นโยบายคุ้มครองสิทธิทรัพย์สินทางปัญญากับความไม่สมมาตรในผลิตภาพในการวิจัยและพัฒนาและสินค้าที่มีความแตกต่างกัน

นายวศิน โรจยารุณ

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาเศรษฐศาสตร์มหาบัณฑิต
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Intellectual Property Rights Protection, Rival's Asymmetry and Differentiated Products

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วศิน โรจยารุณ : นโยบายคุ้มครองสิทธิทรัพย์สินทางปัญญากับความไม่สมมาตรในผลิตภาพในการวิจัยและพัฒนาและสินค้าที่มีความแตกต่างกัน (INTELLECTUAL PROPERTY RIGHTS PROTECTION, RIVAL'S ASYMMETRY AND DIFFERENTIATED PRODUCTS) อ.ที่ปรึกษาวิทยานิพนธ์หลัก : อ.ดร. เขมรัฐ เถลิงศรี 47 หน้า.

งานวิจัยฉบับนี้มุ่งศึกษาความขัดแย้งของมุมมองด้านนโยบายคุ้มครองสิทธิในทรัพย์สินทางปัญญาของประเทศที่เป็นผู้นำทางการคิดค้นเทคโนโลยีและประเทศที่เป็นผู้ตาม และศึกษาความสัมพันธ์ระหว่างข้อขัดแย้งนี้กับระดับความแตกต่างของสินค้า การศึกษาใช้แบบจำลองเกมส์ของผู้เล่นสองรายที่ทำงานวิจัยและพัฒนาเพื่อลดต้นทุนการผลิต โดยที่ฝ่ายผู้นำทางด้านการคิดค้นเทคโนโลยีมีความสามารถในการนำผลวิจัยไปใช้ลดต้นทุนการผลิตได้ดีกว่าผู้ตาม และสินค้าที่ผลิตจากประเทศผู้นำและประเทศผู้ตามมีลักษณะที่แตกต่างกัน ผลการศึกษาพบข้อสรุปที่สำคัญอยู่สองประการ 1.) นโยบายคุ้มครองสิทธิในทรัพย์สินทางปัญญาอาจจะไม่ส่งผลให้ผู้ผลิตทำการวิจัยและพัฒนาเพิ่มขึ้นเสมอไปหากสินค้ามีความแตกต่างกันมากในระดับหนึ่ง 2.) แม้ว่าทั้งสองประเทศจะมีความสามารถในการนำผลวิจัยและพัฒนาไปใช้ต่างกันแต่ความขัดแย้งเกี่ยวกับนโยบายคุ้มครองสิทธิในทรัพย์สินทางปัญญาอาจจะไม่เกิดขึ้นถ้าสินค้ามีความแตกต่างกันมากพอ

สาขาวิชา เศรษฐศาสตร์ ลายมือชื่อนิสิต .....

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This study focuses on a conflict of interests regarding the Intellectual Property Rights protections (IPRs) regime in a North-South context. In order to examine reaction of each related party, a duopolistic Cournot game with cost-reducing R&D model is employed. We observe and compare equilibrium outcomes of 2 regimes: no protection regime and full protection regime. The main feature of this study is an introduction of product differentiation between the North and the South products. The model of Poyago-Theotoky and Teerasuwannajak (2012) is extended to study the consequences of different degrees of product differentiation on the conflict of interests. The analysis leads to 2 main results: 1.) IPR protection may fail to strengthen private R&D incentives if products are significantly differentiated even when R&D productivity of the two countries are very different 2.) The conflict regarding the strength of IPRs protection regime is less severe as products become more differentiated.

Field of Study : ECONOMICS Student's Signature .....

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Chapter 1

Introduction

During the Uruguay round, the World Trade Organization raised concerns on complexity of issue relating to Intellectual Property (IP), WTO member countries passed the Agreement on Trade-related Aspects of Intellectual Property Rights(IPRs) which was known as TRIPs. It is the arrangement for member countries to enforce minimum standard of rules to provide "rights" to "use their own creation exclusively" for the creators. One purpose of this agreement is to encourage private businesses to conduct R&D. By providing some governing rules and tools; such as patent, copyright, trademark and trade secret, IPRs protection succeed in encouraging private incentives to invest in R&D, considering from the fast growth in sectors which knowledge and innovation play a key role[1], such as pharmaceutical, biochemical and IT industries.(Lopez, 2009)

Economists use the term "R&D spillover" to capture the idea that some economic benefits of R&D accrue to agents other than those who engage in R&D activities. Spillover is an example of positive externality. Firms normally decide on R&D investment by considering profits they can derive from R&D activities. However, one serious problem is the knowledge spillover; it is the phenomenon that competitors can replicate existing knowledge of R&D without compensation, which in turn reduces business incentives to conduct R&D since competitors also

[1] R&D may not only benefits business by improving existing product or production process but also could be traded as "knowledge product". For examples, database service, software algorithms or business plan. See Chantel, Grinaud and Tournemaine (2012) for more information.

become stronger by its R&D[2]. IPRs protection could encourage private businesses to engage in R&D by provide "monopoly power" to the creator over their innovation.[3]

While the IPRs protection is widely implemented at a global level, there is a conflict of interests between North and South country in desired policy. Traditionally in economic literature, North country is referred to the country where the majority or all of R&D take place. The North tends to favor IPRs implementation. On the contrary, South country is referred to an imitator and favors lax IPRs protection. Even though South country agrees to follow the agreement on IPRs, there is still lack of incentives to enforce the lawful protection. That is why the question regarding the necessity of IPRs protection arises. Much literature considers this conflict of interests in the context of North-South trade. Theoretical studies in this area focus on the consequences of different levels of protection in terms of a social welfare. These findings show conflict of interests on this issue under various conditions. (e.g. Chin and Grossman, 1990; Diwan and Rodrik, 1991; Deardorff, 1992; Helpman, 1993 Zigic; 1998 and Liao and Wong, 2009)

Notwithstanding, a rapid growth in the automobile sector in China challenges this traditional conflict of interests issue. A weak R&D intensity

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[2] Jaffe (1996) categories R&D spillover into 3 sources. 1) Market spillover refers to benefits occurring to purchasers who buy cheaper or better products 2) knowledge spillover refers to benefits occurring to competitor who could imitate a successful innovation. 3.) Network spillover refers to benefits occurring to all creators who could create new knowledge by assembling knowledge.

[3] Recent view on IPRs protection argues that IPRs may increase spillover since an idea protected by IPRs need to publish (patent or copyrights). This study focus on that the IPRs protection enforces law about imitation; copying is illegal. Spillover remains exist but cost of imitation occur so competitors would not utilize knowledge of R&D spillover anymore.

country, like China, experienced a large expansion in automobile production and became the largest producer in automobile sector since 2009. Global automobile manufacturers' FDI has flowed into China and many joint-venture companies have been established in China as well since the last decade. This FDI comes with technology and knowledge transfer, encourages China to build its own innovative capability (Fang and Mohnen). Local automobile companies are strengthened by innovation spillover and technology leakage as the weak IPRs protection. In the past, Chinese brands were characterized as poor-quality by buyers but, nowadays, those local automobile companies could launch some middle or high grade vehicles similar to those foreign companies.

Nonetheless, foreign automotive companies are not seriously concern about the strength of IPRs protection because the Chinese local automobile companies are neither their direct nor major competitors with those automobile companies from foreign countries. Main reasons for weaker competitiveness are poor consumer perception and brand royalty toward their automobile, Chinese car and foreign-brand car are differentiated in the views of purchasers. A consumer survey data, by TNS consultant company,[4] shows that brand is the major factor influencing customers' decisions to buy a car.[5]

The question posed here is how this product differentiation changes the traditional conflict of interests issue. Does IPRs protection still matter in the environment where consumers view that products are quite different? The traditional model is extended to analyze the role of product differentiation.

[4] In the publication named "Automotive Dealerships in China: Accelerating Performance"

[5] Survey data from 1041 car-buyers across China in early 2007.

According to previous literatures, there is no study that focuses directly on a relationship between product differentiation and the conflict of IPRs protection. Most of them assumed the product homogeneity. Therefore, the objective of this paper is to provide a simple model to fill the gap of the literature by analyzing how product differentiation alters the country's perspective toward IPRs protection. The formal multistage game model used in this study is the model of Poyago-Theotoky and Teerasuwannajak (2012) (henceforth, PT model).[6] This study assume that the North represents country that is superior in their ability to utilize R&D whereas the South refers to the country that although is capable of performing R&D, but has lower ability to utilize it. Beyond most literature on IPRs issue, this study adds the feature of product differentiation into the model in order to capture the variation in consumer perception regarding substitutability between product from the North and South.

In the next chapter, I review existing literature to point out how my model differs from others. The model setup and analysis will be explained thoroughly in the third chapter. And the last chapter will give a brief summary of this study.

[6] The intuition of the model will be discuss in chapter 2

Chapter 2

Literature Review

In this chapter, previous studies associated to this topic are revised. I considered theoretical model relating to R&D decision and North-South disagreement in IPRs regimes. Some literature is examined to clarify my model and point out key difference.

