International Harmonization of the Patent-Awarding Rules

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Abstract:

While the rest of the world issues patents to those who file applications first the U.S. do so to those who can demonstrate to have made inventions first. The U.S. has recently been under pressure to conform to the international rule. In this paper I examine the effect of international harmonization of the patent-awarding rules. In a dynamic two-country model of R&D competition for sequential inventions, I find that harmonization to the first-to-file rule can undermine innovation. This result is more like to arise if secondary innovations are relatively easy and their commercial successes are predominantly in the U.S. markets.

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1. Introduction

When two people apply for a patent on the same invention, a patent is awarded to the person who filed his application first. This simple patent-awarding rule applies in practically everywhere in the world except the U.S.[1] In the U.S., determination has to be made as to priority of invention, and a patent is issued to the person who can demonstrate to have discovered the invention first. Understandably, the U.S. has been under pressure to adopt the first-to-file rule, the international norm. However, the opposition to reform remains strong.[2]

The opposition embraces two principal arguments to bolster its position. One is that the first-to-invent rule protects small inventors who may take longer time to prepare patent applications and who therefore would in a first-to-file system lose to major corporate inventors who maintain an army of patent lawyers in their employ.[3] Lerner (2003) asserts however that this argument is spurious today since the recent patent law reform in the U.S. has created a new provisional patent application, which is much simpler to file. Further, disputes over priority of invention are settled in a legal proceeding called interference, which involves examining laboratory logbooks, establishing dates for prototypes, and so forth at a hearing before the USPTO (U.S. Patent and Trademark Office) Board.[4] In one estimate the adjudication of the average interference costs over one hundred thousand dollars (Kingston 1992). Since the costs of interference are borne equally by the parties involved, a first-to-invent rule does not

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[1] The exception is the Philippines, which uses a first-to-invent rule due to its colonial legacy with the U.S.

[2] A first-to-file rule is contained in the Patent Act of 2005, introduced by Rep. Lamar Smith, R-Texas. This bill however, has not been approved, as of this writing. Also at the 2007 G8 Summit meeting in Germany, President George W. Bush formally stated his support for a first-to-file rule.

[3] See, e.g., Stephenson (2005).

[4] See Cohen and Ishii (2005) for a detailed study of the interference process.

necessarily protect financially constrained small inventors. This point is confirmed in an empirical study of Cohen and Ishii (2005), which finds that interference does not help small individual inventors against large corporations. Thus, according to Lerner (2003), "the greatest beneficiary from the first-to-invent system is the small subset of the patent bar that specializes in international law."

This leads us to examination of the opposition's second argument; a first-to-file rule undermines innovation. Although the reason why first-to-file retards innovation is never explicated, the opposition often adduces the undeniable fact that the U.S. has led the world in R&D for more than a century, attributing that remarkable record to the first-to-invent feature of the patent law that the U.S. has had since 1836.[5]

The objective of the present paper is to evaluate this assertion. To do so, I develop a two-country model of dynamic R&D competition between two inventors for two inventions.[6] I assume two inventions are sequential but are separately patentable in either country. My primary focus is on how the worldwide adoption of the first-to-file rule affects the R&D incentives for primary inventions as well as the decision to patent and disseminate them.

In the analysis to follow I first consider the case in which, to award patents, the U.S. uses a first-to-file rule while the rest of the world uses a first-to-invent rule. I then examine the case, in which patent laws are harmonized internationally so both countries grant patents on a

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[5] For example, "It should be understood that it is because the U.S. has a first to invent structure and the rest of the world has a first to file structure that the U.S. is the production and employment machine that it is." (See http//www.piausa.org/layout/set/print/patent_reform_issue.)

[6] Loury (1979) and Lee and Wilde (1980) are the standard references in the literature on stochastic R&D competition.

first-to-file basis. My main finding is that worldwide adoption of the first-to-file rule can decrease R&D incentives. This outcome is more like to occur for primary inventions that spawn secondary inventions with relative ease and whose commercial successes occur predominantly in the U.S. markets.

