in turn determine fans' reservation value. To maximize the league's joint profit, each franchise should charge ticket price as the same manner as without quality choice case. Since franchise i sets price such that an indifferent consumer $\tilde{x}_i^c = \frac{2 - \alpha n^c - 2p_i^c}{2t}$ is located at the end of its territory, price and demand of franchise i is

$$p_i^c = 1 - \frac{\alpha}{2} n^c - \frac{t}{2n^c} \text{ and } q_i^c = 2\tilde{x}_i^c = \frac{2}{t}(1 - \frac{1}{2}\alpha n^c - p_i^c) = \frac{1}{n^c}.$$

Franchise i's profit becomes

$$\pi_i^c = (p_i^c - c)q_i^c - F = (1 - \frac{\alpha}{2} n^c - \frac{t}{2n^c} - c)\frac{1}{n^c} - F. \tag{A1}$$

[32] Considering the average quality of franchises as the average of the sum of each athlete's quality such as $v = \frac{1}{n} \int_{1-\alpha n}^{1} s ds$, the results in the section still hold.

As the result of collusive ticket pricing in the second period, the league cartel chooses n^c to maximize its joint profits in the first stage:

$$\underset{n^c}{Max}\ n^c \pi_i^c = n^c(1 - \frac{\alpha}{2}n^c - \frac{1}{2n^c} - c)\frac{t}{n^c} - n^c F. \tag{A2}$$

Thus, the optimal number of franchises for the league cartel with full collusion is $n^c = \sqrt{\frac{t}{2F+\alpha}}$.

Quality of Franchise with Semi-collusive Cartel

We now calculate the optimal number of franchises of the semi-collusive league cartel that does not have a complete control over ticket pricing: it is only capable of choosing the number of franchises in the first stage. With the same logic applied for the semi-collusive cartel without quality of franchises in section 2, we observe that the joint profit of the semi-collusive cartel increases by reducing the number of franchises. Consequently, the optimal number of franchises in the case of semi-collusive cartel is determined by increasing each franchise's territory until it becomes a local monopoly. To calculate the optimal number of franchises let us start with profit maximization problem faced by a local monopoly. One additional figure we need to consider with endogenous quality is q_i^m decreases as more franchises enter the market. With inverse relationship between the number and quality of franchises, there is an indifferent consumer, $\tilde{x}^m = \frac{2 - \alpha n^{sc} - 2c}{4t}$, who is located at the end of local monopoly's territory. More specifically, by increasing the number of franchises by Δn, the indifferent consumer decreases by $\frac{\partial \tilde{x}^m}{\partial n} = -\frac{\alpha}{4t}$, which implies that the semi-collusive league cartel can achieve his maximum level of joint profit by reducing less number of franchises compared to the choice without quality of franchises.

As same as the previous local monopoly without quality choice, a monopolistic franchise charges p^m such that his demand is given by $q_i^m = 2\tilde{x}_i^m = \frac{2}{t}(v(n^{sc}) - p_i^m)$ if there are n^{sc} local monopolists in the market. After maximizing the monopoly profit, it sets ticket price as $p_i^m = \frac{v(n^{sc}) + c}{2}$ and its profit is $\pi_i^m = \frac{(v(n^{sc}) - c)^2}{2t} - F$. Similar to assumption 1 the profit of the local monopoly with quality of franchises is nonnegative if and only if the following profitability condition is satisfied.

Assumption A1. Profitability condition

$$v(n^{sc}) - c \geq \sqrt{2tF}$$

When assumption A1 is satisfied, we thus conclude that the semi-collusive league cartel chooses the optimal number of franchises as $\frac{1}{n^{sc}} = q^m = \frac{v(n^{sc}) - c}{t}$: the optimal number of franchises for the semi-collusive league cartel is $n^{sc} = \frac{t}{v(n^{sc}) - c}$.[33]

Under assumption A1, we have

$$n^c = \sqrt{\frac{t}{2F + \alpha}} = \frac{t}{\sqrt{2tF + \alpha t}} < \frac{t}{\sqrt{2tF}} > \frac{t}{v(n^{sc}) - c} = n^{sc}.$$

Proposition A1. Without control over franchises' ticket pricing, there is possibility that the semi-collusive league cartel even provides larger number of franchises compared to the league cartel's choice with full collusion.

One explanation for proposition A1 can be presented as follows. When the market is covered in the case of the semi-collusive cartel, the binding constraint is still the competitive margin. However, reducing the number of franchises alleviates price competition and saves on fixed costs as well as relaxes the reservation value margin. The semi-collusive cartel will reduce the number of franchises until the competition margin is not binding in which the reservation value margin, in turn becomes less constraint. At the market equilibrium, the competition margin is not binding and the only constraint is the relaxed reservation value margin, which implies that every franchise is local monopoly. Therefore, the optimal number of franchises in the regime of semi-collusive cartel with endogenous quality can be larger than the choice without quality of franchises.

Quality of Franchise with Free entry

In this case, we still consider the same case as free entry without quality consideration. Only difference from the previous free entry case is now fans' reservation value is $v(n^f) = 1 - \frac{1}{2}\alpha n^f$. As the same process, two-stage game is considered. In the first stage potential franchises simultaneously choose whether or not to enter. By backward induction, each franchise sets its ticket price to maximize its profit given distance

[33] Explicitly, the optimal number of franchises with semi-collusive cartel is

$$n^{sc} = \frac{(\alpha - c) \pm \sqrt{(1-c)^2 - 2\alpha t}}{\alpha}.$$

between franchises. Suppose that franchise i chooses its ticket price as p_i^f and there exists a fan who is indifferent between buying a ticket form franchise i and buying a ticket from its neighbor franchise j, which satisfies the following:

$$\alpha - \frac{1}{2}\alpha^2 n^f - t\tilde{x}_i^f - p_i^f = \alpha - \frac{1}{2}\alpha^2 n^f - t(\frac{1}{n^f} - \tilde{x}_i^f) - p_i^f .$$

In this case franchise i 's demand is $q_i = 2\tilde{x} = \frac{1}{n^f}$ and it sets ticket price to maximize its profit as follows:

$$\pi_i^f = (p_i^f - c)q_i^f - f = (p_i^f - c)\frac{1}{t}(p_j^f + \frac{t}{n^f} - p_i^f) - F . \tag{A3}$$

Therefore, each franchise sets its price as $p_i^f = c + \frac{t}{n^f}$. In the first stage, potential franchises enter the league until $\pi_i^f = (p_i^f - c)\frac{1}{n^f} - F = 0$. Therefore, the optimal number of franchises with free entry is $n^f = \sqrt{\frac{t}{F}}$.

Socially Optimal Level of Franchise's Quality

When there are n^s franchises at distance of $\frac{1}{n^s}$ apart from its neighbor and they all sell products at price p^s, total surplus generated by franchise i is

$$s(n^s) = 2\int_0^{\frac{1}{2n^s}} (1 - \frac{1}{2}\alpha n^s - p_i^s - tx)dx + \frac{p_i^s}{n^s} - \frac{c}{n^s} - F$$

$$=\frac{1}{n^s}-\frac{\alpha}{2}-\frac{p_i^s}{n^s}-t\left(\frac{1}{2n^s}\right)^2+\frac{p_i^s}{n^s}-\frac{c}{n^s}-F. \tag{A4}$$

Form total surplus of one franchise, we have the total surplus in a n^s-franchise league is

$$S(n^s)=n^s s(n^s)=1-\frac{\alpha}{2}n^s-\frac{t}{4n^s}-c-n^sF. \tag{A5}$$

Maximization with respect to n^s yields the socially optimal number of franchises as

$$n^s=\sqrt{\frac{t}{2(2F+\alpha)}}.$$

Comparison

We now turn to analysis of comparing the optimal number of franchises under different regimes with quality.