Before IPRs regimes were criticized, a number of R&D decision with spillover model were established[1]. The principal work that shed light on later studies were Spencer and Brander (1983) and Katz (1986), they initially developed the multistage game of R&D decision and quantity base on assumption that R&D was undertaken before the associated output was produced and firms anticipated the effect of R&D on output share. d'Aspremont and Jacquermin (1988) followed this assumption and investigated the effect of R&D cooperation as spillover in duopolistic competition. The main feature of d'Aspremont and Jacquermin model is that firms decide on R&D investment in the early stage with potentially spillover to their competitors if they cooperate in R&D competition, and firms competed in the market in the later stage. This formal model was extended by various studies (e.g. Suzumura, 1992; Kamien, Muller and Zang, 1992; Poyago-Theotoky, 1996a and Amir and Wooders, 1997).[2]

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[1] See Loury (1979) Reinganum (1979) and Steward (1983) for examples of "racing game".

[2] Suzumura (1992) studied the effect of cooperation in oligopoly. Kamien et al. (1992) compared various types of cooperation in R&D and good markets competition, Poyako-Theotoky (1996a) analyzed the number of firm endogenously in the formal model. Amir and Wooders (1998) examined stability of the equilibrium in the formal model.

This formal model is considered to be the type of “strategic approach” that players choose R&D level strategically to responding to other competitors.

This formal multistage game model of R&D decision is also used in the study of IPRs protection because the strategic approach could be applied to the North-South conflicts of interests issue. Moreover, the level of spillover could be represented by the strength of IPRs protection. A high level of R&D spillover could be referred as a weak IPRs protection and a low level of R&D spillover refers strong IPRs protection.

Focusing on IPRs issue, the study of Chin and Grossman (1990) is the important work which firstly adapted multistage game of R&D decision to the North-South conflict of interests. They considered the duopolistic quantity competition between North-South. The main assumption is that the North could engage in cost-reducing R&D while the South could not and just imitate technology from the North. They analyzed the welfare of the North and the South, comparing between full IPRs protection and no IPRs protection. The South could imitate R&D knowledge from the North only in no IPRs protection case. The results emphasis on conflict of interest that North and South always disagree on the desired policy because the North benefits from IPRs but the South lose profits unless the South has a large share in the good market which make the South better off in the welfare term. The study of Chin and Grossman not only raised an issue of appropriate IPRs protection regimes but also gave a very useful assumption about Northern-Southern asymmetry that North has capability to conduct R&D while South does not have and just imitate it. Later

study such as Diwan and Rodrik (1991)[3], Helpman (1993)[4] and Žigić (1998)[5] also characterized North and South country by the same way ; R&D is only take place in the North, and the South just imitate it.

However, recent studies characterize North-South asymmetry in the different way. Some assume that the South has capability to engage in R&D but different in "*ex-ante"* characteristic, North has capability and advance in some initial attribute since it is better in infrastructures or has more experience in production. Poyago-Theotoky (1996b) is the first use duopoly model of R&D decision with the assumption that both North and South could engage in cost-reducing R&D cost reduction but different in pre-innovation cost. In addition, North is more productive with low pre-innovation cost whereas South is weaker with high pre-innovation cost. The type of setup also use in the study of Barros and Nilssen (1999)[6] and Ishida, Matsumura and Matsushima (2011).

Another way to characterize North-South asymmetry is assumption about R&D productivity. Liao and Wong (2009) and Poyago-Theotoky and Teerasuwannajak (2012) assumed that North South also had cost-reducing R&D capacity but had lower productivity comparing to the North. By the same level of R&D available for them, North could reduce production cost more than the South.

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[3] Diwan and Rodrik (1991) assumed that North and South have differing technological needs. Due to the R&D resource constrain, North may choose to innovate in the specific area of technology that very useful to North but not much for South.

[4] Helpman (1993) investigated the North-South conflict by using a general equilibrium framework and endogenous growth model to observe how the degree of IPRs protection could affect welfare of both players.

[5] Žigić (1999) emphasized the conflict of interest by allowing a degree of protection between the North and the South to see how it affects equilibrium outcome.

[6] Barros and Nilssen (1999) studied competition in firm heterogeneity, they not only assume ex ante different but also ex post different.

From the reviewed study, I develop a model of multistage game of cost reducing R&D decision with asymmetry between the North and the South. I use the assumption of asymmetric R&D productivity describing the North and the South since it is suitable for this case that the South could engage in R&D itself but not effective as the North. Moreover, there should not be a significant difference in pre-innovation cost since both players produced in the same area. In addition, I assume differentiated products to see the relationship between appropriated IPRs regimes and product differentiation level. At this point, the model of Poyago-Theotoky and Teerasuwannajak (2012) is well-defined in the asymmetry between North-South abd has potential to extend.

In the next chapter, the model is fully explained. I use the multistage game model of R&D decision with spillover in which both players asymmetric in R&D productivity (North and South) compete in R&D market and goods market. In the addition from formal model of d'Aspremont and Jacquermin(1988) and PT model, this study allow for the degree of substitution rate to characterize that product could be substitute but not perfectly since there's some difference in the consumer's perception. To scope the study into private incentives, this study just look for the net profit both players obtain and welfare effect is omitted. I compare the consequence of the competition (R&D outcome and net profit) between no IPRs protection and full IPRs protection to see which IPRs regimes each player prefers.

Chapter 3

Model

In this chapter, the theoretical model is setup and analyzed to observe outcomes of the competition. I explore the role of some variables by shifting in them to investigate the intuition. Then I compare outcomes between two regimes to examine the conflict of the desire regimes.

3.1 Model Setup

Considering the model of quantity-competition between North(n) and South(s) country, both countries produce same goods. They compete in exporting all of their products to third market. A consumer's utility in the market depends on goods consumed by each country (q_n, q_s) and money left after purchasing goods (m). Let $U(q_n, q_s, m) = q_n + q_s - q_n^2/2 - q_s^2/2 - \rho q_n q_s + m$ represents utility function of third country with income constrain defined as $I = P_n q_n + P_s q_s + m$. Third country's demand is in the form of linear function ;

$$P_i = 1 - q_i - \rho q_j \tag{1}$$

$$0 \le q_i < 1 \ , \ \ 0 \le \rho \le 1, \quad i, j \in \{n, s\} \ and \ i \ne j$$

Where P_i is the price of product from country i and q_i is the quantity supplied by country i respect to the output market. ρ indicates the substitution rate between products which reflects product differentiation level. The level of ρ is determined by preference or perception of consumers, $\rho = 0$ represents that products are perfectly differentiated and cannot be substituted for each other. The price of $q_i(P_i)$ would depend on q_i only. And $\rho = 1$ means products are homogeneous and perfectly substitute for one by one.

Both Countries have the same production with constant marginal cost which can be reduced by investing in cost reducing R&D but knowledge, which is output from R&D, can spillover to opponent with the rate of β. Higher rate of β means larger spillover.

$$c_i = \bar{c} - \theta_i(x_i + \beta x_j) \quad (2)$$

$$0 < \bar{c} < 1, \beta \epsilon \{0,1\}$$

Where x_i refers to R&D output level of country i. $\bar{c}$ is pre-innovation marginal cost of production and c_i is marginal cost of production after being improved by cost-reducing R&D. Assuming $\bar{c}$ is large enough so that post-innovation marginal cost in both countries are not less than zero. The term $(x_i + \beta x_j)$ is the total R&D output available for country i, which is called as "effective R&D"[1]. Assume that the North can reduce marginal cost more than the South, given a same level of available R&D output. This proposition refers to the assumption of asymmetric R&D productivity. The North has higher R&D productivity than the South. Given θ_i is the relative R&D productivity of country i to North country, so $\theta_n = 1$ and $\theta_s = \theta \in [0,1]$. This explains the traditional characteristic of North-South countries.

This study will analyze two main cases. The first one is "no spillover case" with the presence of IPRs protection. The second one is "full spillover case" with the absence of IPRs protection. By implementing IPRs protection, no one can utilize opponent's R&D so there is no spillover ($\beta = 0$). Another case, which is no IPRs protection, country can use opponent's R&D by the full amount of rival's R&D investment, so there is full spillover ($\beta = 1$)

[1] Kamian ,Muller and Zang (1992) firstly used the term "effective R&D" to refer to total R&D output which is available for firms.

The cost of R&D is the R&D investment expenditure. Let both countries have a quadratic cost of R&D Investment as below.

$$R_i = \frac{v_i x_i^2}{2} \tag{3}$$

$$v_i > 0$$

Where R_i is the total cost of investing in R&D. v_i is a parameter representing how costly R&D in each country is. It is usually called R&D efficiency. High value of v_i implies reducing a unit of marginal cost of production is costly. However, this study assume that each country has the same R&D efficiency ($v_n = v_n = v$) to focus only on asymmetric R&D productivity.