To the best of my knowledge, this is the first paper that formally studies the effect of international harmonization of patent laws to a first-to-file rule. Scotchmer and Green (1990) have compared the two patent-awarding rules in a single country setting, but their analysis differs significantly in both setup and focus. In setup, they assume exogenous R&D investment, which precludes a direct comparison of R&D incentives between the two patent-awarding rules. Their focus therefore is on how novelty requirements of the patent laws affect disclosure of the intermediate technology. If novelty requirements are so strong that the intermediate innovation infringes the existing patent on the base-level technology, the intermediate innovation is not patented, thereby retarding discovery of the final innovation. Even with a weaker novelty requirement, an inventor may forgo patenting the intermediate invention to force the rival out of competition. However, such an incentive is weaker in first-to-file because the rival could patent the intermediate innovation if the inventor did not. Thus, it is concluded that the first-to-file rule is more conducive to dissemination of the intermediate innovation. This contrasts with our finding that the first-to-file can innovation when both R&D investments and dissemination of primary inventions are endogenously determined.

The remainder of the paper is organized in five sections. The next section delineates the model. Sections 3 and 4 present the model of a non-harmonized and a harmonized world.

Section 5 compares the R&D incentives between the two cases. Section 6 concludes.

2. The model

Consider two inventions A and B. They are sequential in that invention A must be discovered before R&D for invention B can start. Let V denote the total value of the two inventions, and let αV and βV be the values of inventions A and B, respectively, with $\alpha + \beta = 1$. This specification is general enough to subsume two separate cases. When two inventions are non-infringing, the weights α and β represent the profitability of each invention. Alternatively, when there is patent infringement, these weights are the outcome of negotiations between the two patent holders.[7]

I assume two inventions are separately patentable in each country, and let V_u and V_r denote the total value of the two inventions in the United States (U) and the rest of the world (R), respectively. Thus, $V = V_u + V_r$. Then, for example, αV_u represents the value of the patent on A in country U, while $\beta V = \beta(V_u + V_r)$ denotes the value of the patents on B in both countries.[8]

[7] Several authors have studied how to license sequential innovations [e.g., Chang (1995), Green and Scotchmer (1995) and Kao (2009)], in which Nash bargaining is typically used to obtain these shares. We abstract from this issue and treat the weights as exogenous.
[8] The weightss α and β are assumed common across countries.[8]

The model is set in an infinite time horizon, where time flows continuously from zero. At $t = 0$, two symmetric agents (or firms) start an R&D race for a discovery of A. R&D is risky in that a discovery date τ_A is distributed exponentially; that is,

$$\text{Prob}\,(\tau_A \leq t) = 1 - e^{-g(x)t}.$$

Here $g(x)$ is the hazard rate, a strictly concave function of an agent's R&D investment x. Thus, agent i investing $x_i dt$ over a small time increment dt, discovers A with probability $g(x)dt$ during that time interval. Marginal cost of R&D investment is assumed constant and normalized to unity. To ensure the existence of interior solution, I assume $g(x)$ is strictly concave and satisfies the Inada conditions.

Given the exponential distribution, one agent eventually discovers A at a random date τ_A. I call this agent a "leader" and the other a "follower." For clarity of exposition I will refer to a leader as "she" and a follower as "he". At τ_A a leader decides whether to patent A. She also immediately begins R&D for invention B.

A discovery date τ_B of B is exponentially distributed with constant hazard rate λ:

$$\text{Prob}\,(\tau_B \leq t) = 1 - e^{-t\lambda}.$$

The constant hazard rate for B facilitates a comparison of endogenous R&D investments for invention A between the harmonized and the non-harmonized world. It may also a reasonable assumption if B is an application of A to practical use so its discovery depends more on trials and errors than the size of outlays in R&D facilities. Given the constant hazard rate, there is no loss of generality in assuming zero R&D cost for invention B.

When A is invented the public learns about its discovery possibly through the media or conference presentations. However, a follower cannot acquire the necessary information to start R&D for B on his own unless A is patented.[9] Thus, a leader's decision at a discovery determines the nature of R&D competition for B. By patenting A she secures the exclusive right to it but also allows a follower to sidestep invention A and compete with her for a discovery of B. On the other hand, not patenting A keeps the invention secret for a leader but it can also expose her to the risk of losing the patent to a follower when he discovers A. In the next section I elaborate on these points in a model of a non-harmonized world.