Proposition A2. With quality choice, the league cartel provides a larger number of franchises than the socially optimal one, but a smaller number of franchises than free entry one, $n^s<n^c<n^f$. The average quality of franchises is $v(n^f)<v(n^c)<v(a^s)$.

Proof. For the complete cartel case, we can easily verify that $n^s<n^c<n^f$ from

$$\sqrt{\frac{t}{2(F+2\alpha)}}<\sqrt{\frac{t}{2F+\alpha}}<\sqrt{\frac{t}{F}}.$$

With quality choice, we still adopt Spence (1975, 1976)'s analysis: the incentive to increase the number of franchises is related to the marginal increase in gross utility for the marginal consumer in the case of the complete cartel and for the average consumer in the case of a social planner. However, since the consumer' valuation is affected by quality of the product and the number of franchises, in which these are also negatively, the effect of changing the number of franchises will be augmented. More specifically, the complete cartel can raise the price by $\left(\frac{\partial v(n^c)}{\partial n^c} + \left. \frac{\partial p_i^c}{\partial n^c} \right|_{without\ qualtiy} \right) \cdot \Delta n^c$ by increasing the number of franchise by Δn^c. The choice of the complete cartel will depend on the marginal increase in valuation and quality of the marginal consumer against fixed cost. In contrast, the social planner considers marginal increase in valuation and quality of average consumers such as $\frac{\partial}{\partial n^s} \left(2n^s \int_0^{\frac{1}{2n^s}} (v(n^s) - tx)dx \right) \cdot \Delta n^s$.

When the cartel does not have a complete control over franchises with quality choice, it is shown to provide smaller or larger number of franchises compared to the choice of the complete cartel. Since consumers' valuation is correlated with the number of franchises, the outcome is ether fewer franchises with high quality or many franchises with low quality.

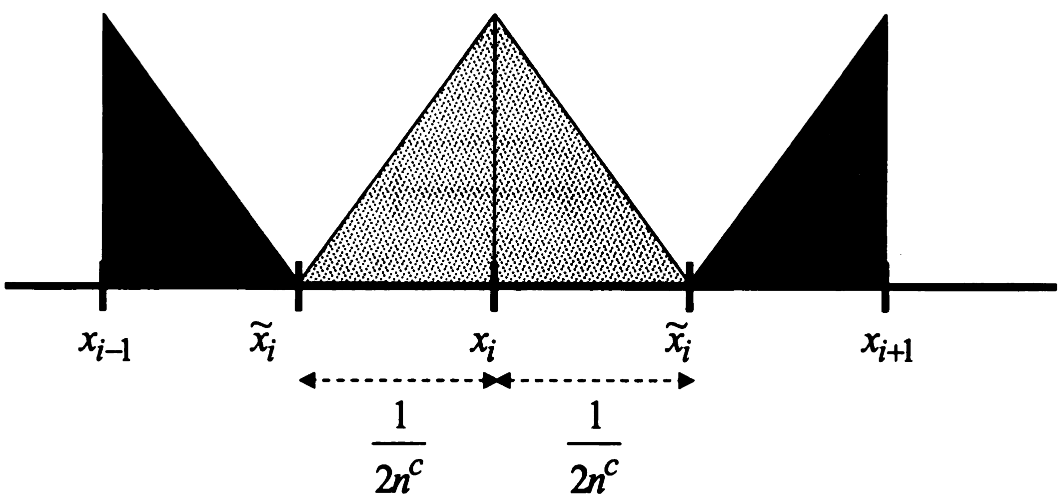

Figure 1. The fully league cartel without quality choice

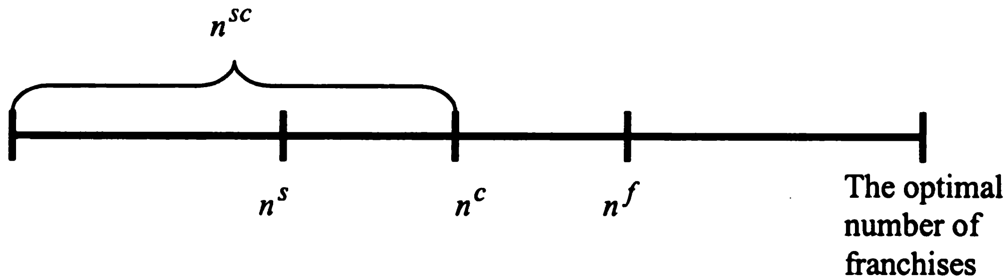

Figure 2. Comparison of the Number of Franchises under Different Regimes

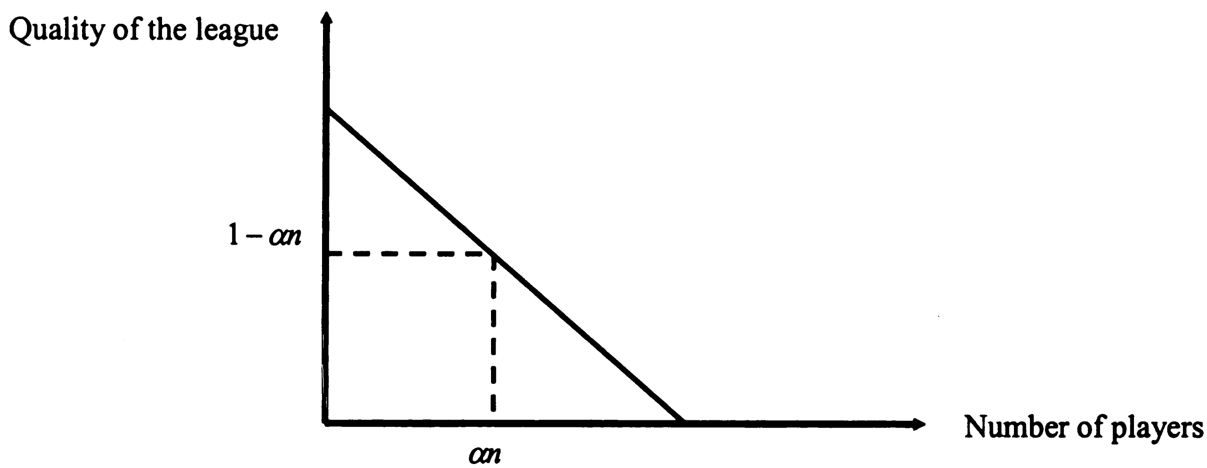

Figure 3. Relationship between quality and number of players

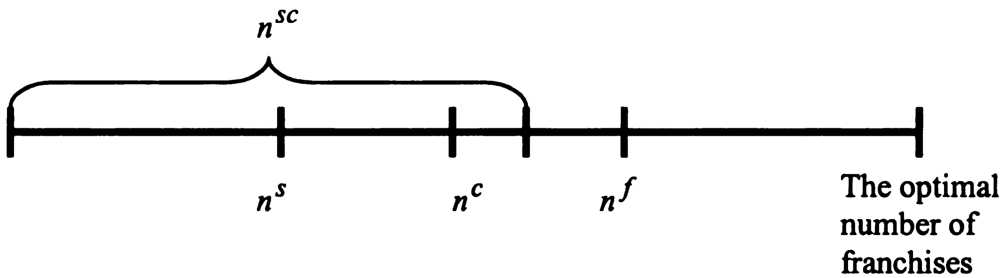

Figure 4. Comparison of the Number of Franchises with Quality

CHAPTER 3

THE QUALITY OF TECHNOLOGY AND PATENT PROTECTION POLICY IN THE INTERNATIONAL LICENSING OF TECHNOLOGY

1. Introduction

Intellectual property rights (IPR) have been controversial policy issue over past two decades. On one hand, developed countries insist that developing countries should implement higher standards. However, developing countries view the adaptation of a strong protection of intellectual property rights as an excessive rent transfer to the high-income developed countries. Along with policy debate of IPR, licensing as a channel of technology transfer has been more important for the following reasons. First, recent empirical evidence suggests that the volume of arm's length's contract has been increased. Mansfield (1995) shows that there has been an increase in recent years in the extent to which technology is transferred by licensing. Second, a technology transferor prefers licensing to FDI because of political reasons in a technology recipient country. For example, in some developing countries government policies traditionally preferred licensing to equity investment as the model of technology transfer (Contractor and Sagafi-Negad, 1981).

