Licensing of complementary technologies and enforcement of intellectual property rights

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by

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Licensing of Complementary Technologies and Enforcement of Intellectual Property Rights

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Abstract

In this paper, we examine the effect of enforcement of IPR on the equilibrium outcome and welfare through unilateral and cross licensing decisions between duopolistic firms with patents of two complementary technologies. We find the conditions on both the imitation cost of the infringer and the probability of the accuser firm winning the lawsuit under that a unilateral licensing/ a cross licensing may be contracted between them, and efficient social surplus of duopoly realizes.

1 Introduction

In some industries, one feature of recent technological innovation is that the firms cannot produce a commodity without using the outcome of plural distinct inventions. Especially in information technology (IT) industries, one product is comprised of numerous separable patentable elements. For example, the production of a mobile phone having a digital camera involves about 19,000 (Japanese) patents and/or utility models.[1] In this environment, which is named "cumulative-systems technologies" (Merges and Nelson [3]) or "complex technologies" (Cohen, Nelson and Walsh [2]), the inventors of the separable patentable elements tend to be different economic agents. In such cases, the coordination among these inventors affects the interests of each inventor and also affects their R&D incentives. In fact, over the last decade of the previous century, a few of studies discussed the effects of the relationships among inventions on incentives for R&D, licensining, the enforcement of patent systems and social welfare. Aoki and Hu[1], Okamura, Shinkai and Tanaka[5] explore this problem in the economic literature.

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Recently, governments in many developed countries including U.S., EU members countries and Japan has been strengthend their policies for protection intellectual property rights(IPR) of their domestic rightsholders. These strength of protection policies of IPR certainly make courts easier relieve their domestic rightsholders for infringment of IPR. Whether these policies improves social welfare or not is not clear when we are in complex technologies environment, especially there exhists complementary among technologies or inventions. As we typically have seen in the IT industries, technological innovations occur on the basis of plural distinct inventions developed in different systems of technologies. In this environment, distinct technologies are complementary to each other as parts of the product produced. In order to explore the effects of the relationships among inventions and the enforcement of patent systems on social welfare, we incorpolates the probability that the plaintiff(rightsholder) wins the lawsuit for infringement of his IPR and imitation cost of infringer into our model. We examine what kind of licensing contract form are desirable from the social welfare point of view under some states of nature of the pair of legitimate availability of technology that each firm faces.

In section 2, we describe our model. In section 3, we derive a equilibrium when one firm's unilateral licensing of two technologies to another firm occurs. In section 4, we derive a equilibrium when one firm's unilateral licensing of one of the two technologies to another firm occurs. Then, we derive a equilibrium when cross-licensing occurs and comparing among three cases.In the final section, we present our concluding remarks.

2 The model

We consider a market in which two firms x and y plan to produce and supply a good. For production of the good, each firm must use two distinct new *completely complementary* technologies, A and B for process innovation. Each firm has already invested in R&D for the these two technologies, A and B, and we know whether they have succeeded in their R&D developments or not, so we also know the states of nature which are their availability of technologies when they produce the good. By "perfectly complementary technologies," we mean that neither firm can produce the goods without using both of the two technologies.

In this paper, we assume that there exists a possibility of spilover of technologies. That is, each firm can produce a good even if it fails to develop a technology/ technologies by infringing its rival's intelectual property rights(IPR) when its rival has succeeded in the development of technology/technologies. But each firm incurs a constant imitation cost $h > 0$ if it infringes its rival's IPR. However, IPR holder can litigate her rival for infringement of her IPR. With probability θ, the plaintiff wins the lawsuit. We look the probability $\theta(0 \leq \theta \leq 1)$ as the magnituides of the government's protection of IPR. Throughout this paper, we ignore the litigation cost for simplicity of the analysis, though it is important in real litigation against the infringement of IPR's. We explore how licensing contract forms (unilateral licensing or cross licensing) between firms affects on market outcomes and welfare when there exist infringement and litigation in this paper.

Let denote AB, if it succeeds in the development of both technologies A and B,

A(B), if it succeeds in the development of technologies A or B, where ,

ϕ, if it fails to develop both technologies A and B.

Then, possible states of nature of the pair of legitimate availability of technology that each firm faces are expressed as Table 1.

Insert here Table 1

For that purpose of the analysis, we concentrates on the three states of nature, $(\phi\ , AB), (A \text{ or } B, AB)$, $(A(B), B(A))$. For the first and the second cases, a unilateral licensing may occur, and a cross licensing may occur for the third case. By symmetry of the firms, we assume that only firm y can decide whether it offers licensing to firm x or not. If each firm fails to develop a technology/ technologies, it can choose whether it infringes its rival's IPR and operates in the market or exits. The market structure, that is, whether monopoly or duopoly prevails depends on the licensing contracts and infringements and states of nature of the pair of legitimate availability of technology each firm faces.

The timing of each corresponding game for these three cases are expressed by the game tree in Figures 1, 3 and 5.

3 Firm y's unilateral licensing of both technologies to firm x– Case a

We consider case 1 in Table 1 in this subsection. We can express the game as an extensive form game in Figure 1. We derive a sub game perfect equilibrium for this game.

Insert here Figure 1

3.1 Firm y's decision at the nodes y_2 and y_3

At the nodes y_2 and in y_3 in Figure 1, firm y decides whether she litigates firm x or not since firm x infringes firm y's technologies at the node x_3. since $\theta\pi^D > 0$, firm y necessary litigates firm x (chooses L). Then, firm x infringes firm y's technologies A and B (chooses I) / exits from the market, if $(1-\theta)\pi^D - 2h \geq 0$ / if otherwise, at the nodes x_2 and in x_3.

3.2 Firm x's decision at the nodes x_1

3.2.1 a-(i)$(1-\theta)\pi^D - 2h \geq 0$

Suppose that $(1-\theta)\pi^D - 2h \geq 0$, so firm x chooses I at the nodes x_2 and in x_3. Suppose also that firm y offers a license of her technologies A and B with the fixed license fee F_y^1 to firm x at node y_1. Note that payoffs $(\pi^D - F_y^1,$ $\pi^D + F_y^1)$ $/((1-\theta)\pi^D - 2h,$ $(1+\theta)\pi^D)$, if firm x accepts/ rejects the offer. Then firm x accepts it if $\pi^D - F_y^1 \geq (1-\theta)\pi^D - 2h$. Now, we solve F_y^1 for this Nash bargaining game.

The Nash bargaining product is defined as follows: $\Pi^1 \equiv [\pi^D - F_y^1 - \{(1-\theta)\pi^D - 2h\}][\ \pi^D + F_y^1 - (1+\theta)\pi^D]$.

$$\frac{\partial \Pi^1}{\partial F_y^1} = -2F_y^1 + 2\theta\pi^D + 2h = 0$$

$$F_y^1 = \theta\pi^D + h \tag{1}$$

From , $\pi^D - F_y^1 = \pi^D - (\theta\pi^D + h) = (1-\theta)\pi^D - h > (1-\theta)\pi^D - 2h$. So firm x accepts the offer at the node x_1 if firm y offer the license to firm x. We see that $\pi^D + F_y^1 = (1-\theta)\pi^D + h > (1-\theta)\pi^D$. The payoff in the right hand side of this inequality is the firm y's payoff when firm y does not offer the license at node y_1. Hence firm y offers the license to firm x at node y_1.