3. A world without patent law harmonization

3.A. Four Phases

In this section I assume that country U uses a first-to-invent rule while country R uses a first-to-file rule. The model can be broken into four "phases." The initial phase begins at t = 0 and ends when one agent discovers A and emerges as a leader. Then, a leader faces four choices: patent the invention in both countries, in either country (U or R) or nowhere. Since getting a patent in one country discloses the invention to a follower, getting patents in both

[9] I assume for simplicity that a patent is issued immediately when an application is filed. This simplifies the analysis without affecting the results.

countries dominates getting a patent only in one country.[10] Thus, there is no loss of generality in limiting a leader's options to just two: patenting A in both countries and not patenting it at all.

Figure 1 depicts the subgame that starts at the end of initial phase.[11] The left-hand branch is taken when a leader patent A, and is called the PL or "patent" phase with a patent on A issued to a leader. In the PL phase, two agents are engaged in an R&D race for invention B. This phase and the game end when one agent discovers B. When a leader chooses not to patent A, she takes the right-hand branch in Figure 1. This branch continues until either a leader discovers B or a follower catches up to her with his own discovery of A. I call this the C or "catching-up" phase. In the C phase if a leader discovers B first, she gets the patents on A and B in both countries, and the game ends.[12] If instead a follower discovers A first, he decides what to do with A. If he patents A, another P phase begins, but this time a follower is the holder of patent on A. I call this the PF phase. If he chooses not to patent A, play moves back to a leader who decides whether to patent A (see Figure 1). If she patents A, another PL phase starts. If she does not patent A, then the NP phase commences, during which invention A remains unpatented. The NP phase and the game end when either agent discovers B.

3.B. Equilibrium profits

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[10] Of greater practical importance is the fact an inventor who gets a patent in one country must file for a patent in other countries within twelve months; failing to do so is interpreted as giving up the patent rights in other countries.

[11] The squares indicate stochastic nodes (that are reached when a discovery is made), while the circle indicates non-stochastic nodes. Stochastic nodes are reached with positive probabilities.

[12] I assume without a loss of generality that an inventor of B always files for the patent.

I now solve the model backward. Begin with the NP phase. Although neither agent wants to patent A, notice the asymmetry between the agents. If a leader wins, she gets the patents on both A and B in both countries. If she loses, she still gets the patent on A in country U, which is worth αV_u, due to the first-to-invent rule there. With the common hazard rate λ, a leader's expected profit during the NP phase is

(1) $$\pi_{NL} \equiv \lambda(V + \alpha V_u)/(r + 2\lambda).$$

In contrast, if a follower wins the NP phase race, he gets $\alpha V_r + \beta V < V$ since a leader can establish priority and get patent on A in country U. If he loses, he gets nothing. Therefore, a follower's expected profit is

(2) $$\pi_{NF} \equiv \lambda(\beta V + \alpha V_R)/(r + 2\lambda) < \pi_{NL}.$$

I now move back to a leader's second node in Figure 1. Here, if she does not patent A, her expected profit is π_{NL} defined in (1). By patenting A in both countries, she can secure the profit αV on A, and starts the PL phase. If she subsequently discovers B, she holds patents on both inventions worth V. Even if she loses, a leader still gets αV from her patents on A. Thus, a leader's expected profit during this PL phase is

(3) $$\pi_{PH} = \lambda(V + \alpha V)/(r + 2\lambda)$$

(PH stands for "patent holder"). Since $\pi_{PH} > \pi_{NL}$, a leader always patents A at her second node.

Now move back to a follower's node in Figure 1. If a follower does not patent A there, a leader will patent A as shown above. During the subsequent PL phase, if a follower wins the race he will get the patent on B in two countries worth βV. If he loses he will get nothing. Thus, a follower's expected profit from not patenting A is

$$\pi_{NH} = \lambda\beta V/(r + 2\lambda)$$

(NH stands for "non-patent holder"). Alternatively, patenting A, a follower starts the PF phase as a patent holder of A in country R (a leader can claim priority of invention in country U). Winning this race, he gets a patent on B and hence the profit $\alpha V_r + \beta V$. If he loses, he still enjoys the patent on A in country R, worth αV_r. Thus, a follower's expected profit from patenting A is computed to be

$$\pi_{PR} \equiv [\lambda(\alpha V_r + \beta V) + \lambda\alpha V_r]/(r + 2\lambda) = \lambda(\beta V + 2\alpha V_r)/(r + 2\lambda). \tag{4}$$

A quick check shows $\pi_{PR} > \pi_{NH}$ so a follower always patents A when he catches up to a leader.