This paper constructs a model incorporating several of the stylized facts regarding technology transfer and licensing. In this paper I examine the validity of patent protection policy in the host country where there exist the licensee's imitation and R&D competition between the licensor and the licensee. Its purpose is to address two interrelated questions: First, are there other concerns except imitation in which the licensor may not transfer the new technology? Second, with endogenous choice of the licensor's R&D expenditure, how does the degree of a patent protection policy effect on the level of technology transferred and the licensor's R&D efforts?

One of the stylized facts for the technology transfer via licensing is the licensor may transfer the old technology when the host country's patent protection policy is not effective. Since the weak patent protection makes imitation possible, the licensor has to transfer the old technology to secure future profit. However, the strong patent protection policy may have a reverse effect on the licensor's incentive to do R&D. Since imitation becomes very costly in the strong patent protection policy, the licensor may have less incentive to develop the next generation technology.

On the other hand, Roberts and Mizouchi (1988) and Davies (1977) show that if the licensee may have a potential ability to develop a newer technology, firms are often reluctant to license their cutting-edge technologies. From the stylized facts, it is possible that there would be missing parts that explain the validity of patent protection policy and strategic behaviors of the licensor and the licensee. This paper examines another aspect of the licensor's strategic behavior where he faces two different concerns: the licensee's imitation and R&D activity.

The effect of the protection of IPR has been studied in a theoretical literature on technology transfer, where can be divided in two categories. First, Helpman (1990), Glass and Saggi (1995), Lai (1998), and Yang and Maskus (2001) use a general equilibrium model with an innovative North and an imitative South to study the effect of IPR. Helpman (1993) finds that stronger IPR would diminish both the rate of innovation for the North and welfare of the South when imitation is the only channel of technology transfer. In his model, stronger IPR implies that imitation becomes more costly, so that it decreases the rate of technology transfer, and reduces incentives to innovate. Glass and Saggi (1995) show similar results with two channels of technology transfer, such as imitation and foreign direct investment (FDI). They conclude that a strengthening of IPR in the South would reduce the rate of innovation in the North and imitation in the South. The rate of technology transfer also would decrease with stronger IPR. Lai (1998) finds that the effect depends crucially on the channel of technology transfer. Stronger IPR in the South would increase the rate of technology transfer, but if only imitation is possible, then the result would be reversed. Yang and Maskus (2001) analyze the effect of the stronger IPR by using a dynamic general-equilibrium model of the product cycle. They have the same results as in previous literature with two channels of the technology transfer: licensing and imitation.

The second approach for IPR is strategic interactions between a technology transferor and a technology recipient. Fosfuri (2000) analyzes the decisions about the entry mode in a foreign country and the quality choices of transferred technology. Fosfuri studies how these are correlated and how both decisions are influenced by the degree of patent protection in the host country. In his model, he shows that the licensing contract is efficient and optimally chosen by the innovator without imitation. Under the presence of imitation, the optimal behavior of the innovator is to choose different strategies to deter technology diffusion by using the different mode of entry such as export or FDI. Although the innovator chooses the licensing mode, he will license the old version of technology from his technology vintage to reduce the licensee's incentive to imitate. Markusen (2001) shows the effect of stronger IPR in the model in which local managers learn the multinational's technology and can defect to start a rival firm. From his result, both the multinational's profit and the host-country's welfare would be improved by stronger IPR if the mode of entry changes from exporting to production within the host country.

This paper takes a different but complementary approach to international technology licensing. I present a model in which the licensee can choose either to copy the licensed technology or to do R&D based on the licensed technology. This consideration reflects a more realistic situation in which the licensor should concern more about both imitation and leapfrogging from the licensee. What it means that the licensor would choose to transfer the old technology due to either the licensee's imitation or R&D activity. To examining these questions I consider the decision of the licensor is examined under two different regimes, which vary according to the degree of a patent protection policy. In the basic model, the optimal level of technology transferred is examined according to the licensee's decision between imitation and R&D. Here, we assume that there is no further R&D activity from the licensor. The optimal choice of the licensor's R&D expenditure is analyzed in the extended model. With the licensor's further R&D ability, we can show the host country's patent protection policy does not have a critical role in determining the quality of technology to transfer. However, the strong patent protection policy is shown to reduce the licensor's R&D expenditure which slows down the innovation.

The basic foundation of this paper is the incomplete licensing contract, which is analogous to the incomplete contract framework by Grossman and Hart (1986), Hart and Moore (1990) and Hart (1995). If the licensee's R&D ability is known to the both parties, then the licensor knows that in the second period there will be either imitation or R&D. The licensor is able to design the first-period contract, which is contingent on the licensee's behavior in the second period according to the licensee's R&D ability. The licensor may include a provision, which requires that the licensee should pay for future payments depending on the choice of the licensee's activity. If the licensee chooses to imitate at the second period, obviously it reveals the licensee has the low ability for R&D. According to the provision, the licensor will be compensated for the loss from the licensee's imitation at the second period. If the licensee decides to do R&D, the licensor will collect an additional payment from the licensee's profit when the licensee succeeds innovation. Since the licensor can extract profit from the licensee because of imitation or R&D, the licensor does not have any incentive to transfer the old technology in the first period. He always transfers the new technology with a contract, which includes either rent from imitation or profit from the success of R&D depending on the licensee's ability to do R&D.

However, these activities may be observable to the parties in the relationship but not verifiable to a third party. Therefore, it may not be enforceable in court. The incompleteness of licensing contract may be caused by the fact that the licensor cannot list all the possible future outcomes from imitation or R&D. With weak patent protection in the host country, which allows the licensee to imitate, the licensee can invent patentable and not infringing technology around the patent by imitation.

The remainder of this paper is organized as follows. In Section 2 I describe the basic model and give an example about the quality differentiated market structure and derive the sub-game perfect Nash equilibrium (SPNE) for the basic licensing game.

Section 3 discusses the effect of the licensor's further R&D activity on the licensing game and derives the SPNE for the extended licensing game. I conclude in Section 4.

2. Basic Model without the Licensor's R&D

I construct a two-period model of an international technology transfer via licensing, where there are two countries: the *source* and the *host* countries. In the source country, there is a firm that has two different levels of patented technologies: the old and the new technologies. I assume that the innovation process occurred before the licensing game, so these technologies are considered as exogenous. Also, there is more than one firm in the host country who are willing to take the license for this technology from the licensor. As a result, the licensor has the bargaining power and makes a take-it-or-leave-it offer to the licensee.

For simplicity, we assume *ex ante* complete licensing agreement possibly can be written. With ex ante complete contract, the level of technology transferred is able to verifiable to a third party, as well as the parties in the relationship, so moral hazard problem is not considered in this model. In this case the licensor will transfer his technology only with a lump-sum payment. Also, to maximize the lump-sum payment from licensing the licensor licenses exclusively, so he can obtain monopoly profit from the host country's market at the first period.