Each country makes decisions on two things; how much to invest in R&D and how much goods to produce. The two countries make decision simultaneously on R&D investment and prior to quantity decision. Their key objective is to maximize their profit net of R&D cost. To find the equilibrium level of quantity of goods and investment expenditure and their profits from the competition, backward induction is utilized in order to find subgame perfect Nash equilibrium (SPNE) in each stage of decision: The first stage is the R&D investment decision and the second stage is the quantity decision.

Main questions of this study are: 1.) How quantity and R&D decision change as products become more differentiated. 2.) How would the comparison result between two regimes change as product differentiation level vary.

3.1.1 No IPRs protection (NP case : $\beta = 1$)

In case of no protection, each country cannot prevent rival to use its R&D. Its marginal cost becomes;

$$c_n = \bar{c} - (x_n + x_s) \tag{4.1}$$

$$c_s = \bar{c} - \theta(x_n + x_s) \tag{4.2}$$

Country's marginal cost is reduced by the sum of R&D output, which is effective R&D. Note that $0 < \theta < 1$, therefore marginal cost of the North is always lower than the South ($c_n < c_s$) no matter how large R&D in each country is.

Quantity decision stage

From linear demand, constant marginal cost, and R&D investment cost, profit function of country i is $\left(1 - q_i - \rho q_j\right)q_i - c_i(q_i) - R_i$. The first order conditions (F.O.C.s) give $1 - 2q_i - \rho q_j - c_i$=0. Thus, quantity decisions are $q_i = \frac{1-\rho q_j - c_i}{2}$. Derive these equations for equilibrium quantities yield [2]

$$q_n^* = \frac{2(1 - c_n) - \rho(1 - c_s)}{(4 - \rho^2)} \tag{5.1}$$

$$q_s^* = \frac{2(1 - c_s) - \rho(1 - c_n)}{(4 - \rho^2)} \tag{5.2}$$

To ensure that both countries compete and supply their products to market, the condition $q_n^* > 0$ and $q_s^* > 0$ is needed. From (4.1)-(5.2) we can show that $\theta > \frac{\rho}{2}$ is sufficient for those conditions[3]. The assumption $\theta > \frac{\rho}{2}$ will be assumed so the South would compete in the market and duopolistic competition exists.

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[2] In quantity decision stage, it is clear that second order derivative is always negative $\left(\frac{d^2\pi_i}{dx_i^2} = -2 < 0\right)$ which yield profit maximize problem.

[3] See appendix A.1 for explanation

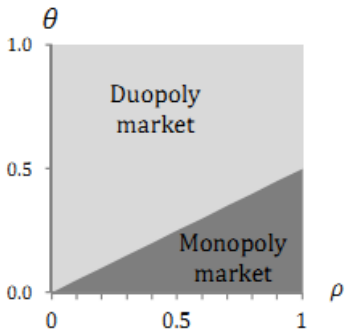

Figure 1 condition for existence of duopolistic competition

Figure 1 summarizes conditions for duopoly markets. In Cournot game, the relative R&D productivity between two countries must not too low for a given level of product differentiation until the South country could compete with the North. This condition is relaxed when product are completely differentiated $(\rho = 0)$, duopoly market exists at any level of relative R&D productivity.

Substitute (4.1)-(4.2) for c_n and c_s in (5.1)-(5.2) to derive equilibrium quantities as a function of R&D output

$$q_n^{NP} = \frac{A(2-\rho) + f_n(x_n + x_s)}{(4-\rho^2)} \tag{6.1}$$

$$q_s^{NP} = \frac{A(2-\rho) + f_s(x_n + x_s)}{(4-\rho^2)} \tag{6.2}$$

Where $A = 1 - \bar{c}$, $f_n = 2 - \theta\rho$ and $f_s = 2\theta - \rho$[4]. Observe that in no IPRs protection case, each country's equilibrium quantity depends on the summation of both countries' R&D. Since R&D could spillover to other, a country's R&D does not only enhance its quantity supply but also enhances rival's quantity supply. $\left(\frac{dq_i^{NP}}{dx_i} > 0, \frac{dq_i^{NP}}{dx_j} < 0\right)$

[4] For the admissible range of $\bar{c}, \theta, \rho$ and the condition $\theta > \frac{\rho}{2}$, we obtain that $A > 0, f_n > 0$ and $f_s > 0$.

R&D decision stage

In R&D decision stage, each country chooses R&D investment level. Profits from exporting products are [5] $(q_i^*)^2$. Profit function for each country is $(q_i^*)^2 - \frac{vx_i^2}{2}$ .First order conditions (F.O.C.s) for the North and the South to maximize the net profit of R&D cost in this stage is $\frac{\partial \pi_i^*}{\partial x_i} = 2q_i^* \frac{\partial q_i^*}{\partial x_i} - vx_i = 0$ which yield;

$$vx_n = 2\frac{f_n}{(4-\rho^2)}q_n^* \tag{7.1}$$

$$vx_s = 2\frac{f_s}{(4-\rho^2)}q_s^* \tag{7.2}$$

Equation (7.1) and (7.2) show conditions for choosing R&D level to optimize profits. R.H.S of (7.1)-(7.2) shows marginal benefits and L.H.S shows marginal cost of R&D output. Observe that marginal benefit depends on the quantities produced (q_i^*) and some parameters. Marginal benefits of R&D output should rise as they produce more.

Derive F.O.C to get the equations which show R&D decision

$$x_n^{NP} = \frac{2f_n[(2-\rho)A + f_n x_s^{NP}]}{v(4-\rho^2)^2 - 2{f_n}^2} \tag{8.1}$$

$$x_s^{NP} = \frac{2f_s[(2-\rho)A + f_s x_n^{NP}]}{v(4-\rho^2)^2 - 2{f_s}^2} \tag{8.2}$$

At this point, condition $v > 1$ is assumed throughout in NP case for the second order conditions and stability conditions[6].

Equation (8.1) and (8.2) shows reaction functions, which are strategies of both countries. Observe that the cross effects $\left(\frac{dx_i}{dx_j}\right)$ are positive[7].

[5] For $P_i q_i^* - c_i(q_i^*) = \left(1 - q_i^* - \rho q_j^* - c_i\right)q_i^*$, use F.O.C. conditions in quantity decision stage $1 - 2q_i - \rho q_j - c_i$=0 to yield $q_i^* = 1 - 2q_i - \rho q_j - c_i$. So $P_i q_i^* - c_i(q_i^*) = (q_i^*)^2$

[6] See appendix A.2 for explanation

This indicates strategic complementary property of their R&D decision; each will increase its R&D investment as its opponent's R&D increase. In the absence of IPRs protection, R&D investment in country i could heightens marginal benefits of R&D of country j. This induces country j to raise its R&D investment.

Compute Nash equilibrium in R&D decision stage to yield equilibrium R&D in NP case;

$$x_n^{NP} = \frac{2Af_n[v(4-\rho^2)(2-\rho) - 2f_s(\theta-1)]}{v(4-\rho^2)\omega} \tag{9.1}$$

$$x_s^{NP} = \frac{2Af_s[v(4-\rho^2)(2-\rho) + 2f_n(\theta-1)]}{v(4-\rho^2)\omega} \tag{9.2}$$

Where $\omega = v(4-\rho^2)^2 - 2\left[{f_n}^2 + {f_s}^2\right]$ which is always positive[8]. Recall that effective R&D available to each country in this case is the sum of R&D output; we can derive effective R&D by using summation of (9.1) and (9.2) which yield $\bar{x} = x_n^{NP} + x_s^{NP} = \frac{2A(2-\rho)^2(1+\theta)}{\omega}$.

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[7] $\frac{dx_n}{dx_s} = \frac{2{f_n}^2}{v(4-\rho^2)^2 - 2{f_n}^2} > 0, \frac{dx_n}{dx_s} = \frac{2{f_s}^2}{v(4-\rho^2)^2 - 2{f_s}^2} > 0$ for $v > 1$ and $\theta > \frac{\rho}{2}$

[8] Let $v = 1$ which is the lowest value as possible. Realize that ω rises as v rise.

$2\omega = 2(4-\rho^2)^2 - 4[(2-\rho\theta)^2 + (2\theta-\rho)^2]$

$2\omega = [(4-\rho^2)^2 - 4(2-\rho\theta)^2] + [(4-\rho^2)^2 - 4(2\theta-\rho)^2]$

$2\omega = \rho(2\theta-\rho)[(4-\rho^2) + 2(2-\rho\theta)] + [4(1-\theta) + \rho(2-\rho)][4-\rho^2+2(2\theta-\rho)]$

Since all terms are positive, we get $\omega > 0$ for $\omega = 1$.Since ω is increasing in v, $\omega > 0$ for all $v > 1$

Table 1 summary of equilibrium outcomes in no IPRs protection.