It is useful to calculate the expected profit to a leader when a follower catches up and patents A, starting the PF phase. If a leader discovers B, she gets the patent on it in both countries in addition to the patent on A issued to her in country U. If she loses, she still gets the patent on A in country U. Therefore, a leader's expected profit during the PF phase is given by

$$\pi_{PU} = [\lambda(\alpha V_u + \beta V) + \lambda\alpha V_u]/(r + 2\lambda) = \lambda(\beta V + 2\alpha V_u)/(r + 2\lambda). \tag{5}$$

I summarize the findings I have obtained so far in

Proposition 1: When a follower catches up to a leader, a follower always patents A, yielding the expected profit π_{PR} to a follower and π_{PU} to a leader.

I next turn to the choice a leader faces at her first node in Figure 1. If she patents A, the PL phase begins so her expected profit is p_{PH} as shown above. On the other hand, if she chooses not to patent A, the C phase starts, in which she discovers B with hazard rate λ while a follower catches up with hazard rate g(y). If a leader discovers B, she will be holding patents on both inventions worth V. If a follower discovers A, he will patent it so a leader's profit will be π_{PU} by Proposition 1. Therefore, a leader's expected profit during the C phase is

$$(\lambda V + g(y)\pi_{PU})/(r + \lambda + g(y)).$$

To evaluate this profit, we need first to determine g(y), a follower's hazard rate in R&D for invention A during the C phase. During that phase, if he catches up, a follower faces the expected profit π_{PR} by Proposition 1. If he does not, he gets nothing. Since marginal cost of R&D investment is constant at unity, a follower thus faces the expected profit:

$$(g(y)\pi_{PR} - y)/(r + \lambda + g(y)),$$

which he maximizes with respect to y. Let y* be the unique maximizer and write the maximized profit as

$$\varphi_F{}^* = (g(y^*)\pi_{PR} - y^*)/(r + \lambda + g(y^*)). \tag{6}$$

Then, I can write a leader's expected profit during the C phase as

(7) $$\varphi_L{}^* = (\lambda V + g(y^*)\pi_{PU})/(r + \lambda + g(y^*)).$$

At her first node, a leader faces the expected profit π_{PH} when she patents A and $\varphi_L{}^*$when she does not. The next result is immediate.

Proposition 2: A leader patents A if and only if $\pi_{PH} \geq \varphi_L{}^*$.

3. C. The initial phase

I am now ready to determine the equilibrium R&D investments in the initial phase. In the initial phase, agents are symmetric. Conditional on there not having been a discovery to date, agent i invests x_i during the interval dt. With probability $g(x_i)$dt agent i discovers A and becomes a leader but with probability $g(x_j)$; $i \neq j$, the rival discovers A so agent i becomes a follower. Given the stationary environment, agent i's optimal R&D investment is stationary and maximizes this expected profit

(8) $$(g(x_i)\Pi_L + g(x_j)\Pi_F - x_i)/(r + g(x_i) + g(x_j)).$$

Here, Π_L and Π_F denote agent i's expected profit from being a leader and a follower, respectively. These profits depend on the equilibrium of the subgame and will be specified below. For a moment, let me proceed with the general notation.

The first-order condition to maximization of (8) is arranged to yield

(9) $$g'(x_i)\{r\Pi_L + x_i + g(x_j)(\Pi_L - \Pi_F)\} - (r + g(x_i) + g(x_j)) = 0.$$

This has the intuitive explanation. An increase in x_i increases probability of discovery for agent i by $g'(x_i)dt$ over a small time increment dt. An earlier discovery increases the expected profit by generating the flow profit $r\Pi_L dt$ and saving $x_i dt$ of R&D cost. A discovery also eliminates the rival's chance of winning, yielding the additional profit $(\Pi_L - \Pi_F)g(x_j)dt$. However, a unit increase in investment costs the agent the interest r and is also wasted with probability $(g(x_i) + g(x_j))dt$ because a discovery occurs with this joint probability without an increase in R&D investment. The optimal investment equates these costs and benefits at a margin.