3.2.2 a-(ii)$(1-\theta)\pi^D - 2h < 0$

Suppose that $(1-\theta)\pi^D - 2h < 0$, so firm x chooses E at the nodes x_2 and in x_3. Note that payoffs $(\pi^D - F_y^2,$ $\pi^D + F_y^2)$ $/(0,$ $\pi^M)$, if firm x accepts/ rejects the offer. Then firm x accepts it if $\pi^D - F_y^2 \geq 0$ at node x_1. Now, we solve F_y^2 for this Nash bargaining game.

The Nash bargaining product is defined as follows: $\Pi^2 \equiv [\pi^D - F_y^2 - 0][\ \pi^D + F_y^2 - \pi^M]$.

$$\frac{\partial \Pi^2}{\partial F_y^2} = -2F_y^1 + \pi^M = 0$$

$$F_y^2 = \frac{1}{2}\pi^M \tag{2}$$

We see that $\pi^D - F_y^2 = \pi^D - \frac{1}{2}\pi^M = \frac{1}{2}(2\pi^D - \pi^M) < 0$. Hence firm x rejects the offer at node x_1. So the payoff $(0,$ $\pi^M)/$ $((1-\theta)\pi^D - 2h,$ $(1+\theta)\pi^D)$ realizes, if firm y does not offer(NO)/ does offer (O)the license at node y_1. Since $\pi^M > (1+\theta)\pi^D$, firm y does not (O) it at node y_1. Denote by $s_i(i_j^k)$, the strategy (action) that firm i takes at node i_j^k $(i = x, y; j = 1, 2, 3, k = a)$,where k stands for case k in Table 1. Summarizing the above discussion, we obtain the following proposition:

Proposition 1 *If* $(1-\theta)\pi^D - 2h \geq 0$*, then the sub game perfect equilibrium is* $\{(s_y(y_1^a), s_y(y_2^a), s_y(y_3^a)), (s_x(x_1^a), s_x(x_2^a), s_x(x_3^a))\} = \{(O, L, L), (A, I, I)\}$*, and the correspondent payoffs are* $(\pi^D - F_y^1,\ \pi^D + F_y^1)$ *where* $F_y^1 = \theta\pi^D + h$*. When* $(1-\theta)\pi^D - 2h < 0$*,the sub game perfect equilibrium is*

$\{(s_y(y_1^a), s_y(y_2^a), s_y(y_3^a)), (s_x(x_1^a), s_x(x_2^a), s_x(x_3^a))\} = \{(NO, L, L), (R, E, E)\}$*, and the correspondent payoffs are* $(0, \pi^M)$.

For case a, we can draw the parameters range where duopoly or monopoly occurs at equilibria in $\theta - h$ plane in Figure 2.

Insert here Figure 2

4 Firm y's unilateral licensing of one technology A or B to firm x—- Case b

We consider case c in Table 1 in this subsection. We can express the game as an extensive form game in Figure 3. We derive a sub game perfect equilibrium for this game.

Insert here Figure 3

4.1 Firm y's decision at the nodes y_2 and y_3

At the nodes y_2 and in y_3 in Figure 2, firm y decides whether she litigates firm x or not since firm x infringes firm y's technologies at the node x_3. since $\theta\pi^D > 0$, firm y necessary litigates firm x (chooses L). Then, firm x infringes firm y's technologies A and B (chooses I) / exits from the market, if $(1-\theta)\pi^D - h \geq 0$ / if otherwise, at the nodes x_2 and in x_3.

4.2 b-(i)$(1-\theta)\pi^D - h \geq 0$

Suppose that $(1-\theta)\pi^D - h \geq 0$, so firm x chooses I at the nodes x_2 and in x_3. Suppose also that firm y offers a license of her technology A or B with the fixed license fee F_y^3 to firm x at node y_1. Note that payoffs $(\pi^D - F_y^3,\ \pi^D + F_y^3)$ $/((1-\theta)\pi^D - h,\ (1+\theta)\pi^D)$, if firm x accepts/ rejects the offer. Then firm x accepts it if $\pi^D - F_y^3 \geq (1-\theta)\pi^D - h$. Now, we solve F_y^3 for this Nash bargaining game.

The Nash bargaining product is defined as follows: $\Pi^3 \equiv [\pi^D - F_y^3 - \{(1-\theta)\pi^D - h\}][\ \pi^D + F_y^3 - (1+\theta)\pi^D]$.

$$\frac{\partial \Pi^3}{\partial F_y^3} = -2F_y^3 + 2\theta\pi^D + h = 0$$

$$F_y^3 = \theta\pi^D + \frac{1}{2}h \tag{3}$$

From , $\pi^D - F_y^3 = \pi^D - (\theta\pi^D + \frac{1}{2}h) = (1-\theta)\pi^D - \frac{1}{2}h > (1-\theta)\pi^D - h$. So firm x accepts the offer at the node x_1 if firm y offers the license to firm x. We see that $\pi^D + F_y^3 = (1-\theta)\pi^D + \frac{1}{2}h > (1-\theta)\pi^D$. The payoff in the right hand side of this inequality is the firm y's payoff when firm y does not offer the license at node y_1. Hence firm y offers the license to firm x at node y_1.

4.2.1 b-(ii)$(1-\theta)\pi^D - h < 0$

Suppose that $(1-\theta)\pi^D - h < 0$, so firm x chooses E at the nodes x_2 and in x_3. Note that payoffs $(\pi^D - F_y^4,\ \pi^D + F_y^4)\ /(0,\ \pi^M)$, if firm x accepts/ rejects the offer. Then firm x accepts it if $\pi^D - F_y^4 \geq 0$ at node x_1. Now, we solve F_y^4 for this Nash bargaining game.

The Nash bargaining product is defined as follows: $\Pi^4 \equiv [\pi^D - F_y^4 - 0][\pi^D + F_y^4 - \pi^M]$. Comparing Π^4 with Π^2, we immediately see that $\Pi^4 = \Pi^2$, hence $F_y^4 = F_y^2 = \frac{1}{2}\pi^M$.