We also assume that the licensing contract is only valid for one period. Invalidity of multi-period contract can be justified as follows. With lump-sum payment the licensor has no commitment mechanism ensuring no more licensing to potential entrants in host country in the second period. For instance, the licensee expects the licensor has an incentive to offer another license to any potential entrant at the beginning of the second period. Therefore, without exclusive licensing commitment in the second period one-period licensing contract is only valid.

To formalize the idea I assume that there are two types of technology that can be licensed: the new and the old technologies. The new technology differs from the old technology in two respects. First, the new technology is superior to the old technology in which it enables the licensee to produce a higher quality product: the quality with the new technology is $\alpha\theta$ while the quality with the old technology is θ, where $\alpha > 1$. If we assume that consumers have utility function as $U = v - p$ and valuation v, which is uniformly distributed over the unit interval as $v_i \in U[0, 1]$. Thus, the quality of the good enters positively into the utility of consumer. In addition, the transfer of the new technology may enable the licensee to develop a next-generation technology and make other technologies obsolete.

I first calculate the licensor's optimal choice of lump-sum fee in the first period. If the licensee is transferred with the old technology, he can produce products with quality level, θ as a monopolist. Then consumers with non-negative net utilities purchase the product: $\theta v - p \geq 0$ with the old technology. Given the purchase decision of consumers, the licensee simply chooses a price that maximizes his profit:

$$\pi_{Old}^{M} = \arg\max_{p_i} \; p_i(1 - \frac{p_i}{\theta}) = \frac{\theta}{4}.$$

As a result the licensor simply charge his lump-sum fee as π_{Old}^{M}. Similarly, the licensee's profit and lump sum fee in the first period with the new technology is shown as: $\pi_{New}^{M} = \frac{\alpha\theta}{4}$.

When the licensee receives the technology, he has two different options for future competition at the end of the first period: imitation or R&D. If he decides to imitate the licensed technology, then he will obtain the same level of technology with certainty. On the other hand, if he decides to use his research capacity for R&D, he has a chance to develop one-level higher technology with probability p. For example, the transfer of old [new] technology endows the licensee with the ability to develop the new [the next generation] technology with probability p. Therefore, at the end of first period, licensee has two strategies, either imitation or R&D [see figure 1].

With licensee's two different options at the end of the first period, we need to calculate what the optimal lump sum fee will be in the second period. Two different outcomes will be possible. If the licensor transfers the old technology and the licensee decides to do imitation at the end of the first period, then the licensor still has the new technology and the licensee has the old one. Since the licensor has the bargaining power, he can make an offer as follows. If there are two firms with different quality, θ and $\alpha\theta$ with new contract with a potential entrant, it will be the duopoly case with two different levels of quality. When consumers make their purchase decision, they choose the one that yields the highest utility. For given price for the low and high quality product, consumers' optimal choices can be divided by as follows:

$\frac{p_{New} - p_{Old}}{\theta(\alpha - 1)} \le v$ purchase the high quality product

$\frac{p_{Old}}{\theta} \le v < \frac{p_{New} - p_{Old}}{\theta(\alpha - 1)}$ purchase the low quality product

$v < \frac{p_{Old}}{\theta}$ no purchase

Now we can denote the profit of the new entrant with high quality as

$$\pi^{D}_{(New,Old)} = \arg\max\left(1-\frac{p_{New}-p_{Old}}{(\alpha-1)\theta}\right)p_{New} = 4A\pi^{M}_{New},$$

where $A = \frac{4\alpha(\alpha-1)}{(4\alpha-1)^2}$.[34]

Also, we can represent the profit of the licensee with low quality as

$$\pi^{D}_{(Old,\ New)} = \arg\max\left(\frac{p_{New}-p_{Old}}{(\alpha-1)\theta}-\frac{p_{Old}}{\theta}\right)p_{Old} = A\pi^{M}_{Old}.$$

As a result, the licensor's optimal lump-sum fee in the second period when the licensee has the old technology is $\pi^{M}_{New} - \pi^{D}_{(Old,\ New)}$.

As another possible outcome, the both parties have the new technology as a result of either of licensee's imitation or R&D activity in the first period. We assume that it leads to *Cournot* type competition between the licensee and new entrant, then we denote the profit of firm i as

$$\pi^{D}_{(New,\ New)} = \arg\max_{q_i} \alpha\theta(1-q_i-q_j)q_i = \frac{4}{9}\pi^{M}_{New}.$$

Therefore, the licensor's optimal lump-sum fee in the second period when the licensee has the new technology is $\pi^{M}_{New} - \pi^{D}_{(New,\ New)}$.

For the last scenario if the licensee with the transferred new technology succeeds to develop the next generation technology, which makes other technologies obsolete and brings the quality level of $\alpha^2\theta$ into consumer's valuation. In this case, the licensor no longer has a dominant position in the second period.

Technology transfer without Imitation: A Benchmark case

As a benchmark case, I first consider a situation where the option to imitate the licensed technology is not available, in which the host government adopts the strong patent protection policy. Under this policy regime, the licensee cannot imitate the licensed technology or invent around the patent. Therefore, the licensee's strategic behavior is only to do R&D. Let $\Pi^B(O, R)$ and $\Pi^B(N, R)$ denote payoffs of the licensee from R&D activity when the old and the new technology is transferred respectively.[35] According to the licensee's R&D ability, which is denoted by p, we have

$$\Pi^B(O, R) = p \cdot \pi^D_{(New,\ New)} = p \cdot \frac{\alpha\theta}{9}, \tag{1}$$

$$\Pi^B(N, R) = p \cdot \pi^M_{NG} = p \cdot \frac{\alpha^2\theta}{4}. \tag{2}$$

Since we assume that the licensee's ability to do R&D is constant, but expected profits from R&D increases with respect to the level of transferred technology, the licensee always prefer the new technology to the old one.

Let $\Pi^S(O, R)$ and $\Pi^S(N, R)$ denote payoffs of the licensor when the old and the new technology is transferred respectively with licensee's R&D activity.[36]

$$\begin{aligned} \Pi^S(O, R) &= \pi^M_{Old} + p \cdot [\pi^M_{New} - \pi^D_{(New,\ New)}] + (1-p) \cdot \pi^M_{New} \\ &= \frac{\theta}{4} + p[\frac{5\alpha\theta}{36}] + (1-p)\frac{\alpha\theta}{4} \end{aligned} \tag{3}$$

$$\Pi^S(N, R) = \pi^M_{New} + p \cdot 0 + (1-p) \cdot \pi^M_{New} = \frac{\alpha\theta}{4} + (1-p)\frac{\alpha\theta}{4}. \tag{4}$$

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[34] The first cell in the subscript denotes his own technology level and the second one indicates his opponent's technology level.

[35] Superscript B denotes the licensee (buyer).

[36] Superscript S denotes the licensor (seller).

Let p^* be the critical value, which satisfies

$$\Pi^S(N,R) - \Pi^S(O,R) = \frac{\theta}{36}(9\alpha - 9 - 5\alpha p) = 0.$$

Hence, if $p < p^*$, the licensor will choose to transfer the new technology. Otherwise, the licensor will transfer the old technology. As the licensee's R&D ability increases, the licensor gets more cautious in protecting the new technology to maintain his dominant position in the second period.

Lemma 1. Let define a set ***P*** as ***P***$= \{p | H(p) = \Pi^S(O,R) - \Pi^S(N,R) > 0\}$. If the parameter of R&D ability, p, belongs to the set ***P***, then the licensor will choose to transfer the old technology.