A Nash equilibrium is the pair (x_i, x_j) of R&D investments that simultaneously solves the first-order conditions (8) of the two agents. I focus on the symmetric equilibrium. Setting $x_i = x_j = x$ in (9) and rearranging yields the symmetric first-order condition:

(10) $$g'(x)\{r\Pi_L + x + g(x_j)(\Pi_L - \Pi_F)\} - (r + 2g(x)) = 0.$$ [13]

Now I can specify the expected profits. If a leader patents A, then by Proposition 2 I put $\Pi_L = \pi_{PH}$ and $\Pi_F = \pi_{NH}$. In this case let x_P^* denote the symmetric R&D investment. On the other hand, if a leader does not patent A at her first node, then $\Pi_L = \varphi_L^*$ and $\Pi_L = \varphi_F^*$. Let x^* denote the equilibrium R&D investment.

4. Harmonization to the first-to-file rule

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[13] The second-order conditions hold globally.

Imagine a harmonized world in which both countries employ first-to-file rules to award patents. In Figure 2, I show the subgame that starts when one agent discovers A and becomes a leader. My analysis follows closely the one in the previous section and hence I only provide a brief description of it. In a world harmonized to the first-to-file rule, a leader loses priority of invention in country U and hence during the NP phase the two agents engage in a winner-takes-it-all race, facing the identical expected profit

$$\pi_{NP} \equiv \lambda V/(r + 2\lambda).$$

Since $\pi_{PH} > \pi_{NP}$ however, a leader always patent A at her second node as she does in a non-harmonized world. Turning to a follower's node, if he patents A he will face the expected profit π_{PH} as a patent holder on A in both countries while, if he does not, he will be forced to compete as a non-patent holder. Since $\pi_{PH} > \pi_{NH}$, a follower always patent A. The next proposition then is the counterpart to Proposition 1.

Proposition 3: Having caught up to a leader, a follower always patents invention A, which yields the expected profit π_{PH} to a follower and π_{NH} to a leader.

I next consider a leader's decision at her first node in Figure 2. If she patents A, then she faces the expected profit π_{PH}. On the other hand, not patenting A she starts the C phase. As before, here a leader's expected profits depend on a follower's R&D investment, y. By

Proposition 3 a follower gets π_{PH} if he catches up, but nothing if a leader discovers B first. Thus, a follower's expected profit during the C phase is

(11) $$(g(y)\pi_{PH} - y)/(r + \lambda + g(y)).$$

Let y** maximize the expression and let

(12) $$\varphi_F{}^{**} = (g(y^{**})\pi_{PL} - y^{**})(r + \lambda + g(y^{**}))$$

denote the maximum value of (11). Then, a leader's expected profit is given by

(13) $$\varphi_L{}^{**} = (\lambda V + g(y^{**})\pi_{NH})/(r + \lambda + g(y^{**})).$$

This reflects the fact that a leader will get the entire value V if she discovers B first but only π_{NH} if a follower catches up by Proposition 3. The following is a counterpart to Proposition 2.

Proposition 4: In a harmonized world, a leader patents A at her first node if and only if $\pi_{PH} > \varphi_L{}^{**}$.

I now determine the equilibrium R&D investments for discoveries of A in the initial phase in a harmonized world. This part of the game is similar to the one developed in the preceding section save the values of the profits Π_L and Π_F. By Proposition 4, if a leader patents A, $\Pi_L = \pi_{PH}$ and $\Pi_F = \pi_{NH}$ as in a non-harmonized world. Then the equilibrium R&D investment is x_P* as in a non-harmonized world. Thus, as long as a leader patents A in both worlds, patent law harmonization has no effect on R&D. On the other hand, if a leader does not patent A, then $\Pi_L = \varphi_L{}^{**}$ and $\Pi_L = \varphi_F{}^{**}$. In this case, let x** denote the symmetric equilibrium R&D investments in a harmonized world. The focus is now on a comparison between x* and x**.

5. The R&D effect of international patent law harmonization

Now I compare the R&D investments before and after patent law harmonization. Here I use two facts. A first is that the equilibrium R&D investments are positively related to a leader's profit Π_L and the leader-follower profit differential Π_L - Π_F. This can easily be verified by observing equation (10). A second useful fact is given in the next proposition, and proven in Appendix A.