We see that $\pi^D - F_y^4 = \pi^D - \frac{1}{2}\pi^M = \frac{1}{2}(2\pi^D - \pi^M) < 0$. Hence firm x rejects the offer at node x_1. So the payoff $(0,\ \pi^M)/\ ((1-\theta)\pi^D - h,\ (1+\theta)\pi^D)$ realizes, if firm y does not offer(NO)/ does offer (O)the license at node y_1. Since $\pi^M > (1+\theta)\pi^D$, firm y does not (O) it at node y_1. Summarizing the above discussion, we obtain the following proposition:

Proposition 2 *If $(1-\theta)\pi^D - h \geq 0$, then the sub game perfect equilibrium is $\{(s_y(y_1^b), s_y(y_2^b), s_y(y_3^b)), (s_x(x_1^b), s_x(x_2^b), s_x(x_3^b))\} = \{(O, L, L), (A, I, I)\}$, and the correspondent payoffs are $(\pi^D - F_y^3,\ \pi^D + F_y^3)$ where $F_y^3 = \theta\pi^D + \frac{1}{2}h$. When $(1-\theta)\pi^D - h < 0$,the sub game perfect equilibrium is*
$\{(s_y(y_1^b), s_y(y_2^b), s_y(y_3^b)), (s_x(x_1^b), s_x(x_2^b), s_x(x_3^b))\} = \{(NO, L, L), (R, E, E)\}$, and the correspondent payoffs are $(0, \pi^M)$.

For case b, we can draw the parameters range where duopoly or monopoly occurs at equilibria in $\theta - h$ plane in Figure 4.

Insert here Figure 4

5 Firm y's cross licensing offer – Case c

We consider case c in Table 1 in this subsection where each firm has a patent of distinct technology. We can express the game as a complex extensive form game in Figure 5. We derive a sub game perfect equilibrium for this game. Here we assume that only firm y offers cross license to firm x for simplicity and consistency of our discussion on all cases a, b and c in Table 1.

Insert here Figure 5

5.1 Firm x's decision at the nodes x_4, x_5, x_6, x_7, x_8 and x_9

Note that firm y *does infringe* firm x's patent at the preceding node of each of x_4, x_5, x_6, x_7, x_8 and x_9.

At nodes x_4 and x_5, firm x always litigates firm y from assumption $\theta\pi^M > \theta\pi^D > 0$. Similarly, we can conclude that firm x always litigates firm y at nodes x_6, x_7, x_8 and x_9 from assumption since $\theta\pi^M > \theta\pi^D > 0$. $\pi^D - h > (1-\theta)\pi^D - h \Longleftrightarrow \theta\pi^D > 0 \Longleftrightarrow (1+\theta)\pi^D - h > \pi^D - h$.

5.2 Firm y's decision at the nodes y_3, y_5, y_6, y_7, y_8 and y_9

Note that firm y chooses her decision at the nodes y_3, y_5, y_6, y_7, y_8 and y_9, under the supposition that firm x always litigates firm y at nodes x_6, x_7, x_8 and x_9. From this fact and the game tree in Figure 5, we can easily derive the following lemma.

Lemma 3 *If $\frac{\pi^D}{\pi^M} > \theta$ and $\pi^D - h \geq \theta\pi^M$, then firm y infringes firm x's patent, but if $\frac{\pi^D}{\pi^M} > \theta$ and $\pi^D - h < \theta\pi^M$, or $\frac{\pi^D}{\pi^M} \leq \theta$, then she exits from the market at the nodes y_8 and y_6. At the nodes y_3, y_5, y_7 and y_9, if $(1-\theta)\pi^M - h \geq 0$, then firm y infringes firm x's patent, but if $h \geq (1-\theta)\pi^M$, then she exits from the market.*

5.3 Firm y's decision at the nodes y_2 and y_4

When $\pi^D - \theta\pi^M > h$ and $\frac{\pi^D}{\pi^M} > \theta$, firm y infringes at all the nodes y_3, y_5, y_6, y_7, y_8 and y_9 from the above lemma. When $\frac{\pi^D}{\pi^M} > \theta$ and $\pi^D - h < \theta\pi^M$, or $\frac{\pi^D}{\pi^M} \leq \theta$, then she exits from the market at the nodes y_8 and y_6, but firm y infringes all the nodes y_3, y_5, y_7 and y_9. So when $\pi^D - \theta\pi^M > h$ and $\frac{\pi^D}{\pi^M} > \theta$, if $\pi^D - h \geq (1-\theta)\pi^D - h$ then firm y litigates firm x but does not litigate otherwise at the nodes y_2 and y_4. However, firm y always litigates at these nodes since $\pi^D - h \geq (1-\theta)\pi^D \Longleftrightarrow \theta\pi^D \geq 0$ and the latter inequality holds from the assumption. When $\frac{\pi^D}{\pi^M} > \theta$ and $\pi^D - h < \theta\pi^M$, or $\frac{\pi^D}{\pi^M} \leq \theta$, if $h > \max\{(1-\theta)\pi^D - \theta\pi^M, 0\}$, then firm y litigates firm x , but if $h \leq \max\{(1-\theta)\pi^D - \theta\pi^M, 0\}$, then does not litigate at the nodes y_2 and y_4. If $(1-\theta)\pi^M > h \geq \max\{\pi^D - \theta\pi^M, 0\}$, then firm y infringes at the nodes y_3, y_5, y_7 and y_9, but exits from the market at the nodes y_6 and y_8. Taking into account these facts and from Fifure 5, firm y's optimal decision at the nodes y_2 and y_4 can be characterize as follows: If $h > \max\{(1-\theta)\pi^D - \theta\pi^M, 0\}$, then firm y should litigate firm x , but if $h \leq \max\{(1-\theta)\pi^D - \theta\pi^M, 0\}$, then should not litigate at the nodes y_2 and y_4. When $h \geq (1-\theta)\pi^M$, from the lemma, firm y exits from the market at all the nodes y_3, y_5, y_6, y_7, y_8 and y_9. However, from Figure 5, the realizing firm y's payoff when firm y litigates is $\theta\pi^M$, which is greater than 0, the realizing firm y's payoff when firm y does not, so firm y should litigate firm x in this case. Sumarizing the above discussion, we obtain the following lemma.

Lemma 4 *If* $\frac{\pi^D}{\pi^M} > \theta$ *and* $\pi^D - \theta\pi^M > h$ *, firm y always litigates firm x at the nodes* y_2 *and* y_4*. When* $\frac{\pi^D}{\pi^M} > \theta$ *and* $\pi^D - h < \theta\pi^M$*, or* $\frac{\pi^D}{\pi^M} \leq \theta$ *or* $(1-\theta)\pi^M > h \geq \pi^D - \theta\pi^M$*, if* $h > \max\{(1-\theta)\pi^D - \theta\pi^M, 0\}$*, then firm y litigates firm x , but if* $h \leq \max\{(1-\theta)\pi^D - \theta\pi^M, 0\}$*, then does not litigate at the nodes* y_2 *and* y_4*. When* $h \geq (1-\theta)\pi^M$*, firm y litigates firm x at the nodes* y_2 *and* y_4*.*