Technology Transfer with Imitation

Now I introduce the possibility of imitation of the transferred technology. With weak patent protection policy of the host country, the licensee has another option, which is imitate the transferred technology. Let $\Pi^B(O, I)$ and $\Pi^B(N, I)$ denote payoffs of the licensee from imitation when the old and the new technology is transferred respectively. Since the licensee's probability to imitate is given by one, we have

$$\Pi^B(O, I) = \pi^D_{(Old,New)} = A \cdot \frac{\theta}{4}, \tag{5}$$

$$\Pi^B(N, I) = \pi^D_{(New,\, New)} = \frac{\alpha\theta}{9}. \tag{6}$$

During the first stage, the licensee chooses either to imitate or to do R&D based on payoffs with different level of technology transferred in the first stage. By comparing the licensee's expected payoffs from each outcome, we can conclude that the licensee's optimal choice is imitate no matter what technology is transferred if $p < \frac{9A}{4\alpha}$. Also, if $p > \frac{4}{9\alpha}$, the licensee chooses to do R&D regardless of the level of technology transferred. In the medium range of the licensee's R&D ability ($\frac{9A}{4\alpha} < p < \frac{4}{9\alpha}$) his choice will be to do R&D when the old technology is licensed, and vice versa [see figure 3].

We now calculate the licensor's payoffs with imitation from the licensee. Let $\Pi^S(O, I)$ and $\Pi^S(N, I)$ denote payoffs of the licensor when the old and the new technology is transferred respectively with licensee's imitation activity.

$$\Pi^S(O, I) = \pi^M_{Old} + (\pi^M_{New} - \pi^D_{(New, Old)}) = \frac{\theta}{4}(1 + \alpha - A), \tag{7}$$

$$\Pi^S(N, I) = \pi^M_{New} + (\pi^M_{New} - \pi^D_{(New, New)}) = \frac{14}{36}\alpha\theta. \tag{8}$$

Given the licensee's choices according to R&D ability, the licensor's optimal choice of the level of technology. If $p < \frac{9A}{4\alpha}$, which induces the licensee to imitate no matter what level of technology licensed, the licensor will choose the level of technology by comparing $\Pi^S(O, I)$ and $\Pi^S(N, I)$. The licensor's optimal choice will be presented in proposition 1.

Proposition 1. In the regime of weak patent protection policy with low R&D ability of the licensee [$p < \frac{9A}{4\alpha}$], the level of technology depends on the quality gap (α) between the old and the new technologies regardless of the licensee's R&D ability.

Proof. By calculating $\Pi^S(O,I)-\Pi^S(N,I)=\frac{\theta}{4}(1-A-\frac{5}{9}\alpha)$, we denote α^* as the critical value satisfying $\Pi^S(O,I)=\Pi^S(N,I)$. If $\alpha<\alpha^*$, the licensor will transfer the new technology. Otherwise, the old technology is transferred.

The intuition underlying Proposition 1 is straightforward. Due to the licensee's imitation activity the licensor faces two different trade-offs: increasing licensing fee in the first period with licensing of the new technology or securing the future profit by transferring the old one. If the quality gap between technologies is narrow, the licensor is better off with licensing the new technology, which increases the licensing fee in the first period. Since both technologies have little difference with respect to quality of the product, the licensor has less incentive to secure the future profit.

When the licensee's R&D ability belongs $\frac{9A}{4\alpha}<p<\frac{4}{9\alpha}$ which induces the licensee to imitate the new technology or to do R&D based on the old technology. In this case the licensor will choose the level of technology by comparing $\Pi^S(O,R)$ and $\Pi^S(N,I)$. The licensor's optimal choice will be presented in proposition 2.

Proposition 2. In the regime of weak patent protection policy with medium R&D ability of the licensee [$\frac{9A}{4\alpha}<p<\frac{4}{9\alpha}$], the level of technology depends on the quality gap (α) between the old and the new technologies and the licensee's R&D ability.

Proof. By calculating $\Pi^S(O, R) - \Pi^S(N, I) = \frac{\theta}{36}[9(1-\alpha) + 4\alpha(1-p)]$, we denote $\hat{p}(\alpha)$ as the critical value satisfying $\Pi^S(O, R) = \Pi^S(N, I)$. If $p < \hat{p}(\alpha)$, the licensor will transfer the old technology. Otherwise, the new technology is transferred.

The intuition underlying Proposition 2 is as follows: Due to the licensee's two different response to the level of technology transferred the licensor faces two different trade-offs: maximizing licensing fee in the first period or securing the future profit. As the quality gap increases with fixed the licensee's R&D ability, the licensor puts more emphasis on maximizing the licensing fee in the first period than maintaining the dominant position in the future.

As the last case with $p > \frac{4}{9\alpha}$, the licensee chooses to do R&D regardless of the level of technology transferred. With licensee's only imitation choice, it will be the same configuration as the benchmark case with strong patent protection policy. To evaluate the effectiveness of the strong patent protection I summarize the results under weak patent protection regime in figure 4. We observe change of the level of technology transferred, which is shown as gray area under the weak protection. Therefore, we can conclude that the effectiveness of patent policy depends on the quality gap. Moreover, a surprising result is that the larger quality gap is not a necessary condition for transferring the old technology.

3. The Extended Model with the Licensor's Endogenous Choice of R&D Expenditure

We now consider the licensor's R&D activity at the end of the first period. Given the quality gap (α) and the licensee's R&D ability, the licensor decides on how much R&D expenditure is to be made. For this analysis, we assume that the licensor would be successful in innovation with probability $q(e)$ depending on the R&D expenditure e. So the probability of the licensor's failure to innovate the next-generation technology is $(1-q(e))$. Also, $q(e)$ is assumed to be increasing and strictly concave in e with $q(0)=0$ and $q(e)<1$ for any $e<\infty$.

Technology transfer without Imitation: A Benchmark case

As a benchmark case, I first examine the licensor's optimal choice of R&D expenditure when the option to imitate the licensed technology is not available with adaptation of the strong patent protection policy. Under this policy regime, the licensee cannot imitate the licensed technology or invent around the patent. Therefore, the licensee's only strategic behavior is to do R&D. Let $\Pi^{B'}(O, R)$ and $\Pi^{B'}(N, R)$ denote payoffs of the licensee from R&D activity when the old and the new technology is transferred respectively. According to the licensee's R&D ability, which is denoted by p, we have

$$\Pi^{B'}(O, R) = p(1-q)\cdot \pi^{D}_{(New,\ New)} = p(1-q)\cdot\frac{\alpha\theta}{9}, \tag{9}$$

$$\Pi^{B'}(N, R) = pq\cdot \pi^{D}_{(NG, NG)} + p(1-q)\pi^{M}_{NG} = pq\cdot\frac{\alpha^2\theta}{9} + p(1-q)\frac{\alpha^2\theta}{4}. \tag{10}$$

Since we assume that the licensee's ability to do R&D is constant, but expected profits from R&D increases with respect to the level of transferred technology, the licensee always prefer the new technology to the old one.

Let $\Pi^{S'}(O, R)$ and $\Pi^{S'}(N, R)$ denote payoffs of the licensor when the old and the new technology is transferred respectively with licensee's R&D activity.

$$\Pi^{S'}(O, R)$$
$$= \pi_{Old}^{M} + q(e)\cdot\pi_{NG}^{M} + (1-p)(1-q(e))\cdot\pi_{New}^{M} + p(1-q(e))\cdot[\pi_{New}^{M} - \pi_{(New,\ New)}^{D}] - e$$
$$= \frac{\theta}{4} + q(e)\frac{\alpha^2\theta}{4} + (1-p)(1-q(e))\frac{\alpha\theta}{4} + p(1-q(e))\left(\frac{\alpha\theta}{4} - \frac{\alpha\theta}{9}\right) - e, \tag{11}$$

$$\Pi^{S'}(N, R) = \pi_{New}^{M} + (1-p)q(e)\cdot\pi_{NG}^{M} + pq(e)\cdot\pi_{(NG,NG)}^{D} + (1-p)(1-q(e))\pi_{New}^{M} - e$$
$$= \frac{\alpha\theta}{4} + (1-p)q(e)\frac{\alpha^2\theta}{4} + pq(e)\frac{\alpha^2\theta}{9} + (1-p)(1-q(e))\frac{\alpha\theta}{4} - e. \tag{12}$$

Let p^{**} be the critical value, which satisfies

$$\Pi^{S'}(O,R) - \Pi^{S'}(N,R) = \frac{\theta}{36}[9(1-\alpha) + 5\alpha(1-q(e)+\alpha q(e))p^{**}] = 0.$$

Hence, if $p < p^{**}$, the licensor will choose to transfer the new technology. Otherwise, the licensor will transfer the old one.