Proposition 5: (i) $\varphi_L{}^{**} < \varphi_L{}^{*}$ and (ii) $\varphi_F{}^{**} > \varphi_F{}^{*}$.

This proposition says that harmonization reduces a leader's expected profit and increases a follower's expected profit during the C phase. This can be explained intuitively as follows. If a leader does not get a patents on A, her hold on invention A is more tenuous in a harmonized world, where a follower can get patents on A in both countries when he catches up, than in a non-harmonized world, where a leader can at least get the patent in country U. Thus, a leader's expected profit is greater in a non-harmonized world. This explains Result (i) of Proposition 5.

The difference in a follower's profits can be explained similarly. Suppose a follower's R&D investment is fixed during the C phase. When he catches up, a follower can get patents on A in both countries in a harmonized world, but only in country R in a non-harmonized world. Thus, a follower's profit is greater with harmonization. In addition, a greater expected profit induces a follower to invest more in R&D during the C phase, raising his profit even more in a harmonized world. This explains part (ii) of Proposition 5.

I now proceed to compare the R&D investments. Proposition 5 points to the following three mutually exclusive possibilities facing a leader at her first node.

Case 1: $\pi_{PH} < \varphi_L^{**} < \varphi_L^{*}$

Case 2: $\varphi_L^{**} < \pi_{PH} < \varphi_L^{*}$

Case 3: $\varphi_L^{**} < \varphi_L^{*} < \pi_{PH}$

Case 1: $\pi_{PH} < \varphi_L^{**} < \varphi_L^{*}$.

If these conditions hold, a leader does not patent A before or after harmonization. Therefore, $(\Pi_L, \Pi_F) = (\varphi_L^{*}, \varphi_F^{*})$ for a non-harmonized world and $(\Pi_L, \Pi_F) = (\varphi_L^{**}, \varphi_f^{**})$ for a harmonized world. By Proposition 5 harmonization yields a smaller profit to a leader and a greater profit to a follower. With a success less rewarding and a failure more tolerable, harmonization softens competition, reducing incentives to invest in R&D. Therefore, $x^{**} < x^{*}$; harmonization reduces investments in R&D.

Case 2: $\varphi_L{}^{**} < \pi_{PH} < \varphi_L{}^{*}$.

In this case a leader files an application in a harmonized world but does not in a non-harmonized world. Therefore, $(\Pi_L, \Pi_F) = (\varphi_L{}^{*}, \varphi_F{}^{*})$ in a non-harmonized world and $(\Pi_L, \Pi_F) = (\pi_{PH}, \pi_{NH})$ in a harmonized world. By assumption $\varphi_{Ln} > \pi_{PH}$ so harmonization still reduce a leader's profit. On the other hand, the effect on the leader-follower profit differential

$$\Delta \equiv (\varphi_L{}^{*} - \varphi_F{}^{*}) - (\pi_{PH} - \pi_{NH})$$

cannot be signed immediately. However, I prove in Appendix B that harmonization narrows the leader-follower profit differential too. Thus, I conclude that $x^{**} < x^{*}$.

Case 3: $\varphi_L{}^{**} < \varphi_L{}^{*} < \pi_{PH}$.

In this case, a leader patents A before and after harmonization. The symmetric R&D investment is $x_P{}^{*}$ before and after harmonization. Therefore, harmonization has no effect.

The next proposition summarizes the key findings.

Proposition 6:

(A) If $\varphi_L{}^{*} \leq \pi_{PH}$ invention A is patented before and after harmonization, and hence harmonization has no effect on the speeds of discoveries of A.

(B) If $\pi_{PH} < \varphi_L{}^{*}$ harmonization slows the speeds of discoveries of A.

Thus, harmonization reduces R&D incentives if $\pi_{PH} < \varphi_L$*. Substituting, I can rewrite this condition as

(14) $$(r + \lambda)\pi_{PH} - \lambda V + g(y^*)(\pi_{PH} - \pi_{PU}) < 0.$$

Substitution shows that

(15) $$\pi_{PH} - \pi_{PU} = 2\alpha V_r/(r + 2\lambda) > 0.$$

By (15) the necessary condition for (14) to hold is $(r + \lambda)\pi_{PH} - \lambda V < 0$. This condition in turn can be expressed as

$$(r + \lambda)(1 + \alpha) - (r + 2\lambda) = \alpha r - \beta\lambda < 0.$$

Thus, $\alpha r < \beta\lambda$ is necessary for the negative effect of harmonization on R&D investment. Given the interest rate r, the higher λ and the larger the β, the more likely the above inequality holds. That is, R&D investments are more like to decrease in the wake of harmonization if primary inventions are relatively easier to commercialize (high λ) and have higher commercial values (large β relative to α).