5.4 Firm x's decision at the nodes x_2 and x_3

From the above two lemmas and the game tree in Figure 5, we immediately see that firm x always infringes firm y's patent when $\frac{1}{2} > \frac{\pi^D}{\pi^M} > \theta$ and $\pi^D - \theta\pi^M > h$ at the nodes x_2 and x_3, since $\pi^D - h > \theta\pi^M$, where the left/ right hand side of the inequality stands for firm x's payoff when firm x chooses I / E at nodes x_2 and x_3 *:* When $\frac{1}{2} > \frac{\pi^D}{\pi^M} > \theta$ and $(1-\theta)\pi^M > h \geq \pi^D - \theta\pi^M$, we see that if $\pi^M - 2\theta\pi^M \geq h \Leftrightarrow (1-\theta)\pi^M \geq \theta\pi^M / \pi^M - 2\theta\pi^M < h \Leftrightarrow (1-\theta)\pi^M < \theta\pi^M$, firm x chooses I /E at nodes x_2 and x_3 from the above two lemmas and the game treei n Figure5.When $\frac{\pi^D}{\pi^M} > \theta$ and $h \geq (1-\theta)\pi^M$, firm x also exits from the market at nodes x_2 and x_3 since $h \geq (1-\theta)\pi^M$. When $\frac{\pi^D}{\pi^M} \leq \theta$ and $\pi^M - \theta\pi^M > h > 0$, firm x chooses I /E at nodes x_2 and x_3 if $\pi^M - 2\theta\pi^M \geq h > 0/\ \pi^M - 2\theta\pi^M \leq h < (1-\theta)\pi^M$. But if $\frac{\pi^D}{\pi^M} \leq \theta$ and $(1-\theta)\pi^M \leq h$, firm x always exits form the market at nodes x_2 and x_3 . Sumarizing these, we present the following lemma.

Lemma 5 *If* $\frac{1}{2} > \frac{\pi^D}{\pi^M} > \theta$ *and* $\pi^D - \theta\pi^M > h$ *, firm x always infringes firm y's patent at the nodes* x_2 *and* x_3*. When* $\frac{1}{2} > \frac{\pi^D}{\pi^M} > \theta$ *and* $(1-\theta)\pi^M > h \geq \pi^D - \theta\pi^M$*, if* $\pi^M - 2\theta\pi^M \geq h/\pi^M - 2\theta\pi^M < h$*, then firm x infringes firm y's patent /exits from the msrket at nodes* x_2 *and* x_3*. When* $\frac{\pi^D}{\pi^M} > \theta$ *and* $h \geq (1-\theta)\pi^M$*, firm x also exits from the market at nodes* x_2 *and* x_3*. When* $\frac{\pi^D}{\pi^M} \leq \theta$ *and* $\pi^M - \theta\pi^M > h > 0$*, firm x chooses I /E at nodes* x_2 *and* x_3 *if* $\pi^M - 2\theta\pi^M \geq h > 0/\ \pi^M - 2\theta\pi^M \leq h < (1-\theta)\pi^M$*. But if* $\frac{\pi^D}{\pi^M} \leq \theta$ *and* $(1-\theta)\pi^M \leq h$*, firm x always exits form the market at nodes* x_2 *and* x_3 *.*

5.5 Firm x's/y's decision at the nodes x_1/ y_1

From Lemma 3, Lemma 4, Lemma 5 and the game tree in Figure 5, firm y always offers a cross license contract at node y_1 and firm x accepts it at node x_1 when $\frac{1}{2} > \frac{\pi^D}{\pi^M} > \theta$ and $\pi^D - \theta\pi^M > h$, since $\pi^D > \pi^D - h$. When $\frac{1}{2} > \frac{\pi^D}{\pi^M} > \theta$ and $(1-\theta)\pi^M > h \geq \pi^D - \theta\pi^M$, if $\pi^M - \pi^D - \theta\pi^M \geq h \geq \pi^D - \theta\pi^M / (1-2\theta)\pi^M > h \geq \pi^M - \pi^D - \theta\pi^M$, then firm y always offers a cross license contract at node $y_1$and firm x rejects/accepts it at node x_1. If $\frac{1}{2} > \frac{\pi^D}{\pi^M} > \theta$ and $(1-\theta)\pi^M > h \geq (1-2\theta)\pi^M$ or $h \geq (1-\theta)\pi^M$, firm y always offers a cross license contract at node $y_1$and firm x accepts it at node x_1. When $\frac{\pi^D}{\pi^M} \leq \theta$ and $\pi^M - \pi^D - \theta\pi^M \geq h > 0$, firm y does not offer her cross licence contract at node y_1 since firm x always rejects it t node x_1 even if she offer the contract to firm x.at nodes x_1.

If $h > \pi^M - \pi^D - \theta\pi^M$, then firm y always offers a cross license contract at node y_1 and firm x accepts it at node x_1. Sumarizing the above, we present the following lemma.

Lemma 6 *Firm y always offers a cross license contract at node y_1 and firm x accepts it at node x_1 when $\frac{1}{2} > \frac{\pi^D}{\pi^M} > \theta$ and $\pi^D - \theta\pi^M > h$. When $\frac{1}{2} > \frac{\pi^D}{\pi^M} > \theta$ and $(1-\theta)\pi^M > h \geq \pi^D - \theta\pi^M$, if $\pi^M - \pi^D - \theta\pi^M \geq h \geq \pi^D - \theta\pi^M$ /$(1-2\theta)\pi^M > h \geq \pi^M - \pi^D - \theta\pi^M$, then firm y always offers a cross license contract at node $y_1$and firm x rejects/ accepts it at node x_1. If $\frac{1}{2} > \frac{\pi^D}{\pi^M} > \theta$ and $(1-\theta)\pi^M > h \geq (1-2\theta)\pi^M$ or $h \geq (1-\theta)\pi^M$, firm y always offers a cross license contract at node $y_1$and firm x accepts it at node x_1. When $\frac{\pi^D}{\pi^M} \leq \theta$ and $\pi^M - \pi^D - \theta\pi^M \geq h > 0$, firm y does not offer her cross licence contract at node y_1 since firm x always rejects it t node x_1. If $h > \pi^M - \pi^D - \theta\pi^M$, then firm y always offers a cross license contract at node y_1 and firm x accepts it at node x_1.*

5.6 Equilibrium of the Entire Game

By Lemma 3, Lemma 4, Lemma 5 and Lemma 6, we can obtain the main result of this section.

Proposition 7 *When $\frac{1}{2} > \frac{\pi^D}{\pi^M} > \theta$ and $\pi^D - \theta\pi^M > h$, then the sub game perfect equilibrium is*
$\{(O,L,I,L,I,I,I,I,I),(A,I,I,L,L,L,L,L,L)\}$ and the correspondent payoff is $(\ \pi^D, \pi^D)$.

When $\frac{1}{2} > \frac{\pi^D}{\pi^M} > \theta$ and $\pi^M - \pi^D - \theta\pi^M \geq h \geq \pi^D - \theta\pi^M$, then the sub game perfect equilibrium is$\{(O,L,I,L,I,E,I,E,I),(R,I,I,L,L,L,L,L,L)\}$ and the correspondent payoff is $(\ (1-\theta)\pi^M - h, \theta\pi^M)$.

When $\frac{1}{2} > \frac{\pi^D}{\pi^M} > \theta$ and $(1-2\theta)\pi^M > h \geq \pi^M - \pi^D - \theta\pi^M$, then the sub game perfect equilibrium is $\{(O,L,I,L,I,E,I,E,I),(A,I,I,L,L,L,L,L,L)\}$ and the correspondent payoff is $(\ \pi^D, \pi^D)$.