Lemma 2. Let define a set $\boldsymbol{P}$ as $\boldsymbol{P} = \{p | H(p) = \Pi^{S}(O,R) - \Pi^{S}(N,R) > 0\}$. If the parameter of R&D ability, p, belongs to the set $\boldsymbol{P}$, then the licensor will choose to transfer the old technology.

We now turn to the licensor's optimal R&D expenditure problem with $p < p^{**}$ in which the licensor transfers the new technology. The licensor chooses the optimal level of expenditure by maximizing (12). The first order condition yields

$$q'(e^*(N,R)) = \frac{36}{\alpha\theta(9(1-p)(\alpha-1)+4\alpha p)}. \qquad (13)$$

For the other case the licensor will choose to transfer the old technology and the licensor's objective becomes maximizing (11). The first order condition yields

$$q'(e^*(O,R)) = \frac{36}{\alpha\theta(9(\alpha-1)+4p)}. \qquad (14)$$

Proposition 3. With strong patent protection policy, the licensor will engage in R&D more intensively when the old technology is transferred [$e^*(O,R) > e^*(N,R)$].

Proof. Comparing (13) and (14) we easily conclude that $q'(e^*(O,R)) < q'(e^*(N,R))$. It implies $e^*(O,R) > e^*(N,R)$.

Technology Transfer with Imitation

Now we consider the possibility when the licensee has another option, which is imitation with weak patent protection policy of the host country. Since both decisions, which are the licensor's R&D expenditure and the licensee's technology adaptation, will happen during the first stage, we can denote $\Pi^{B'}(O, I)$ and $\Pi^{B'}(N, I)$ as payoffs of the licensee from imitation when the old and the new technology is transferred respectively with given expenditure level e. Since the licensee's probability to imitate is given by one, we have

$$\Pi^{B'}(O, I) = (1-q)\pi^{D}_{(Old,New)} = (1-q)A\cdot\frac{\theta}{4}, \qquad (15)$$

$$\Pi^{B'}(N, I) = (1-q)\pi^{D}_{(New,\ New)} = (1-q)\frac{\alpha\theta}{9}. \qquad (16)$$

During the first stage, the licensee chooses either to imitate or to do R&D based on payoffs with different level of technology transferred in the first stage. By comparing the licensee's expected payoffs from each outcome, we can conclude that the licensee's optimal choice is imitate no matter what technology is transferred if $p < \frac{9A}{4\alpha}$. Also, if $p > \frac{4(1-q)}{\alpha(9-5q)}$, the licensee chooses to do R&D regardless of the level of technology transferred. In the medium range of the licensee's R&D ability ($\frac{9A}{4\alpha} < p < \frac{4(1-q)}{\alpha(9-5q)}$) his choice will be to do R&D when the old technology is licensed, and vice versa.

We now calculate the licensor's payoffs with imitation from the licensee. Let $\Pi^{S'}(O, I)$ and $\Pi^{S'}(N, I)$ denote payoffs of the licensor with choice of R&D expenditure e when the old or the new technology is transferred respectively with licensee's imitation activity.

$$\begin{aligned}\Pi^{S'}(O, I) &= \pi_{Old}^{M} + q(e)\pi_{NG}^{M} + (1-q(e))(\pi_{New}^{M} - \pi_{(New,\, Old)}^{D}) - e \\ &= \frac{\theta}{4}[1 + q(e)\alpha^2 + (1-q(e))(\alpha - A)] - e,\end{aligned} \tag{17}$$

$$\begin{aligned}\Pi^{S'}(N, I) &= \pi_{New}^{M} + q(e)\pi_{NG}^{M} + (1-q(e))(\pi_{New}^{M} - \pi_{(New,New)}^{D}) - e \\ &= \frac{\theta}{36}[9\alpha + q(e)9\alpha^2 + (1-q(e))5\alpha] - e.\end{aligned} \tag{18}$$

Given the licensee's choices according to R&D ability, the licensor is now able to choose the optimal level of R&D expenditure, which induces selection of the level of technology. If $p < \frac{9A}{4\alpha}$, which induces the licensee to imitate no matter what level of technology licensed, the licensor will choose the level of technology by comparing

$\Pi^{S'}(O, I)$ and $\Pi^{S'}(N, I)$. Suppose that the licensor selects the old technology with expectation of licensee's imitation activity to occur, and his optimal level of R&D expenditure is determined by maximizing (17) with respect to e. The first order condition yields

$$q'(e^*(O,I)) = \frac{4}{\theta(\alpha^2 - \alpha + A)}. \tag{19}$$

For the other case the licensor chooses to transfer the old technology expecting imitation from the licensee. The licensor's objective becomes maximizing (18). The first order condition yields

$$q'(e^*(N, I)) = \frac{36}{\alpha\theta(9\alpha - 5)}. \tag{20}$$

Therefore, the licensor's optimal choice is now comparison of $\Pi^{S'}(e^*(O, I))$ and $\Pi^{S'}(e^*(N, I))$ with his optimal choice of R&D expenditure for each case. The licensor's optimal choice will be presented in proposition 4.

Proposition 4. In the regime of weak patent protection policy with the low R&D ability of the licensee [$p < \frac{9A}{4\alpha}$], the level of technology depends on the quality gap (α) between the old and the new technologies regardless of the licensee's R&D ability. Moreover, the licensor will engage in R&D more intensively when the new technology is transferred [$e^*(O,I) < e^*(N,I)$].

Proof. Since both $\Pi^{S'}(e^*(O, I))$ and $\Pi^{S'}(e^*(N, I))$ are the function of only quality gap (α) the optimal level of technology transferred depends on quality gap. Comparing

(19) and (20) we easily conclude that $q'(e^*(O,I)) > q'(e^*(N,I))$. It implies $e^*(O,I) < e^*(N,I)$.

The intuition underlying Proposition 4 is straightforward. Facing the licensee's imitation, the licensor's decision of transferring the new technology depends on how much monopoly profit increases in the first period and how much he needs to compensate more to renew the contract in the second period. However, with endogenous choice of his own R&D expenditure, he has one additional variable to control. If he chooses to license the new technology, then he engages in R&D more intensively in order to secure the future profit. In contrast, with licensing the old technology, the licensor has less incentive to put his effort to develop the next generation technology because he already prevents the licensee to acquire the new technology in the second period.

When the licensee's R&D ability belongs $\frac{9A}{4\alpha} < p < \frac{4(1-q)}{\alpha(9-5q)}$ which induces the licensee to imitate the new technology or to do R&D based on the old technology. In this case the licensor will choose the level of technology by comparing $\Pi^{S'}(e^*(O, R))$ and $\Pi^{S'}(e^*(N, I))$. The licensor's optimal choice will be presented in proposition 5.