Further, an increase in V_r increases the term in (15) and also $g(y^*)$ through (6). Therefore, if country R generates more values for the invention relative to country U, then the less likely the patent harmonization reduces investments in R&D. The following is a summary.

Proposition 7: Harmonization of the patent-awarding rules is more likely to reduce R&D investment if primary inventions can be commercialized with relative ease and generate commercial values predominantly in the United States.

7. Concluding remarks

While practically every country in the world awards a patent to the person who files an application first, in the U.S. the person who can demonstrate to have made a discovery first gets the patent regardless of the filing date. Naturally the U.S. has been under tremendous pressure to conform to the international norm. In this paper I develop a two-country model of an R&D competition for two sequential inventions and use it to study the effect of international patent law harmonization to the first-to-file rule. The primary finding is the patent law harmonization can reduce R&D investments. Further analysis shows that the negative impact on R&D investments are more likely if primary inventions have high commercial value predominantly in the United States and are relatively easy to commercialize.

My model assumes the absence of entry into competition, especially for a secondary innovation. Since corporate inventors discover the majority of significant inventions in the real world, lack of fee entry is not an unrealistic assumption.[14] However, the possibility of entry will still be an interesting extension. Obviously, entry intensifies competition for a secondary invention, making it less profitable to patent the primary invention. Our analysis then suggests

[14] In Kamien and Zang (2000), for example, entry is only possible if firms keep abreast of recent scientific developments or have absorptive capacity.

that free entry into an R&D competition for a secondary invention makes a reduction in R&D investment more likely in a harmonized world. However, complete analysis must also take into account the fact entry may change the nature of post-discovery games, indirectly affecting the equilibrium R&D.

Beside the first-to-invent rule, the U.S. patent laws retain other unique features. For example, in Europe and Japan patent applications are automatically published in 18 months after the filing dates, whereas before 1999 all applications in the U.S. were kept confidential until patents were actually issued. Although the American Investors Protection Act of 1999 eliminated this feature for inventors who seek patents outside the U.S., inventors choosing not to file for a foreign patent can still opt for non-publication of their applications, leaving open the possibility of notorious “submarine” patents; see Graham and Mowrey (2004). Aoki and Prusa (1996) and Aoki and Spiegel (2003) have compared the two patent disclosure rules in a one-country setting. However, the full implications of harmonization in patent disclosure rules in a multi-country setting remain unexamined. It is hoped that future research will study the effect of international harmonization of this and other differences among national patent laws in an international context.

Appendices

A. Proof of Proposition 5: First I compare a follower's profits between:

$$\varphi_F{}^* = (g(y^*)\pi_{PR} - y^*)/(r + \lambda + g(y^*)$$

for a non-harmonized world and

$$\varphi_F{}^{**} = (g(y^{**})\pi_{PH} - y^{**})/(r + \lambda + g(y^{**})$$

for a harmonized world. $\pi_{PH} > \pi_{PR}$ implies $y^{**} > y^*$. Then it is immediately that $\varphi_F{}^{**} > \varphi_F{}^*$. I next compare a leader's profits

$$\varphi_L{}^* = [\lambda V + g(y^*)\pi_{PU}]/(r + \lambda + g(y^*))$$

for a non-harmonized world and

$$\varphi_L{}^{**} = [\lambda V + g(y^{**})\pi_{NH}]/(r + \lambda + g(y^{**}))$$

for a harmonized world. Define the function $f(y) = [\lambda V + g(y)\pi_{NH}]/(r + \lambda + g(y))$.Then,

$$m'(y) = g'(y)[\pi_{NH}(r + \lambda) - \lambda V]/(r + \lambda + g(y))^2.$$

Substituting for π_{NH}, I rewrite the expression in brackets on the right as

$$\pi_{NH}(r + \lambda) - \lambda V = (r + \lambda)\lambda\beta V/(r + 2\lambda) - \lambda V < 0.$$