When $\frac{1}{2} > \frac{\pi^D}{\pi^M} > \theta$ and $(1-\theta)\pi^M > h \geq (1-2\theta)\pi^M$, then the sub game perfect equilibrium is $\{(O,L,I,L,I,E,I,E,I),(A,E,E,L,L,L,L,L,L)\}$ and the correspondent payoff is $(\ \pi^D, \pi^D)$.

When $\frac{1}{2} > \frac{\pi^D}{\pi^M} > \theta$ and $h \geq (1-\theta)\pi^M$, then then the sub game perfect equilibrium is $\{(O,L,E,L,E,E,E,E,E),(A,E,E,L,L,L,L,L,L)\}$ and the correspondent payoff is $(\ \pi^D, \pi^D)$. When $\frac{\pi^D}{\pi^M} \leq \theta$ and $\pi^M - \pi^D - \theta\pi^M \geq h > 0$, then the sub game perfect equilibrium is $\{(NO,L,I,L,I,E,I,E,I),(R,I,I,L,L,L,L,L,L)\}$ and the correspondent payoff is $(\ (1-\theta)\pi^M - h, \theta\pi^M)$.

If $\frac{\pi^D}{\pi^M} \leq \theta$ and $(1-2\theta)\pi^M > h \geq \pi^M - \pi^D - \theta\pi^M$, then the sub game perfect equilibrium is $\{(O,L,I,L,I,E,I,E,I),(A,I,I,L,L,L,L,L,L)\}$ and the correspondent payoff is $(\ \pi^D, \pi^D)$. If $\frac{\pi^D}{\pi^M} \leq \theta$ and $(1-\theta)\pi^M > h \geq (1-2\theta)\pi^M$, then the sub game perfect equilibrium is $\{(O,L,I,L,I,E,I,E,I),(A,E,E,L,L,L,L,L,L)\}$ and the correspondent payoff is $(\ \pi^D, \pi^D)$.

When $\frac{\pi^D}{\pi^M} \leq \theta$ and $h \geq (1-\theta)\pi^M$, then then the sub game perfect equilibrium is $\{(O, L, E, L, E, E, E, E, E), (A, E, E, L, L, L, L, L, L)\}$ and the correspondent payoff is $(\ \pi^D, \pi^D)$.

For case c, we can draw the parameters range where duopoly or monopoly occurs at equilibria in $\theta - h$ plane in Figure 6.

Insert here Figure 6

Comparing Figure 6 with Figure 2 and Figure 4, we see that the area of duopoly at the equilibrium expands in $\theta - h$ plane as the state of nature of the pair of legitimate availability of technology each firm faces transits from $(\phi\ , AB)$ or (A or B, AB) to $(A(B), B(A))$.Furthermore, in the state $(A(B), B(A))$ in which a cross licensing may occur, the possibility that welfare superior duopoly market outcome occurs increases as the magnituides of the government's protection of IPR s θ increases.

6 Concluding Remarks

In this paper, we have explored how licensing contract forms (unilateral licensing or cross licensing) between firms affects on market outcomes and welfare when there exist infringement and litigation.by analyzing a simple duopolistic firms facing technological innovation in completely complementary technologies for process innovation. In this paper, we assume that there exists a possibility of spilover of technologies. That is, each firm can produce a good even if it fails to develop technologies by infringing its rival's intelectual property rights(IPR) when its rival has succeeded in the development of technologies. For that purpose of the analysis, we concentrates on the three states of nature, $(\phi\ , AB)$, (A or B, AB), $(A(B), B(A))$. For the first and the second cases, a unilateral licensing may occur, and a cross licensing may occur for the third case. We formulated three multi-stage games for these three cases, and derive a sub game perfect equilibrium in each cases. Comparing these three equilibria, we find that the area of duopoly at the equilibrium expands in $\theta - h$ plane as the state of nature of the pair of legitimate availability of technology each firm faces transits from $(\phi\ , AB)$ or (A or B, AB) to $(A(B), B(A))$.Furthermore, in the state $(A(B), B(A))$ in which a cross licensing may occur, the possibility that welfare superior duopoly market outcome occurs increases as the magnituides of the government's protection of IPR s θ increases.

There remain many topics for future research. We focused on the licensing contract game in order to make our analysis easy. Preceding the licensing contract stage, however, we have to add firms' R&D competition stage and explore firm's incentives for R&D. To clarify how governments should plan and exercise policy for technologies under complementary technological innovations, it is important for us to explore the implications on economic welfare at the equilibrium in our model.

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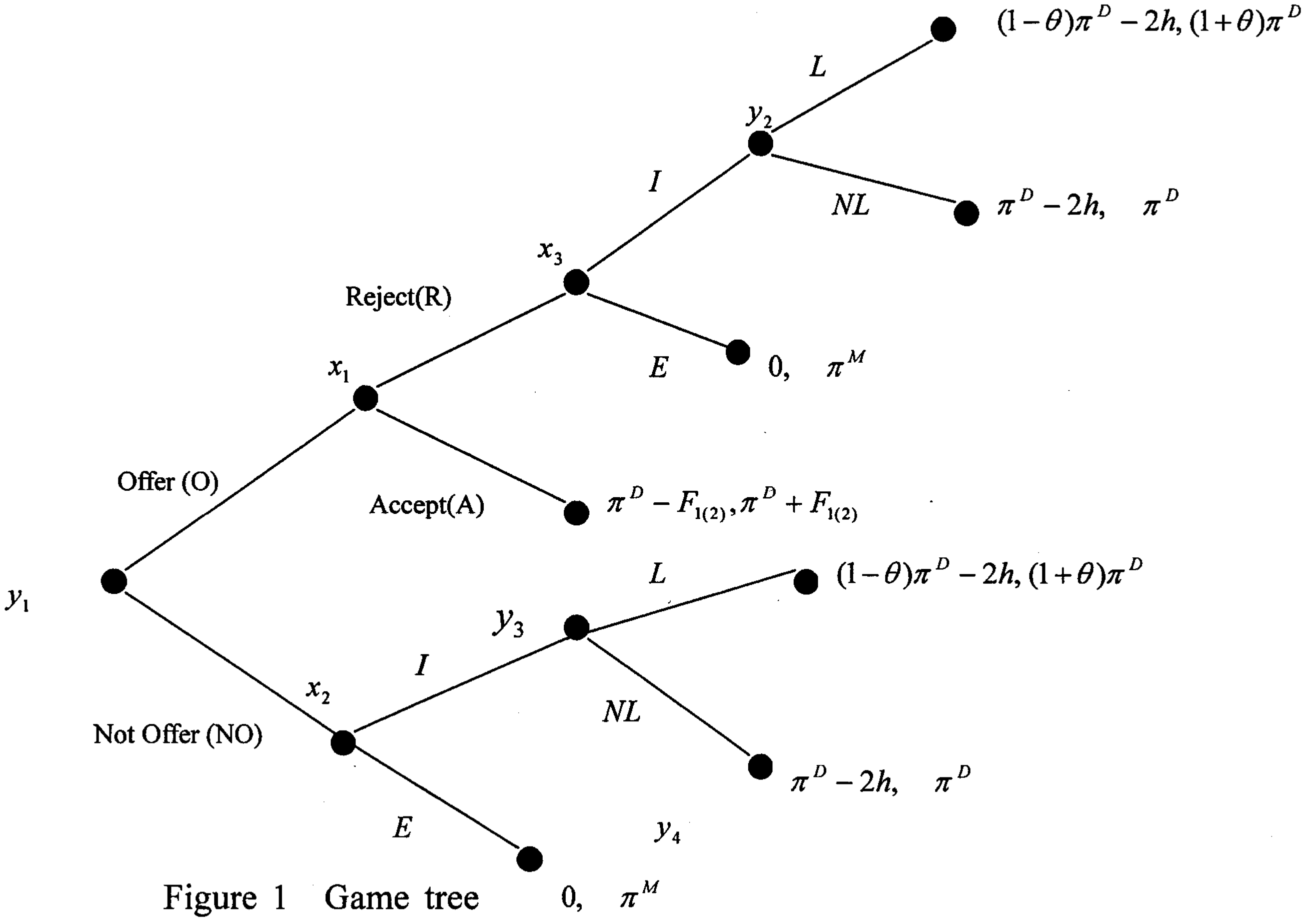