Outcomes	Country	expression
Equilibrium R&D output (x_i^{NP})	North(n)	$\frac{2Af_n[v(4-\rho^2)(2-\rho)+2(1-\theta)f_s]}{v(4-\rho^2)\omega}$
	South(s)	$\frac{2Af_s[v(4-\rho^2)(2-\rho)-2(1-\theta)f_n]}{v(4-\rho^2)\omega}$
Equilibrium quantity (q_i^{NP})	North(n)	$A\left[\frac{v(4-\rho^2)(2-\rho)+2(1-\theta)f_n}{\omega}\right]$
	South(s)	$A\left[\frac{v(4-\rho^2)(2-\rho)-2(1-\theta)f_s}{\omega}\right]$
Equilibrium profit (π_i^{NP})	North(n)	$\frac{A^2\left(v(4-\rho^2)^2-2{f_n}^2\right)[v(4-\rho^2)(2-\rho)+2(1-\theta)f_s]^2}{v(4-\rho^2)\omega^2}$
	South(s)	$\frac{A^2\left(v(4-\rho^2)^2-2{f_s}^2\right)[v(4-\rho^2)(2-\rho)-2(1-\theta)f_n]^2}{v(4-\rho^2)\omega^2}$

The corresponding equilibrium quantity and profit are summarized in table 1. Observe that $x_n^{NP} > x_s^{NP}$, $q_n^{NP} > q_s^{NP}$ and $\pi_n^{NP} > \pi_s^{NP}$[9] which refers that in the absence of IPRs protection, the North always invests more in R&D, supply more quantities and captures more profits than the South.

[9] $x_n^{NP} - x_s^{NP} = \frac{2A(1+\theta)\left[v(4-\rho^2)^2+4(2-\theta\rho)(2\theta-\rho)\right]}{v(4-\rho^2)\omega} > 0$, $q_n^{NP} - q_s^{NP} = \frac{2(2+\rho)(1-\theta)^2}{\omega} > 0$, and See appendix B.1 for $\pi_n^{NP} > \pi_s^{NP}$.

3.1.2 Full protection (FP case : $\boldsymbol{\beta = 0}$)

A country's R&D is protected when IPRs are implemented, this can prevent rival to use own country's R&D. Thus, marginal cost of production will be reduced by its own country's R&D only and effective R&D becomes its own R&D output only.

$$c_n = \bar{c} - x_n \tag{10.1}$$

$$c_s = \bar{c} - \theta x_s \tag{10.2}$$

It is obvious that country with higher R&D productivity does not strengthen opponent anymore. I assume that the North will invest in R&D more than the South ($x_n^{FP} > x_s^{FP}$) because of higher R&D productivity[10].

Quantity decision stage

Both countries also encounter with linear demand, their F.O.C. condition to maximize profit in quantity stage and strategies are also the same, which are equation (5.1)-(5.2). Equations (10.1)-(10.2) are used to obtain equilibrium quantity in full IPRs protection case

$$q_n^{NP} = \frac{A(2-\rho) + 2x_n - \rho\theta x_s}{(4-\rho^2)} \tag{11.1}$$

$$q_s^{NP} = \frac{A(2-\rho) - \rho x_n + 2\theta x_s}{(4-\rho^2)} \tag{11.2}$$

Note that the assumption $\theta > \frac{\rho}{2}$ is also assumed in this case to ensure duopolistic competition[11], figure 1 still hold for full IPRs protection case. It is obvious that quantity does not depend on the sum of R&D as in full protection

[10] This assumption will be checked in the part of equilibrium analysis.

[11] See appendix A1 for explanation

case since spillover is gone, an increasing in a country's R&D enhance own quantities but reduce rival's quantities $\left(\frac{\partial q_i^*}{\partial x_i} > 0, \frac{\partial q_i^*}{\partial x_j} < 0\right)$.

R&D decision stage

Each country chooses R&D level to maximize its profit net of R&D cost. The profit function is shown as $\pi_i = (q_i^*)^2 - R_i(x_i)$, F.O.C. conditions for choosing R&D level are;

$$vx_n = q_n^* \frac{4}{(4-\rho^2)} \tag{12.1}$$

$$vx_s = q_s^* \frac{4\theta}{(4-\rho^2)} \tag{12.2}$$

By (11.1)-(12.2), we obtain reaction functions of the North and the South

$$x_n = \frac{4[(2-\rho)A - \rho\theta x_s]}{v(4-\rho^2)^2 - 8} \tag{13.1}$$

$$x_s = \frac{4\theta[(2-\rho)A - \rho x_n]}{v(4-\rho^2)^2 - 8\theta} \tag{13.2}$$

Equations (13.1)-(13.2) show strategies of each country responding to rival's strategies and $v > \frac{4}{3}$ is assumed for second order conditions and stability conditions in the case of full protection[12]. Notice that the cross term effects $\left(\frac{dx_i}{dx_j}\right)$ are negative for both countries[13]. In the presence of IPRs protection, a rise in R&D investment heightens the country's profit per unit of quantity through a decreasing in marginal cost of production. This induces country to supply more quantities which in turn reduces opponent's price and profit. Such a decline in profit per unit reduces marginal benefits of R&D output which results in a decrease in R&D investment. Therefore, country will decrease its R&D

[12] See appendix A.2 for explanation

[13] In this case, $\frac{dx_n}{dx_s} = \frac{-4\rho\theta}{v(4-\rho^2)^2-8} < 0$ and $\frac{dx_n}{dx_s} = \frac{-4\rho\theta}{v(4-\rho^2)^2-8\theta} < 0$ for $v > \frac{4}{3}, \theta > \frac{\rho}{2}$

investment in respond to an increase in rival's R&D investment; it is the property of strategic substitutability. IPRs implementation transforms the nature of R&D decision.

Use (13.1)-(13.2) to derive equilibrium R&D in the case of full protection;

$$x_n^{FP} = \frac{4A(2-\rho)[v(4-\rho^2)^2 - 8\theta^2 - 4\rho\theta^2]}{\varphi} \tag{14.1}$$

$$x_s^{FP} = \frac{4\theta A(2-\rho)[v(4-\rho^2)^2 - 8 - 4\rho]}{\varphi} \tag{14.2}$$

Where $\varphi = (v(4-\rho^2)^2 - 8\theta^2)(v(4-\rho^2)^2 - 8) - (4\rho\theta)^2$. Equilibrium quantity and profit are summarized in table 2.

Table 2 summary of equilibrium outcomes in full IPRs protection.

Outcomes	Country	expression
Equilibrium R&D output (x_i^{FP})	North(n)	$\frac{4A(2-\rho)[v(4-\rho^2)^2 - 8\theta^2 - 4\rho\theta^2]}{\varphi}$
	South(s)	$\frac{4\theta A(2-\rho)[v(4-\rho^2)^2 - 8 - 4\rho]}{\varphi}$
Equilibrium quantity (q_i^{FP})	North(n)	$\frac{Av(2-\rho)(4-\rho^2)[v(4-\rho^2)^2 - 8\theta^2 - 4\rho\theta^2]}{\varphi}$
	South(s)	$\frac{Av(2-\rho)(4-\rho^2)[v(4-\rho^2)^2 - 8 - 4\rho]}{\varphi}$
Equilibrium profit (π_i^{FP})	North(n)	$\frac{v(v(4-\rho^2)^2 - 8)[A(2-\rho)]^2[v(4-\rho^2)^2 - 8\theta^2 - 4\rho\theta^2]^2}{\varphi^2}$
	South(s)	$\frac{v(v(4-\rho^2)^2 - 8\theta^2)[A(2-\rho)]^2[v(4-\rho^2)^2 - 8 - 4\rho]^2}{\varphi^2}$

Observe that $x_n^{FP} > x_s^{FP}$, $q_n^{FP} > q_s^{FP}$ and $\pi_n^{FP} > \pi_s^{FP}$[14], represents that in full protection case, there is no major different in market position; the North still invests in R&D more than the South. It also supplies more quantities and gets more profits than the South. In conclusion, R&D productivity can be seen as one kind of competitive advantage no matter IPRs are implemented or not. This proposition still holds in homogeneous product case.

3.2 Shift in exogenous variables

In this section, I examine how equilibrium outcome change in respond to shift in exogenous variables in the model. I focus on shifting in two variables including, product differentiation level(ρ) and relative R&D productivity(θ). Due to the complexity of the expression, this section will show the relationship between equilibrium outcomes and product differentiation by calibration.

Before start analysis, I firstly analyze the effect of autonomous R&D on players' profits. As PT model divide players' motive to invest in R&D into two sorts.The first one is to increase their profits directly. The second one is to response to rival's action. This can be shown by the first stage profit function which depend on their autonomous quantity supply ,rival's quantity and their own R&D level ,or $\pi_i = f(q_i, q_j, x_i)$:

$$\frac{d\pi_i}{dx_i} = \underbrace{\frac{\partial \pi_i}{\partial q_i}\frac{\partial q_i}{\partial x_i}}_{\text{0 from FOC in quantity decision stage}} + \underbrace{\frac{\partial \pi_i}{\partial q_j}\frac{\partial q_j}{\partial x_i}}_{\text{Strategic motive}} + \underbrace{\frac{\partial \pi_i}{\partial x_i}}_{\text{Profit motive}}$$

$$= 0 + -\rho q_i \frac{\partial q_j}{\partial x_i} + \frac{\partial \pi_i}{\partial x_i} \qquad (15)$$

[14] $x_n^{NP} - x_s^{NP} = \frac{2A(1+\theta)\left[v(4-\rho^2)^2+4(2-\theta\rho)(2\theta-\rho)\right]}{v(4-\rho^2)\omega} > 0$, $q_n^{NP} - q_s^{NP} = \frac{2(2+\rho)(1-\theta)^2}{\omega} > 0$ and see appendix B.2 for $\pi_n^{FP} > \pi_s^{FP}$.