Thus, $m'(y) < 0$. Since $y^{**} > y^*$,

$$\begin{aligned}\varphi_L{}^{**} &= [\lambda V + g(y^{**})\pi_{NH}]/(r + \lambda + g(y^{**}))\\ &< [\lambda V + g(y^*)\pi_{NH}]/(r + \lambda + g(y^*))\\ &< [\lambda V + g(y^*)\pi_{PU}]/(r + \lambda + g(y^*)) = \varphi_L{}^{**},\end{aligned}$$

where the final inequality follows because $\pi_{PU} > \pi_{NH}$. ❑

B. Proof that harmonization narrows the leader-follower profit differential in Case 2

Since $\varphi_L{}^* > \pi_{PH}$, to show $\Delta > 0$ it suffices to show that

$$\pi_{NH} - \varphi_F{}^* = \pi_{NH} - (g(y^*)\pi_{PR} - y^*)/(r + \lambda + g(y^*)) > 0.$$

This is equivalent to

$$D \equiv y^* + (r + \lambda)\pi_{NH} + g(y^*)(\pi_{NH} - \pi_{PR}) > 0.$$

Thus, I need to show D > 0. First, using the definitions I obtain

$$\varphi_L{}^* - \pi_{PH} = (\lambda V + g(y^*)\pi_{PU})/(r + \lambda + g(y^*)) - \pi_{PH} > 0$$

which simplifies to

(B1) $$g(y^*)(\pi_{PU} - \pi_{PH}) > \pi_{PH}(r + \lambda) - \lambda V.$$

Next, it is easy to verify that

$$\pi_{NH} + \pi_{PH} = \pi_{PR} + \pi_{PU} = 2\lambda V/(r + 2\lambda).$$

Hence,

$$\pi_{NH} - \pi_{PR} = \pi_{PU} - \pi_{PH}.$$

Substituting, I can rewrite the condition in (B1) as

$$g(y^*)(\pi_{NH} - \pi_{PR}) > \pi_{PH}(r + \lambda) - \lambda V.$$

Then,

$$D > y^* + (r + \lambda)(\pi_{NH} + \pi_{PH}) - \lambda V.$$

But

$$(r + \lambda)(\pi_{NH} + \pi_{PH}) - \lambda V = \lambda V[2(r + \lambda)/(r + 2\lambda) - 1] > 0.$$

Therefore, $D > 0$. ❑

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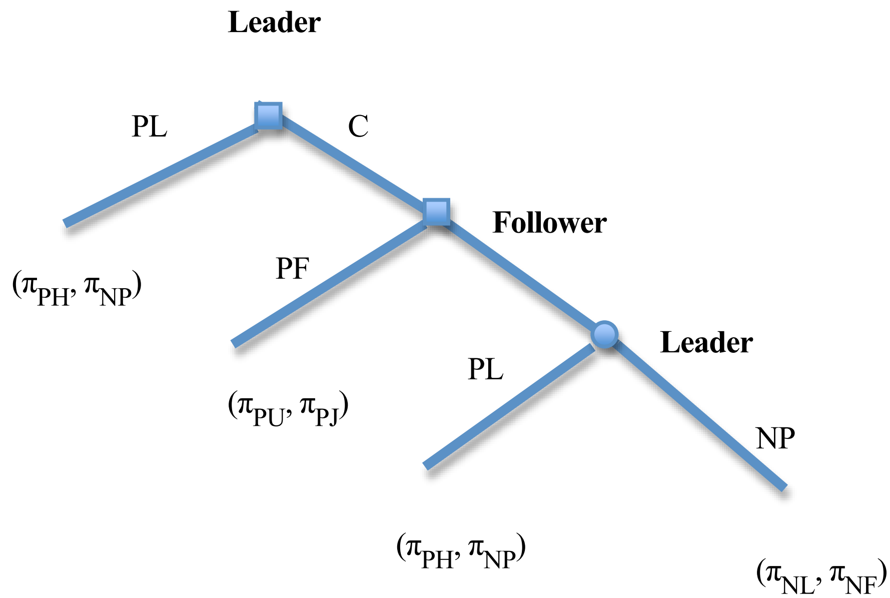
Figure 1: A non-harmonized world



The square nodes are stochastic

The oval nodes are non stochastic

Figure 2: A harmonized world