Figure 1 Game tree in state (ϕ , AB)

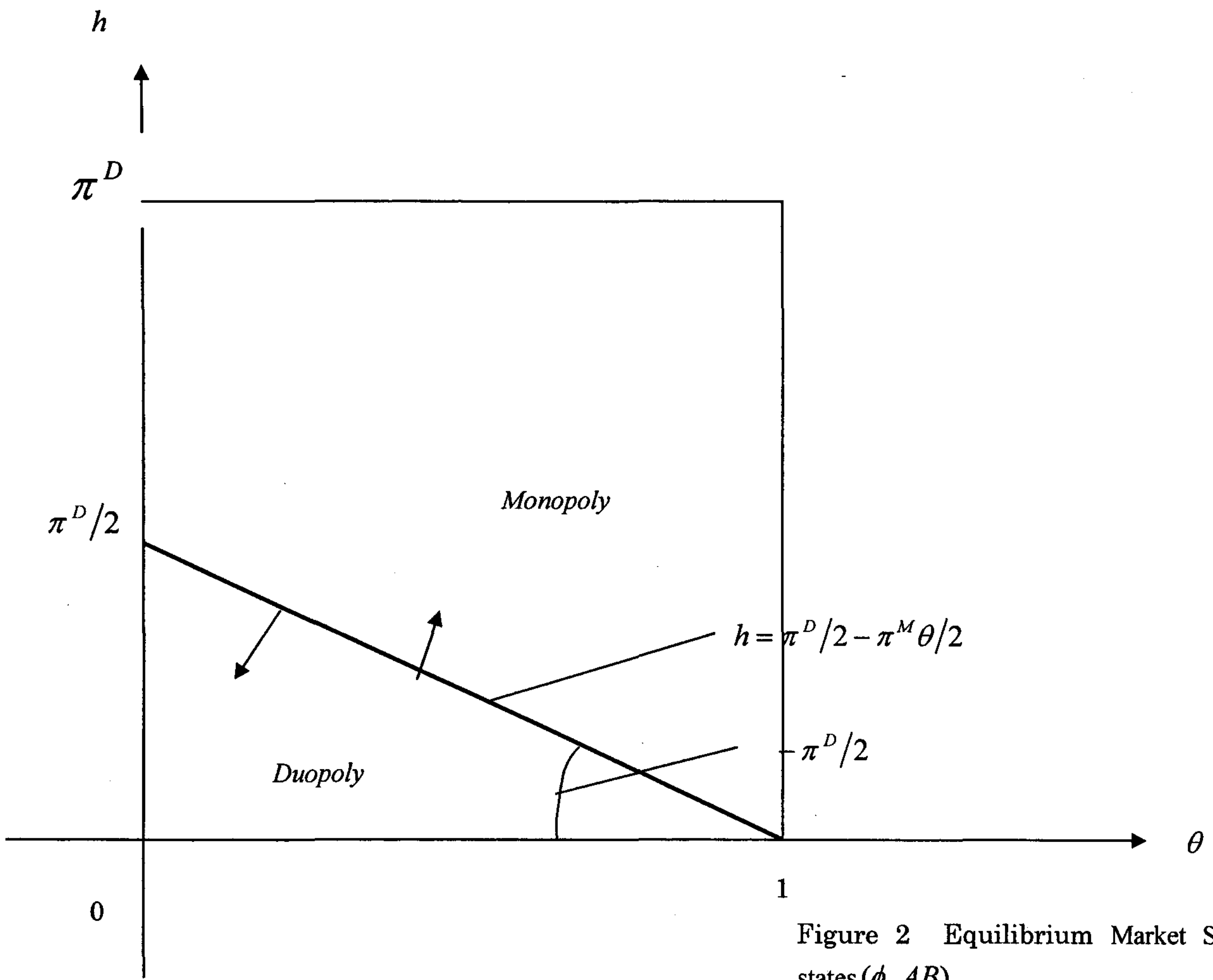

Figure 2 Equilibrium Market Structure in states (ϕ, AB)