The strategic motives (2nd term) indicates that their R&D decision may influence opponent's quantity, which in turn effects their profits. The profit motive(3rd term) indicates that their R&D investment can increase profits by reducing marginal cost of production. The efficient level of R&D investment is determined by $\frac{d\pi_i}{dx_i} = \frac{\partial \pi_i}{\partial q_i}\frac{\partial q_i}{\partial x_i} + \frac{\partial \pi_i}{\partial x_i} = 0$, which is the level that profit motive is equal to zero.[15] Observe that the sign of strategic motive depends on the sign of $\frac{\partial q_j}{\partial x_i}$, which is not equal to zero, R&D decision of the game always deviates from the efficient level; countries may invest in R&D too much or too low.

In the case of no protection, North's R&D enhances South's quantity by spillover in R&D$\left(\frac{\partial q_j^{NP}}{\partial x_i} > 0\right)$, which in turn reduces North's profit. Similarly, South's R&D benefits North's quantity and reduces South's profit. This circumstances cause both countries to underinvest in R&D comparing to efficient level. In conclusion, the strategic motive is negative in the no protection case.

In the case of full protection, North's R&D hurts South's quantity because the absent of spillover prevents South country from exploiting North's R&D$\left(\frac{\partial q_j^{FP}}{\partial x_i} < 0\right)$. The North's R&D only benefits its own country and increase country's profit. South's R&D investment also reduces North's quantity and increases its profit. Hence, both countries tend to overinvest in R&D comparing to efficient level. In conclusion, the strategic motive is positive in the full protection case.

[15] At this level marginal benefit of R&D investment is equal to its marginal cost. Marginal benefit is measure by production cost reduce by R&D, which is the pure profit motive.

3.2.1 No IPRs protection case

Table 3 Equilibrium outcome responding to an increase in ρ (product become less differentiated given IPRs are not protected.)

	North country(n)	South country(s)
x_i^{NP}	$x_n^{NP} \downarrow$	$x_s^{NP} \downarrow$
q_i^{NP}	$q_n^{NP} \downarrow$	$q_s^{NP} \downarrow$
π_i^{NP}	$\pi_n^{NP} \downarrow$	$\pi_s^{NP} \downarrow$

Recall that a rise in substitution rates (ρ) means that products become less differentiated. Changing in ρ can effect R&D decision in two ways. Firstly, the profit motive will be smaller as ρ becomes higher. From (1) the market demand is $P_i = 1 - q_i - \rho q_j$, an increase in ρ will reduce product price. This induces producer to supply less quantity, which finally reduce the marginal benefit of R&D investment. This in turn induces country to invest less in R&D. Secondly, strategic motive will be larger in magnitude as ρ increase.[16] In the no IPRs protection case, country tends to fear that its R&D would benefits its rival via spillover. As product become more alike, country's tends to invest in R&D less as ρ increase. Since both effects discourage producers' R&D investment, both countries will reduce their R&D investment as a result of an increase in ρ. Their effective R&D, which is equal to sum of R&D, will fall as both countries reduce their R&D investment. Since their effective R&D falls, their quantities also fall as well. Finally, both countries will be able to capture fewer profits as a result of

[16] Since their products have more substitutability, they need to decide more carefully on opponent's action. This is represented by the larger in strategic motive term.

less quantity supply, higher substitution rate and higher marginal cost of production.

Table 4 Equilibrium outcome responding to an increase in θ (South becomes stronger given IPRs are not protected.)

	North country(n)	South country(s)
x_i^{NP}	$x_n^{NP} \uparrow$ when ρ is low $x_n^{NP} \downarrow$ when ρ is high	$x_s^{NP} \uparrow$
q_i^{NP}	$q_n^{NP} \uparrow$ when ρ is low $q_n^{NP} \downarrow$ when ρ is high	$q_s^{NP} \uparrow$
π_i^{NP}	$\pi_n^{NP} \uparrow$	$\pi_s^{NP} \uparrow$

An increase in South's R&D productivity is beneficial to itself. The South will invest more in R&D, supply more quantity and capture more profit as a result of its increase in R&D utilization. Moreover, the North also benefits from the South's improvement. The North's profit always increases even its R&D investment and quantity supply may decrease, when the South become a stronger competitor.

The reason for North's reduction in R&D is the strategic motive. Because South country better utilizes in R&D output, it should produce more for a given level of effective R&D output. North country knows that its R&D output may help enhance South's quantity for a larger unit, thus North may *reduce its R&D investment* (larger in Strategic motive decrease R&D incentives). However, South's increasing in R&D investment also enhance North's quantity since R&D could spillover, North should *invest more in R&D* since marginal benefits to reducing cost is larger(larger in Profit motive increase R&D incentives). Since there's two effects on North's decision on R&D, North may reduce or expand its

R&D respond to a rise in South's R&D productivity. Notice that North will reduce its R&D investment following strategic motive. As I already show that strategic motive will be smaller as ρ fall and vanish when products are perfect differentiated($\rho = 0$), North may disregard on strategic motive as products become more differentiated. *In summary, when R&D productivity becomes closer, South country always increases its R&D investment ,while North country heightens its R&D investment if products are very differentiated, but it reduce its R&D investment if products are very similar.*

Futuremore, an increase in θ leads to an increasing in both countries' profits. It's admittedly that South country gain benefits from higher productivity. However, the result may raise concern on how North country captures benefit from rival's strengthening. The reason behind this is the spillover, an increase in South's R&D output can help North in two ways 1.) It improves North's marginal cost and, 2.)North might free ride on South's R&D by reducing its R&D investment, since the increase in South's R&D compensates the decrease in North's R&D. Therefore, North can reduce R&D cost while keeping its marginal cost at the same. However, as I have already shown that North country tends to increase its R&D investment when products are much differentiated; North will not free ride on South's R&D investment if products are much differentiated. This finding is the extension from homogeneous product case, which concludes that North always free ride on South's R&D by reducing its R&D investment in responding to an increase in relative R&D productivity.

3.2.2 Full IPRs protection case

Table 5 Equilibrium outcome responding to an increase in ρ in (product become less differentiated given IPRs are fully protected)

	North country(n)	South country(s)
x_i^{FP}	$x_n^{FP} \downarrow$ when ρ is low $x_n^{FP} \uparrow$ when ρ is high (U-shape relationship)	For $\theta > \tilde{\theta}$ $x_s^{FP} \downarrow$ when ρ is high $x_s^{FP} \uparrow$ when ρ is low For $\theta \leq \tilde{\theta}$ $x_s^{FP} \downarrow$
q_i^{FP}	$q_n^{FP} \downarrow$ when ρ is low $q_n^{FP} \uparrow$ when ρ is high (U-shape relationship)	$q_s^{FP} \downarrow$
π_i^{FP}	$\pi_n^{FP} \downarrow$ when ρ is low $\pi_n^{FP} \uparrow$ when ρ is high (U-shape relationship)	$\pi_s^{FP} \downarrow$

In full protection case, both countries overinvest comparing to efficient level in R&D, represented by the positive sign of the strategic motive term. As I have already shown in no IPRs protection case that profit motive is smaller which induces country to invest less in R&D. And strategic motive is larger as ρ increase; both countries should invest more in R&D when there is no spillover. Since changing in ρ affects the net effect of these opposing motives, R&D investment may rise or fall as a result of changing in product differentiation level. Observe that both countries outweigh profit motive when products are very differentiated, and focus on strategic motive mainly when products are very similar, there should be U-shape relationship.

Recall that the condition for duopolistic market competition is $\theta > \frac{\rho}{2}$,an increase in ρ means that the duopolistic condition is more stringent or the equilibrium outcome is closer to corner solution. If South country is so weak, it tend to shut down when products become more similar; the South quantity

supplies and R&D fall slightly. This explains why South country always decreases its R&D investment response to an increase in ρ if relative R&D productivity is very low. Since the South tend to leaves the markets, its profit should fall slightly corresponding to its decision. At last, North will snatch market share and get large profitability since the South tend to shut down; its profit increase when ρ is high and θ is low enough.

Table 6 Equilibrium outcome responding to an increase in θ (South becomes stronger given IPRs are fully protected)

	North country(n)	South country(s)
x_i^{NP}	$x_n^{NP}\downarrow$	$x_n^{NP}\uparrow$
q_i^{NP}	$q_n^{NP}\downarrow$	$q_n^{NP}\uparrow$
π_i^{NP}	$\pi_n^{NP}\downarrow$	$\pi_n^{NP}\uparrow$

It's obvious that South country always increase its R&D investment , supplies more unit and captures more profit as a result of better utilizing R&D. As R&D spillover is eliminated by IPRs protection, North cannot capture any benefits from an increase in South's R&D. Moreover, an increase in South's quantity hurts North's product price. This in turn reduces North's marginal benefits of R&D, result in a decline in North's R&D investment and profit at the end of the game.