Proposition 5. In the regime of with weak patent protection policy with medium level of R&D ability of the licensee [$\frac{9A}{4\alpha} < p < \frac{4(1-q)}{\alpha(9-5q)}$], the level of technology depends on the quality gap (α) between the old and the new technologies and the licensee's R&D ability. Moreover, the licensor will engage in R&D more intensively when the new technology is transferred [$e^*(O,R) < e^*(N,I)$].

Proof. Since $\Pi^{S'}(e^*(O, R))$ is the function of quality gap (α) and the licensee's R&D ability the optimal level of technology transferred depends on a and p. Comparing (14) and (20) we easily conclude that $q'(e^*(O,R)) > q'(e^*(N,I))$. It implies $e^*(O,R) < e^*(N,I)$.

As the last case with $p > \dfrac{4(1-q)}{\alpha(9-5q)}$, the licensee chooses to do R&D regardless of the level of technology transferred. With licensee's only imitation choice, it will be the same configuration as the benchmark case with strong patent protection policy. To evaluate the effectiveness of the strong patent protection I summarize the results under weak patent protection regime in figure 6. We observe possible change of the level of technology transferred compared in the regime of strong patent protection policy shown in figure. Therefore, we can conclude that the effectiveness of patent policy depends on the quality gap and the licensee's R&D ability. Moreover, we conclude that the strong patent policy has a reverse effect on the licensor's incentive to engage in innovation.

4. Concluding Remarks

In this paper I develop a simple licensing model of international technology to study the effect of strong patent protection policy on the choice of level of technology and further R&D activity. I examine the decision of licensor under four possible regimes, which vary according to the degree of a patent protection policy and the licensor's further R&D activity.

In the basic model without the licensor's endogenous choice of R&D expenditure, the level of technology depends on the quality gap and the relative magnitude of the licensee's R&D with presence of the licensee's imitation. Since the level of technology licensed is only determined by the licensee's R&D ability in the strong protection regime, the strong protection policy is shown to be partially effective. Moreover, a surprising result is that the larger quality gap is not a necessary condition for transferring the old technology.

In the extended model with the licensor's endogenous choice of R&D expenditure, the effectiveness of the strong patent protection policy is partially supported. In contrast, the licensor's optimal R&D expenditure level is reduced in the weak protection regime, which confirms the reverse effect of strong patent protection policy on the licensor's innovation efforts.

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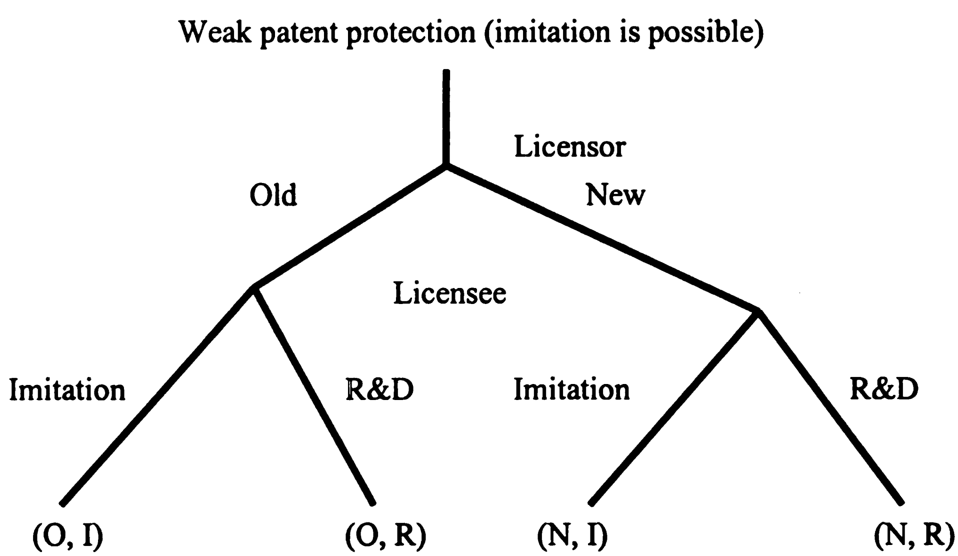