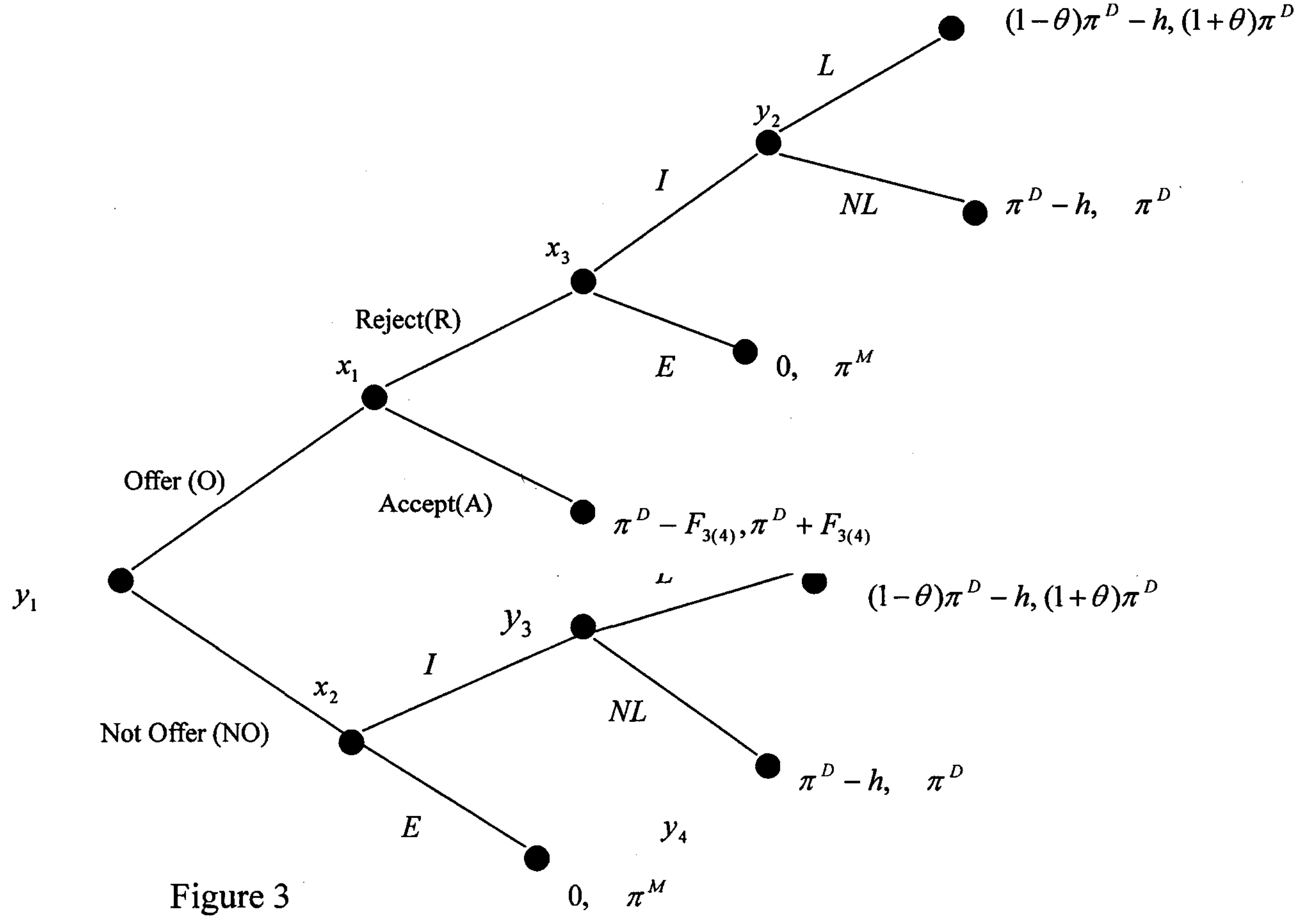

Figure 3
Game tree in state
(*A(B), AB*)