3.3 Comparing between two regimes

Since IPRs protection can change the nature of R&D decision in each country, equilibrium outcomes are affected as well. To observe the effects of IPRs protection, I examine the difference of outcomes between two cases. Due to the complexity of derived expression of agents' reactions, the comparison cannot be computed directly. Therefore, I obtain the comparison result by employing the calibration methodology.

3.3.1 Comparison of R&D output

There is an unusual result after comparing R&D output between two regimes. The result shows that IPRs protection might not be able to encourage producer to invest in R&D. This result can be found by adjusting assumption of the homogeneous product case. The equilibrium R&D in the full protection case is always higher than in the no protection case when products are perfectly substituted. Nevertheless, this does not hold if products are differentiated significantly.

Table 7 comparison of R&D output between the homogeneous product case and the differentiated products case ($v = 1.5$, $\bar{c} = 0.75$)

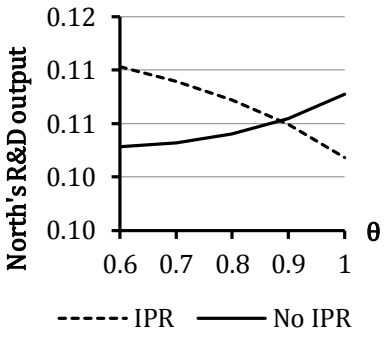
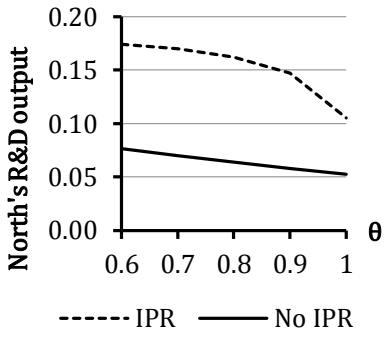
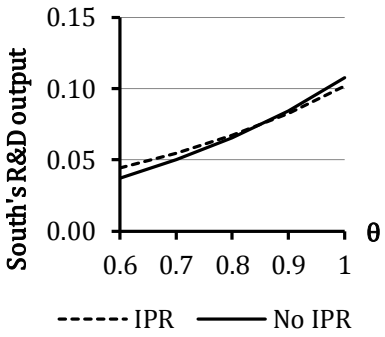
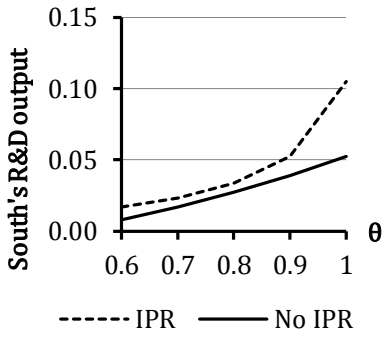
	Product differentiated case ($\rho = 0.4$)	**Homogeneous product case ($\rho = 1$)**
North country		
South country		

Table 7 shows results from the calibration, comparing between homogeneous product case ($\rho = 1$) and differentiated products case ($\rho = 0.4$). Results show that in homogeneous product case, IPRs protection always heightens both firm's R&D investment (R&D output level in the IPRs protection case is always higher than in the no IPRs protection case). Nevertheless, results from the differentiated products case are significantly different. It is possible that IPRs protection may reduce firm's R&D (There is a crossing in R&D level between regimes).

Proposition 1 *IPRs protection may fail to strengthen private R&D incentives if products are significantly different, while R&D productivity of each country is not substantially different.*

The reason why IPRs may fail to strengten private R&D incentives when products are highly differentiated is that both countries pay less attention on stratergic motive. Since market is more independent, they need not to underinvest in R&D when IPRs are not implemented, and not to overinvest in R&D when IPRs are implemented.

3.3.2 Comparison of profits

The main question is how IPRs protection affects each country's profitability. For South country, IPRs protection always reduces profitability. Moreover, I found that $\Delta\pi_n \gtrless 0$, which means that IPRs protection may increase or decrease North's profit depend on the level of θ and ρ.

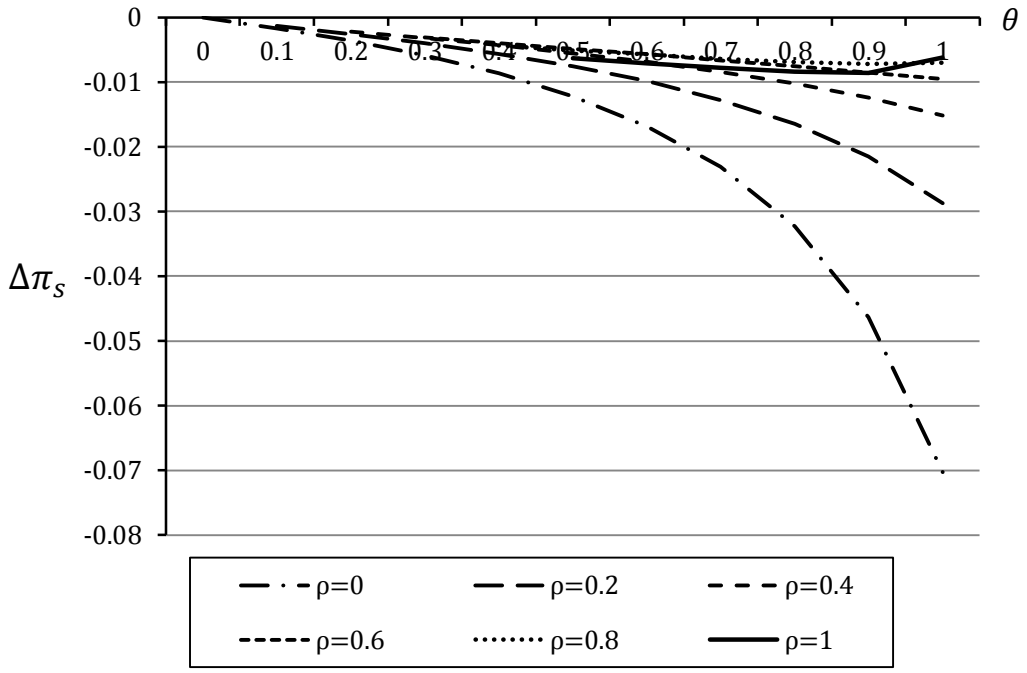


Figure 2 Calibration results when comparing South's profit across two regimes

$(v = 1.5\ ,\ \bar{c} = 0.75\ )$

Figure 2 shows the calibration result for South's profit, this graph plots between $\Delta\pi_s(\pi_s^{FP} - \pi_s^{NP})$ as vertical axis and θ as horizontal axis. Each line shows the calibration result of a different value of ρ. This graph shows that $\Delta\pi_s$ is always negative, which means that $\pi_s^{FP} < \pi_s^{NP}$ for any value of θ and ρ. The South's profit always decreases when IPRs are implemented.

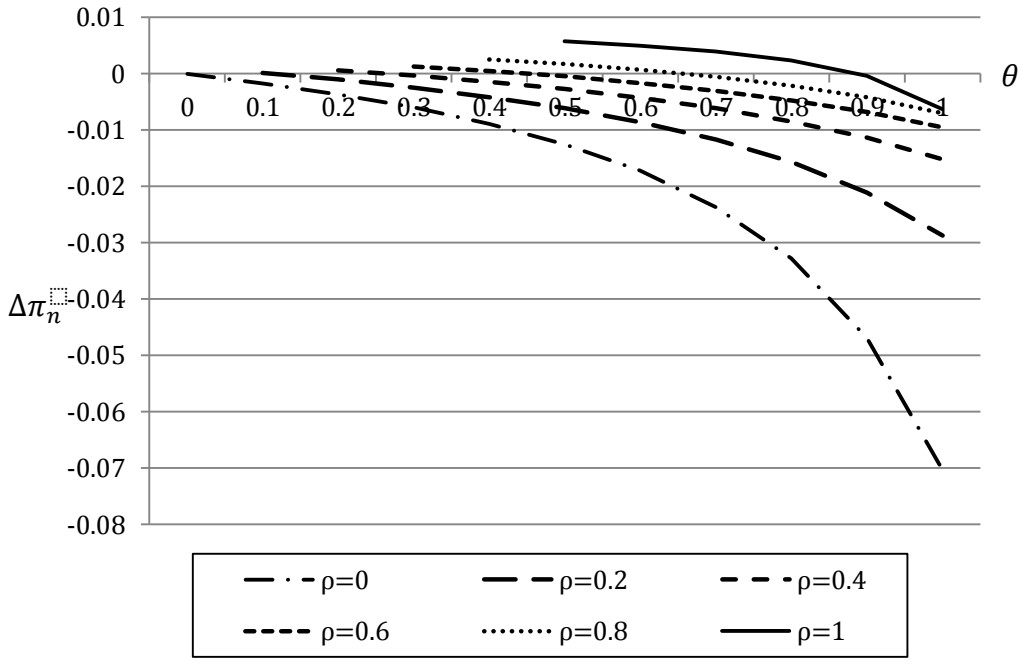


Figure 3 Calibration results when comparing North's profit across two regimes $(v = 1.5, \bar{c} = 0.75)$

Figure 3 shows calibration result for the North, this graph plots the difference of profits between two regimes $(\pi_n^{FP} - \pi_n^{NP})$ which shows both positive and negative value. This result infers that IPRs protection may increase or decrease the North's profit. Recall that ρ (substitution rate) refers to product differentiation level. Lower ρ means product more differentiation. For a given level of $\theta, \Delta\pi_n$ decreases when ρ fall. This means that North country tends to lose from IPRs protection when products are more differentiated. This figure also illustrated the result of PT model of homogeneous product case by the line that $\rho = 1$.