Figure 1. Game structure

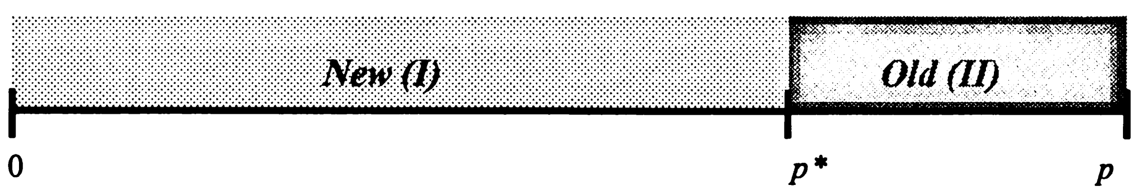

Figure 2. The basic model with a strong patent protection

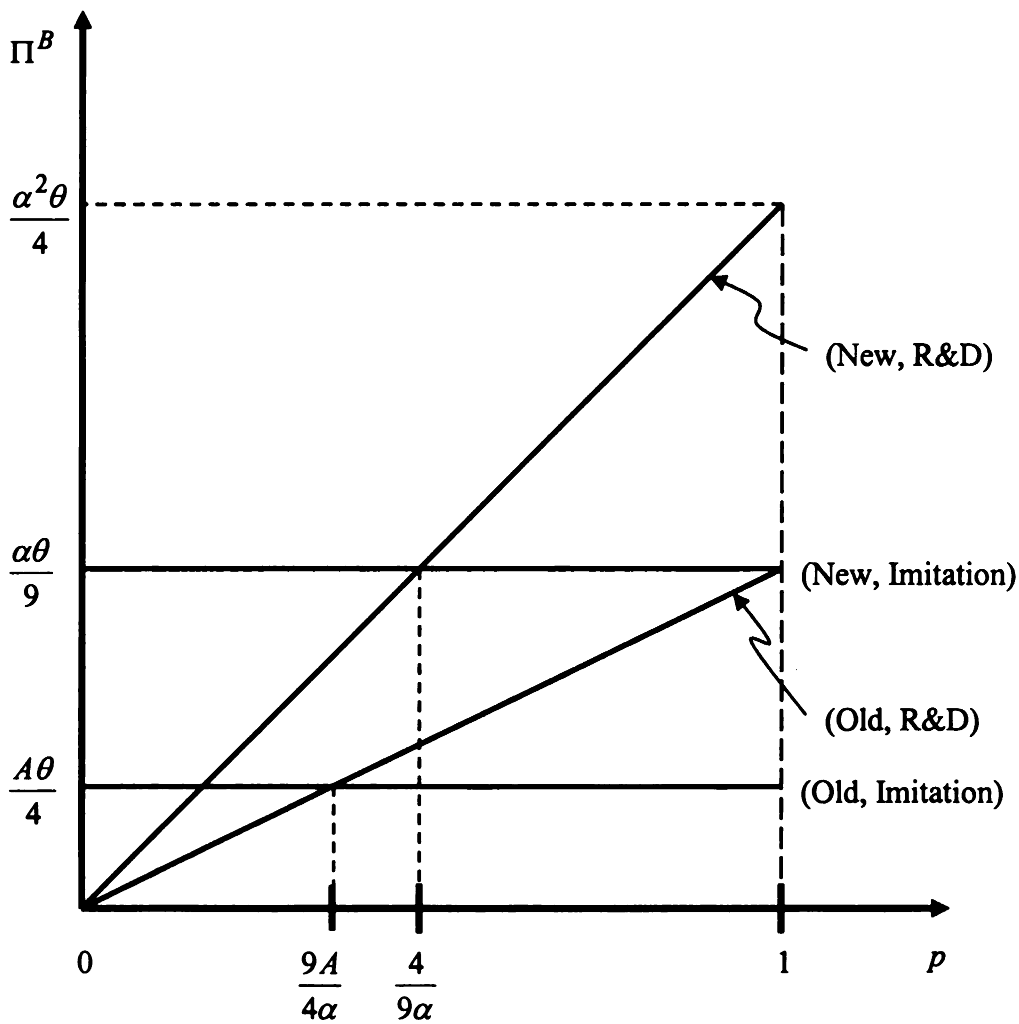

Figure 3. The optimal choice of licensee

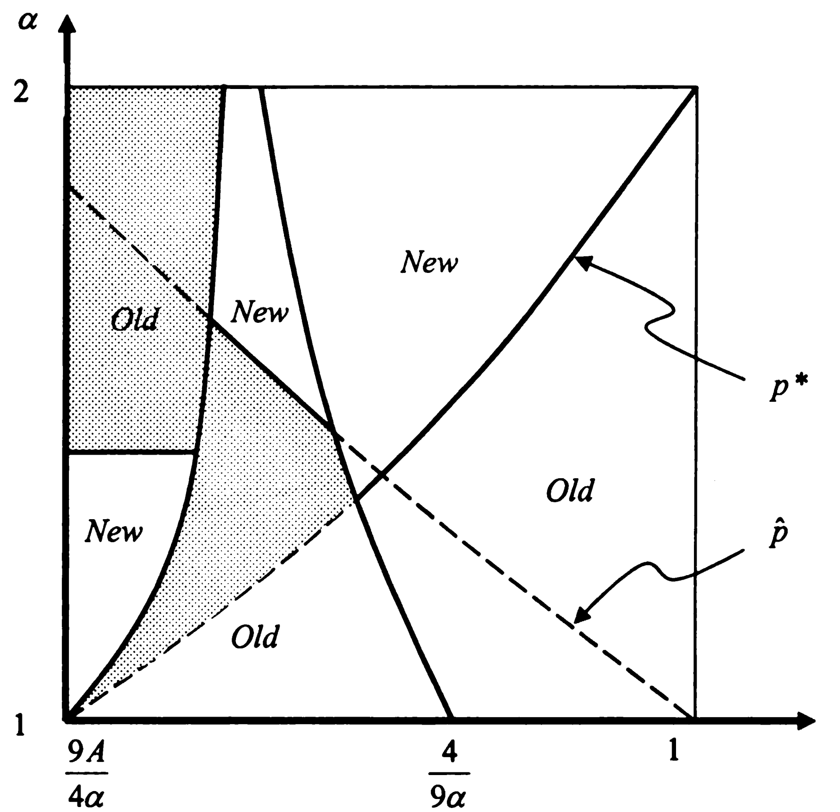

Figure 4. The basic model with weak protection policy

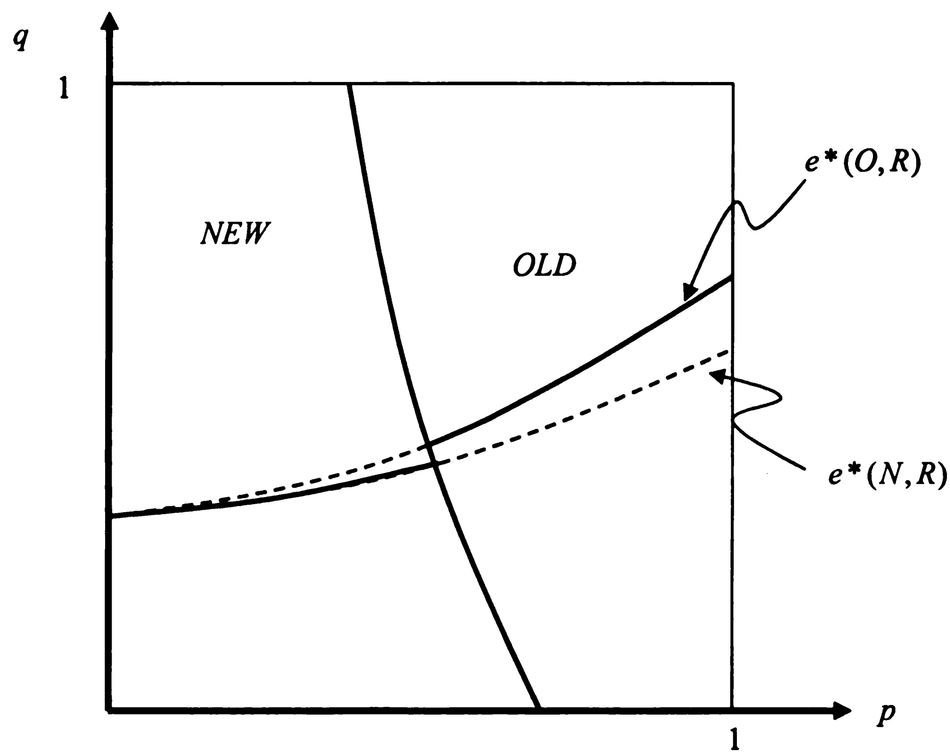

Figure 5. The extended model with strong patent protection policy

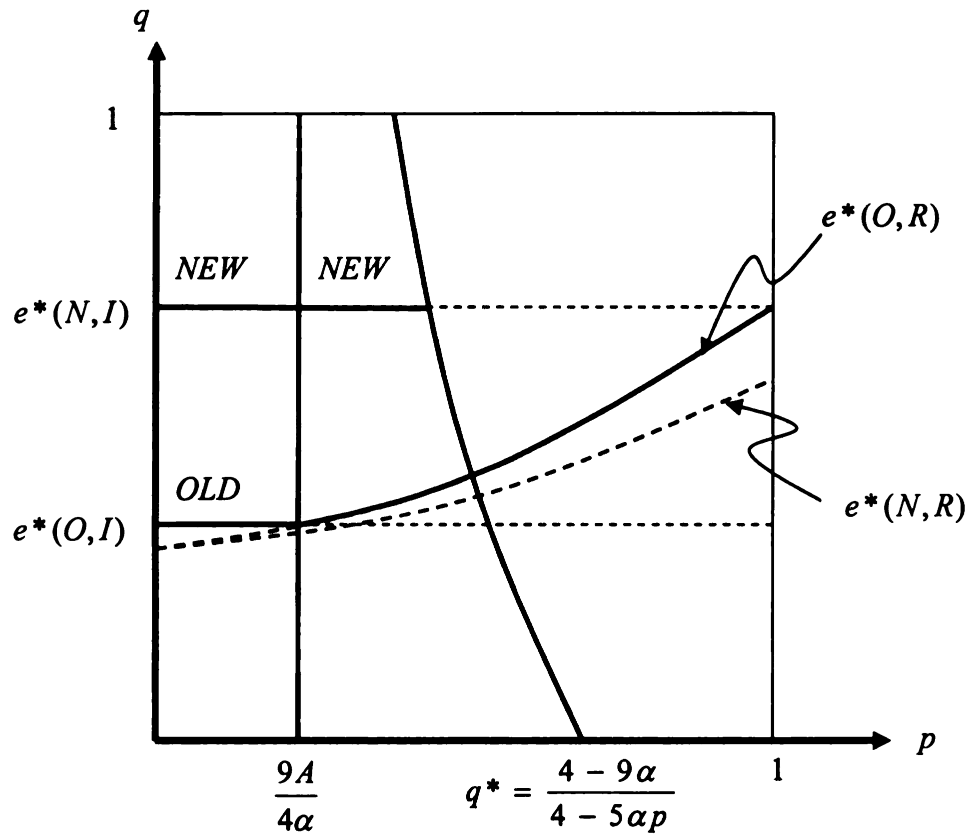

Figure 6. The extended model with weak patent protection policy