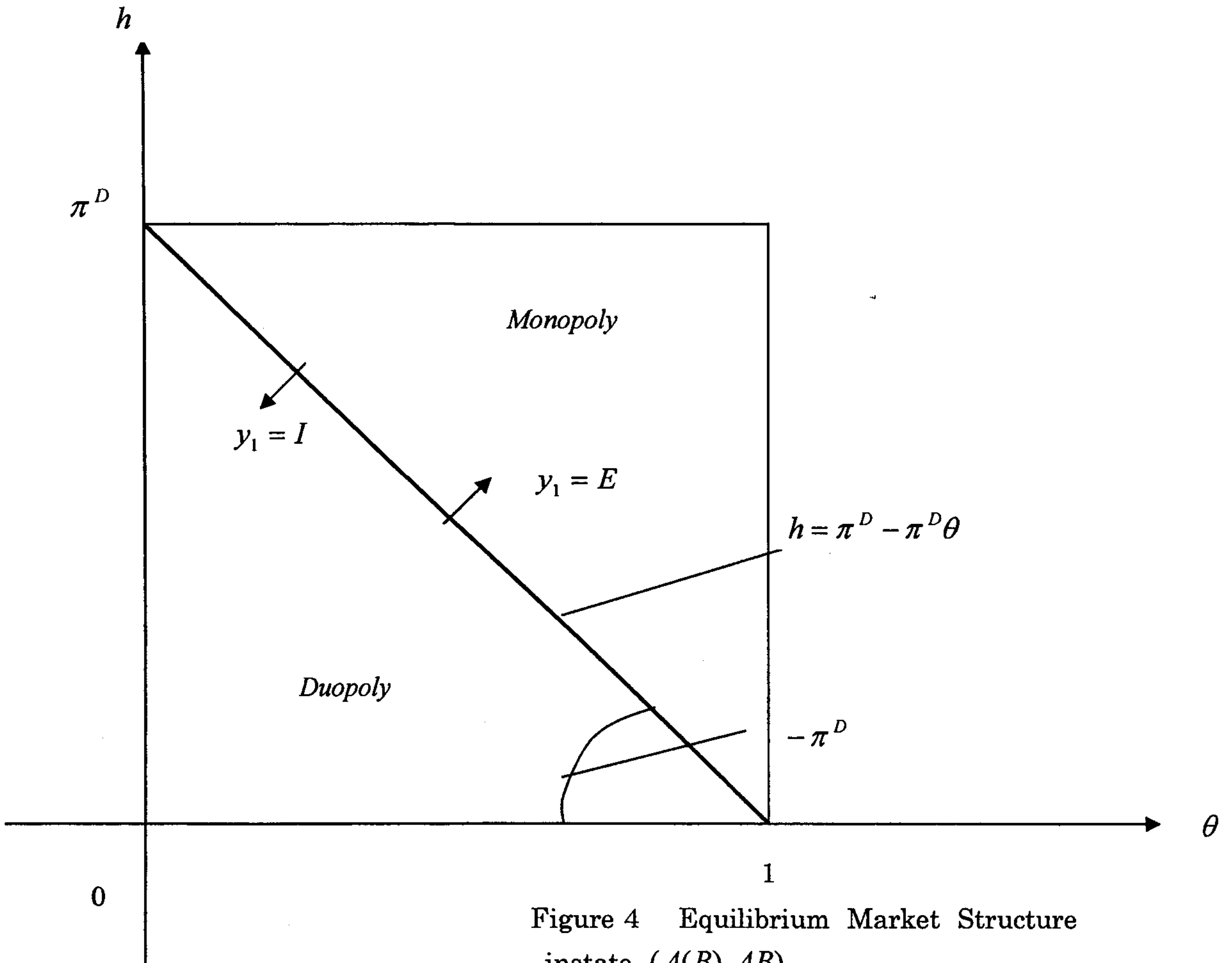

Figure 4 Equilibrium Market Structure instate $(A(B), AB)$

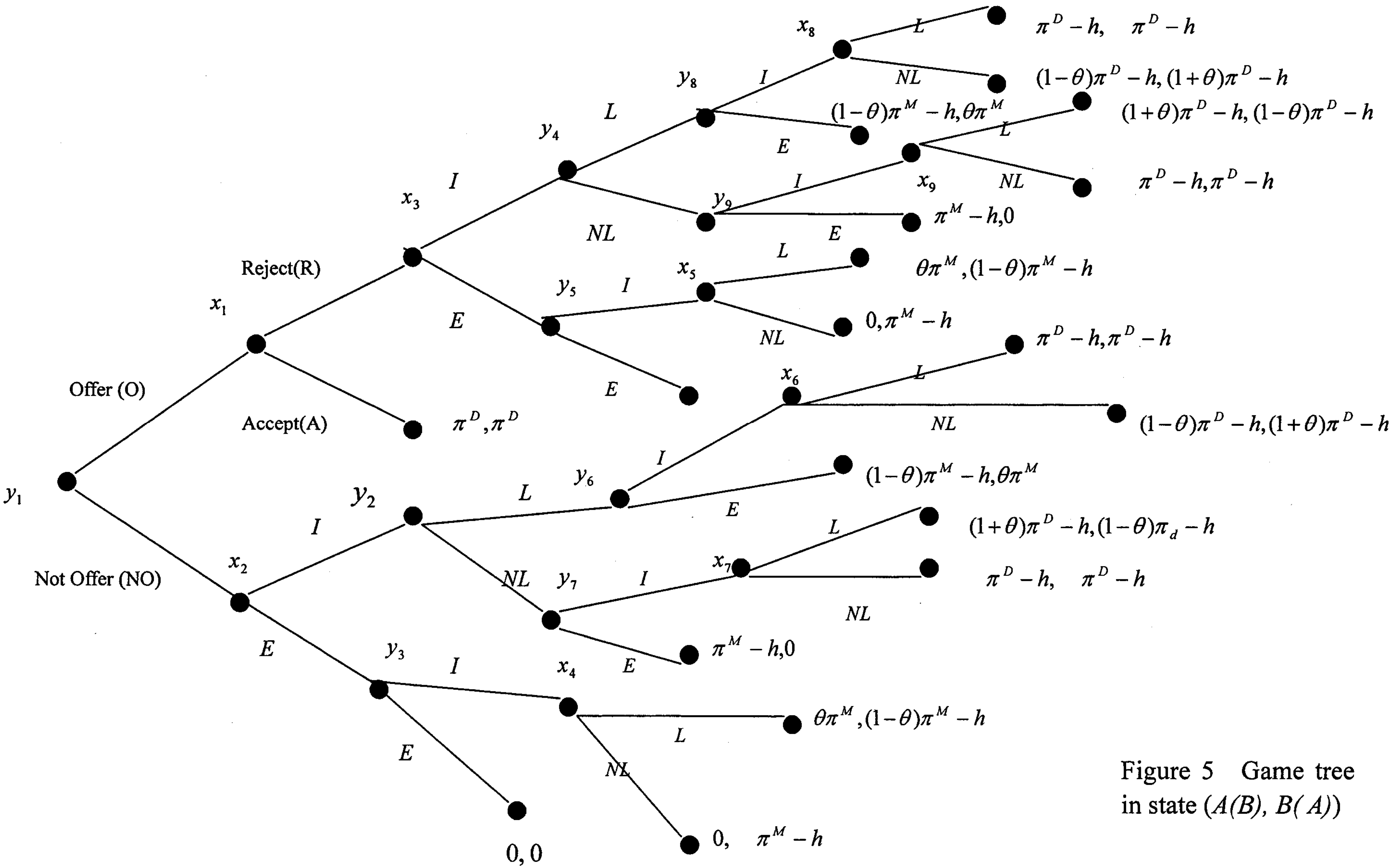

Figure 5 Game tree in state (*A(B), B(A)*)

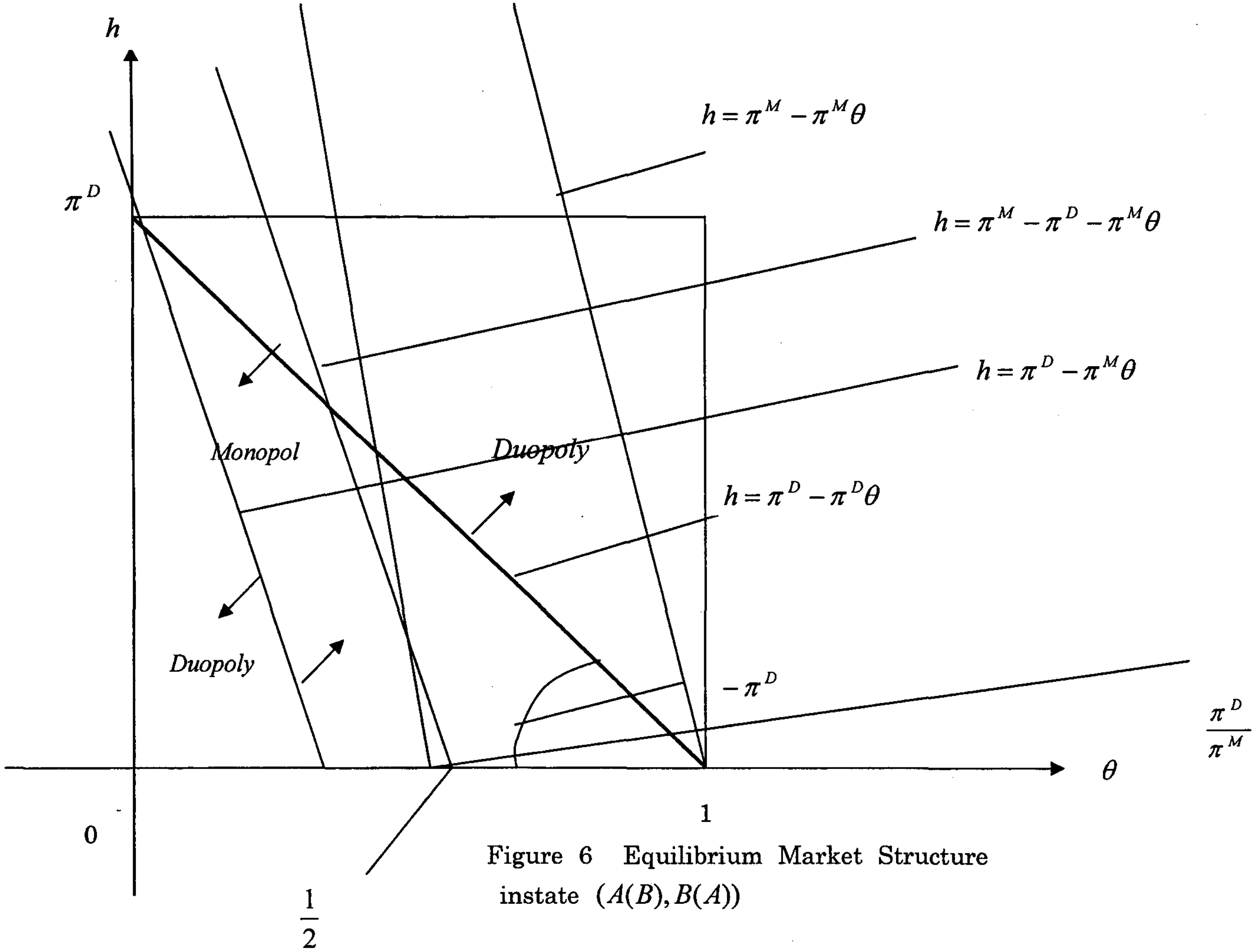

Figure 6 Equilibrium Market Structure instate $(A(B),B(A))$