Proposition 2 *While South's profit always decreased by IPRs protection, North's profit decrease if product is much differentiated and South's R&D productivity is substantially high.*

This result is not surprising as South country always prefer no IPRs protection since it has lower incentives to invest in R&D, comparing to the North. The South gains some benefit from North's R&D when there is full spillover. The IPRs protection enforces South country to conduct R&D. Since its R&D productivity is low, it has to spend large expenditure on R&D. Moreover, the North also tends to lose its profit from IPRs protection when products become more differentiated. Therefore, IPRs are less attractive when products become more differentiated. In addition, North country will not need IPRs protection at all, for an extreme case of perfectly differentiated products.

As product differentiation plays a key role on North's profit and desired regimes, an underlying intuition is the strategic motive. As I have shown that, both countries would overinvest or underinvest in R&D to influence rival's quantity. This strategy is less necessary when products become more differentiated because each country's profit is less affected by its rival's quantity and R&D investment so countries need not to overinvest or underinvest.

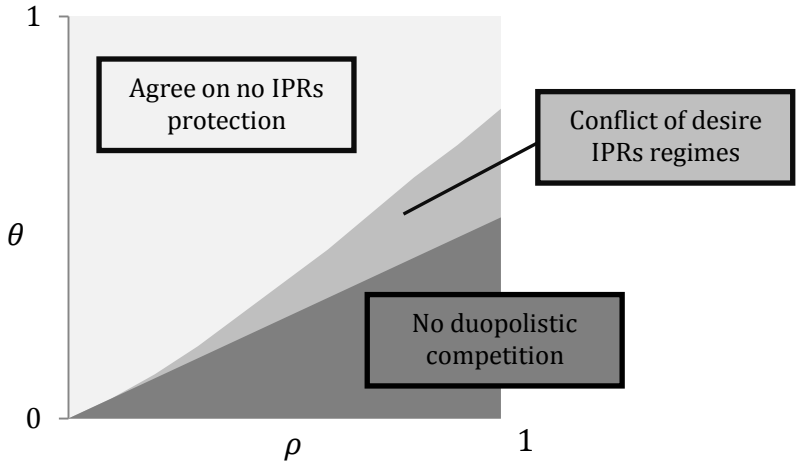


Figure 4 Summarize outcomes of conflict between North and South

Figure 4 summarizes outcomes of conflict between the North and the South by calibration ($v = 1.5$). The conflict of desired IPRs regimes disappears

when product differentiation level is high enough (a low value of θ) and level of difference in R&D productivity is low (high value of θ). While PT model shows that there exists a minimum level of South's R&D productivity$(\tilde{\theta})$ that make North prefers no IPRs protection, this study show that the critical value$(\tilde{\theta})$ decreases when products become more differentiated and reach zero when products are perfectly different.

Chapter 4

Conclusion

The objective of this paper is to study how product differentiation affects the possibility of conflicts regarding IPRs issue between countries which are at different stages of their R&D capability. The model of Poyago-Theotoky and Teerasuwannajak (2012) or PT model is extended to study consequences of changes in the degree of product differentiation .Two-stages game of quantity and R&D decision is applied to analyze players' strategies. The outcomes of the game associated with different IPRs regimes are compared.

The first finding that IPRs protection may fail to strengthen R&D incentives contrasts with the traditional view which perceive IPRs protection as a tool to encourage R&D. While a number of previous studies including PT model conclude that IPRs always encourage R&D (e.g. Chin and Grossman, 1990; Diwan and Rodrick, 1992 and Zigic, 1996), this study shows that when products are very differentiated and R&D productivity is not substantially different, IPRs protection may reduce R&D incentives. The intuition behind this finding is that when products are more differentiated, their price become more independent, so higher profits are incurred from those products. Thus, when IPRs are not protected, a country fears less that its R&D could spillover to benefit rival which in turn, would reduce its own profit. Therefore, spillover has less adverse impact on R&D incentives. This result is in line with De Bondt, Slaets and Cassiman (1992) which point out that when products are differentiated in quantity competition with cost-reducing game, players will not respond to rival's action as much as in the homogeneous product case.

The second result underlines the conflict of interests. Most of the existing literature (except PT model) shows that while protections increase the North's profit, they have adverse effects on the South's one. However, this study argues that in the case where the South also has R&D capability but is lower in R&D productivity than the North, the North may prefer no IPRs protection if products are very differentiated and South's R&D productivity is sufficiently close to North. This result extends from PT model which studies the homogeneous product case and also finds a critical level of South's R&D productivity that could make the North prefers no IPRs protection. This study finds that the critical level decrease when products become more differentiated and reach zero when products are perfectly different.

The results can be used to illustrate the case where the discovered knowledge does not pertain to any specific use. For example, a can-making machine that was innovated by Pepsi could also be used by Coke, an improved technique to produce CPU could benefit to all PC producers, a new cooling system designed by a factory may apply to other factories. Competitors could hire engineers who install new type of machine. However, as I assume product differentiation, this model may not apply with product-specific innovation. A new production line of touchscreen of iPhone could benefit Apple, but not other smartphone manufacturers.

This model is different from the model of Diwan and Rodrick (1992) which assumes continuum range of technology preference; the North and the South country may have different technology need and taste. For example, labor is cheap in the South but expensive in the North, so the North's labor-saving innovations are less useful in the South. In this view, the model here does not aim

to reflect variety of technologies but assumes only basic knowledge innovation that is available for capture by both the North and the South. Product differentiation affects spillover rate between players is left for the future work.

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Appendices

Appendix A

Proof of some conditions

A1: Condition for duopolistic competition

To ensure that there are 2 producers competing in the markets, we must get $q_n^* > 0$ and $q_s^* > 0$. Nevertheless, from the condition that $c_n < c_s$, we find that $q_n^* > q_s^*$ [1]. The corner solution of the game exists when $q_s^* = 0$. The condition for interior solution is

$$q_s^* = \frac{2(1-c_s) - \rho(1-c_n)}{(4-\rho^2)} > 0$$

$$2(1-c_s) > \rho(1-c_n)$$

Above inequality is the condition of a duopolistic competition, which means that marginal cost of North country must not be too low when comparing to the South's for a given level of product differentiation.

For no IPRs protection case, substitute (4.1)-(4.2) for c_n and c_s yield;

$$(2-\rho)(1-\bar{c}) > (\rho - 2\theta)(x_n + x_s) \qquad \text{(a.1)}$$

Since L.H.S is always negative and reaches its minimum value at zero, the condition to make (a.2) hold for all possible value of ρ and $\bar{c}$ is:

$$\theta > \frac{\rho}{2} \qquad \text{(a.2)}$$

Using the same logic, duopolistic condition in full IPRs protection case is, substitute (10.1)-(10.2) for c_n and c_s is $(2-\rho)(1-\bar{c}) > \rho x_n - 2\theta x_s$ which

[1] Present by observing the sign of $[q_n^* - q_s^*]$,from (6.1)-(6.2) we get $q_n^* - q_s^* = \frac{(2-\rho)(c_s - c_n)}{(4-\rho^2)}$ .for $(2-\rho) > 0$ and $(4-\rho^2) > 0$,The sign of $[q_n^* - q_s^*]$ must be equal to the sign of $(c_s - c_n)$ which is always positive ,so $q_n^* - q_s^* > 0$ or $q_n^* > q_s^*$

should yield $> \frac{\rho}{2}\frac{x_n}{x_s}$. However, $\theta > \frac{\rho}{2}$ is more comfortable and sufficient since we could reasonably assume that $x_n > x_s$.

Equation (a.2) means that two countries could engage in competition only if their R&D capabilities are not too different. Recall that θ is the relative R&D productivity, lower θ represents higher different in R&D productivity. This condition is less stringent as products become more differentiated ($\rho \to 0$)[2].

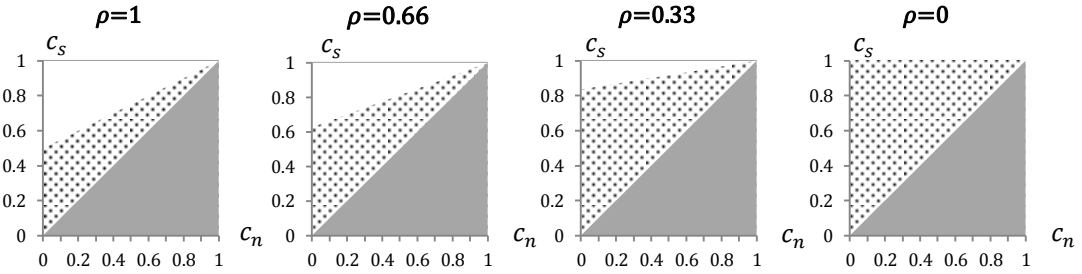

Figure A.1 combination of the North's and the South's post-innovation marginal cost

Figure A.1 illustrates outcomes of competition. Vertical axis shows marginal cost of South country (c_s). And horizontal axis shows marginal cost of North country (c_n). Gray area shows irrelevant outcomes where South's marginal cost is lower than the North's. Dot area shows outcomes of duopoly competition. White area shows outcome of monopoly as the South cannot compete with the North. The area of possible outcome of duopoly is larger when products are more differentiated (lower ρ).It will be largest when products are perfectly differentiated ($\rho = 0$).

[2] It can imply that any country can compete in the market when products are perfectly different, their quantity has no effect on rival's price

A2 : Second order conditions (S.O.C.s) in R&D decision stage and Stability condition of R&D subgame

To ensure maximization problem, second order condition (S.O.C.) must be negative. For no IPRs protection, S.O.C.s in R&D decision stage are;

$$\frac{\partial^2 \pi_n^{NP}}{\partial x_n^2} = \frac{2(2-\theta\rho)^2}{(4-\rho^2)^2} - v < 0$$
$$\frac{\partial^2 \pi_s^{NP}}{\partial x_s^2} = \frac{2(2\theta-\rho)^2}{(4-\rho^2)^2} - v < 0$$

For North country, the S.O.C. is $> \frac{2(2-\theta\rho)^2}{(4-\rho^2)^2}$. For possible value of θ, ρ and the condition $> \frac{\rho}{2}$, the R.H.S of inequality reaches its maximum at $\frac{1}{2}$ $\left(\rho = 0 \; or \; \theta = \frac{\rho}{2}\right)$. The South's S.O.C. is $v > \frac{2(2\theta-\rho)^2}{(4-\rho^2)^2}$ and the R.H.S also reaches its maximum at $\frac{1}{2}$ $(\rho = 0)$. So, $v > \frac{1}{2}$ is sufficient for both countries's S.O.C.

A sufficient condition to ensure stability[3] is that the slope of the reaction functions must be in range of (-1,1), from (8.1-8.2) we have

$$\frac{dx_n}{dx_s} = \frac{2(2-\theta\rho)^2}{v(4-\rho^2)^2 - 2(2-\theta\rho)^2} > 0$$
$$\frac{dx_s}{dx_n} = \frac{2(2\theta-\rho)^2}{v(4-\rho^2)^2 - 2(2\theta-\rho)^2} > 0$$

We found that $\frac{dx_n}{dx_s} > 0$ and $\frac{dx_s}{dx_n} > 0$, so we only need $\frac{dx_n}{dx_s} < 1$ and $\frac{dx_s}{dx_n} < 1$ to ensure the stability. The conditions are $\frac{2(2-\theta\rho)^2}{v(4-\rho^2)^2-2M^2} < 1$ and $\frac{2(2\theta-\rho)^2}{v(4-\rho^2)^2-2N^2} < 1$. Derive inequality to get $v > \frac{4(2-\theta\rho)^2}{(4-\rho^2)^2}$ and $> \frac{4(2\theta-\rho)^2}{(4-\rho^2)^2}$. For the admissible range of ρ and θ, v must more than 1 [4].In conclusion, $v > 1$ *is sufficient for S.O.C and stable equilibrium condition for both countries in no IPRs protection case.*

[3] Definition of "stable equilibrium" is that the outcomes of game will convert to equilibrium automatically.

[4] Conditions for stable equilibrium are $v > \frac{4(2-\theta\rho)^2}{(4-\rho^2)^2}$ and $v > \frac{4(2\theta-\rho)^2}{(4-\rho^2)^2}$, which are similar to S.O.C.

By the same process, sufficient conditions for S.O.C. in full protection case are $v > \frac{8}{(4-\rho^2)^2}$ and $v > \frac{8\theta^2}{(4-\rho^2)^2}$ for North and South, respectively. R.H.S of both inequality reaches their maximum value at $\frac{1}{2}$ ($\rho = 0$ and $\theta = 1$) ,so $v > \frac{1}{2}$ satisfied S.O.C.s

Next is the stability property of equilibrium, condition to obtain stable equilibrium is the same as the previous case, the slope of reaction functions must be in the range of (-1,1). Again, we compute slope by deriving first order derivatives;

$$\frac{dx_n}{dx_s} = \frac{-4\rho\theta}{v(4-\rho^2)^2 - 8} < 0$$
$$\frac{dx_s}{dx_n} = \frac{-4\rho\theta}{v(4-\rho^2)^2 - 8\theta} < 0$$

We will see that slope of reaction functions are always negative. So $\frac{-4\rho\theta}{v(4-\rho^2)^2-8\theta} > -1$ and $\frac{-4\rho\theta}{v(4-\rho^2)^2-8} > -1$ satisfy the stability conditions. For the possible range of θ and ρ, v must be higher than 1 for North country and higher than $\frac{4}{3}$ for South country. In brief, $v > \frac{4}{3}$ *satisfies both S.O.C. and stability condition for both countries in full IPRs protection case*.

Appendix B

Comparing equilibrium profits between players

B.1 prove for $\boldsymbol{\pi_n^{NP} - \pi_s^{NP} > 0}$,

from $\pi_i^* = (q_i^*)^2 - \frac{v}{2}(x_i^*)^2$,

$$\begin{aligned}\pi_n^{NP} - \pi_s^{NP} &= (q_n^{NP})^2 - (q_s^{NP})^2 - \frac{v}{2}[(x_n^{NP})^2 - (x_s^{NP})^2] \\ &= (q_n^{NP} - q_s^{NP})(q_n^{NP} + q_s^{NP}) - \frac{v}{2}(x_n^{NP} + x_s^{NP})(x_n^{NP} - x_s^{NP}) \\ &= (q_n^{NP} - q_s^{NP})(q_n^{NP} + q_s^{NP}) - \frac{v}{2}\bar{x}(x_n^{NP} - x_s^{NP})\end{aligned}$$

From (6.1)-(6.2); rearrange to yield $x_n^{NP} = \frac{2(2-\theta\rho)q_n^{NP}}{v(4-\rho^2)}$ and $x_s^{NP} = \frac{2(2\theta-\rho)q_s^{NP}}{v(4-\rho^2)}$;

$$\pi_n^{NP} - \pi_s^{NP} = (q_n^{NP} - q_s^{NP})(q_n^{NP} + q_s^{NP}) - \bar{x}\left(\frac{(2-\theta\rho)q_n^{NP} - (2\theta-\rho)q_s^{NP}}{(4-\rho^2)}\right)$$

From (10.1)-(10.2) ,rearrange to yield $(q_n^{NP} - q_s^{NP})$ as follows;

$$\begin{aligned}\pi_n^{NP} - \pi_s^{NP} &= \frac{(1-\theta)(2+\rho)}{(4-\rho^2)}\bar{x}(q_n^{NP} + q_s^{NP}) - \bar{x}\left(\frac{(2-\theta\rho)q_n^{NP} - (2\theta-\rho)q_s^{NP}}{(4-\rho^2)}\right) \\ &= \bar{x}\frac{[(1-\theta)(2+\rho)(q_n^{NP} + q_s^{NP}) - (2-\theta\rho)q_n^{NP} + (2\theta-\rho)q_s^{NP}]}{(4-\rho^2)} \\ &= \frac{\bar{x}}{(4-\rho^2)}[(2-\theta\rho)q_s^{NP} - (2\theta-\rho)q_n^{NP}]\end{aligned}$$

Finally , use (10.1)-(10.2) to yield;

$$\pi_n^{NP} - \pi_s^{NP} = \frac{\bar{x}}{(4-\rho^2)}A(1-\theta)(2+\rho)$$

Since $0 \leq \rho \leq 1$, $0 < \theta < 1$, $A > 0$ and $\bar{x} > 0$, R.H.S should be positive or

$\pi_n^{NP} > \pi_s^{NP}$

B.2 prove for $\boldsymbol{\pi_n^{FP} - \pi_s^{FP} > 0}$,

Recall that when there is no difference between countries ($\theta = 1$), both countries should obtain the same level of profit or $\pi_n^{FP} - \pi_s^{FP} = 0$. Since a fall in θ leads to an increase in π_n^{FP} and decrease in π_s^{FP}, their profit gap should larger. Therefore, the weaker player, like South country, should obtain less profit than the stronger player, like North country.

BIOGRAPHY

Wasin Rojayaroon was born in Bangkok, Thailand. In the secondary level, he graduated from the Mathematics-Science program at the Wat-Rat-O-Rot School in 2006. He received the bachelor degree in Economics from the Faculty of Economics, Chulalongkorn University in academic year 2009. His major field was Monetary Economics and his minor field was Labor Economics. Later, he started his Master Degree in Economics in the faculty of Economics, Chulalongkorn University, in academic year 2010.