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The Utility Standard and the Patentability of Basic Research

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Abstract

We explore the consequences of the utility requirement for patents on speed of innovation. Basic research output, that has no immediate application except for as a step to further research, may not be patentable because it does not fulfill the utility requirement of patentability. Patentability of basic research differs from the questions analyzed in the past sequential innovation framework, in that basic research has no market value in itself and patentability of the first-stage invention, rather than that of the second-stage invention, is an issue. There is never immediate gain for the innovator (or static loss to society) of obtaining a patent and the gain is purely from appropriating future success of the application technology. We extend Denicolo (2000) model to identify conditions in which allowing basic research to be patented is socially desirable.

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1 Introduction

Utility, together with novelty and inventive step (or non-obviousness), constitutes one of the three basic requirements for patentability. When research is directly guided by "real-world" necessities, it is easy to establish the utility of inventions. However, when it is driven by the discovery of new scientific tools, as in the biotechnology industry, it may bring about an intermediate technology, the real world utility of which can be discovered only after further research. The utility requirement may reject patentability of such an intermediate technology.

Despite of increasing importance of utility standard in science-driven innovation, there are no substantive economic analyses of the standard.[1] The purpose of this paper is to present a framework and analyze the welfare implications of the utility standard. The economic rationale of utility standard can be best clarified in the context of cumulative innovation, since such standard rejects patentability on the reason that research is still incomplete. The past studies on the role of patent in cumulative innovation have focused mainly on the patentability of follow-up inventions and the infringement possibility of such inventions on the prior inventions (Scotchmer and Green (1995) and Denicolo (2000)). This study focuses on the economic effects of the patentability of first stage inventions, while assuming patentability of the second stage inventions.

We first identify how utility requirement differs from the novelty requirement, using the framework of Scotchmer and Green (1990). Then, we extend Denicolo (2000)'s model of the two stage patent race with free entry, incorporating trade secret protection and fixed cost of research so as to analyze the economic effects of utility standard in sequential innovation. We consider two patent regimes, the monopoly case where the patent holder of the intermediate technology can block the entry in the D stage research, and the ex-post license case, where such firm cannot block the entry but can collect half of the commercialization revenue in case a competitor is successful in the D stage research. This is because enforcing the patent of an intermediate technology against the follow-up research might be difficult, since research process itself can be kept secret. In such a case, the patent holder may be able to enforce its right only ex-post when the successful firm in the development stage wishes to commercialize its patent.

Because of free entry in both basic research and development stages (R stage

[1] There have been some legal analysis of this issue, notably Grady and Alexander (1992), Merges (1997), and Heller and Eisenberg (1998).

and D stage respectively), the rent obtained from the commercialization of the completed technology is dissipated, irrespective of the patentability of an intermediate research. In the patentability case, it will be dissipated more in the R stage (larger R expenditures and more entries in R stage competition). We show that preventing dissipation of the rent in the D stage through a patent can be critical to guarantee investment in basic research, particularly if spillover is very likely, or research in either stage is very expensive. We also show that patentability becomes less attractive as the variable or the fixed cost of the R stage research declines. We also extend the analysis to the case where the patent of the intermediate technology resulting from basic research cannot prevent entry of competing firms in development stage research either due to a compulsory license or due to a constraint in enforcing the patent right to the development stage research even if it is enforceable at the commercialization stage.

In the remainder of this section, we present a brief background and issues regarding the utility requirement. Section 2 reviews three papers we feel our work is most closely related, and clarifies the difference between utility and novelty standard. Section 3 presents the analysis of utility standard based on two-stage patent race. Sections on welfare implications and compulsory licensing follow.

1.1 Utility and description requirements

Utility, together with novelty and inventive step (or non-obviousness), constitutes one of the three basic requirements for patentability. It requires that invention can bring about a specific technical effect. In Japan, the patent law requires industrial applicability of an invention (Article 29). In addition it qualifies invention as technical idea (Article 2)[2]. This requires that "invention has to be sufficiently specific and objective so as to allow the persons with ordinal knowledge in the related technical area to reproduce the intended technical effects. If the technologies are not developed enough to this degree, invention is incomplete, not satisfying the requirement of Article 2"[3]. Thus, patentability of invention can be denied if it is technically incomplete. The description and the enablement requirement on patent specification in Article 36.4 stipulates a

[2] It says that "Invention" in this Law means the highly advanced creation of technical ideas by which a law of nature is utilized.

[3] See the Japanese Supreme Court decision (October 13 in 1977). The Japanese Supreme Court denied a patent application for nuclear reactor in 1969, pointing out that the invention is incomplete, since it does not clarify specific measures to ensure safety of the reactor operation among others.

similar requirement[4].

In the U.S.A utility requirement is defined in Section 101, which states that "Whoever invents any new and useful process, machine, manufacture, improvement thereof, or composition of mater may obtain a patent therefore"[5] The recent guidelines of the USPTO interprets that Section 101 requires that "an invention must be supported by a specific, substantial and credible utility." According to the guideline, utility specific to the subject matter, instead of general utility, has to be claimed. Utilities that require or constitute carrying out further research to identify or reasonably confirm a "real world" context of use are not substantial utilities. In addition, an assertion is credible unless the logic underlying the assertion is seriously flawed, or the facts upon which the assertion is based are inconsistent with the logic underlying the assertion. The utility requirement is also implicit in Section 112, which requires written descriptions of the invention and of the manner and process of making and using it without undue experimentation."

1.2 When does utility requirement becomes an issue ?

Utility requirement can become an important issue in cumulative research area, which is driven by scientific discoveries. When research is directly guided by "real-world" necessities, it would be easy to establish the utility of inventions. However, when R&D is driven by the discovery of new scientific tools, as in biotechnology industry, it may bring about research outcomes, the real world utility of which can be discovered only after further research. Utility requirement and description requirement may reject patentability of such intermediate research results.

Traditionally, utility requirement has been an issue in chemical industry. In this industry, research may yield synthesized compounds for which no particular use is known. The following U.S. Supreme Court ruling (the Brenner ruling) supports the denial of the patent for such compounds if it fails to disclose any utility, even though it is closely related to another compound which is useful[6].

[4] It says that "the detailed explanation of the invention under the preceding Subsection (iii) shall state the invention, as provided for in an ordinance of the Ministry of Economy, Trade and Industry, in a manner sufficiently clear and complete for the invention to be carried out by a person having ordinary skill in the art to which the invention pertains."

[5] The law of nature, physical phenomena, and abstract ideas are not regarded to be patentable subject matter.

[6] There is a ruling by a lower court, consistent with the Brenner ruling, saying that chemical compound is not presumed useful merely because it is similar to other useful compounds (in re Kirk, 376 F. 2d 936, 942, 153 U.S.P.Q. 48, 54 (C. C. P. A. 1967)).

“Until the process claim has been reduced to production of a particular product shown to be useful, the metes and bounds of that monopoly are not capable of precise delineation. It may engross a vast, unknown, and perhaps unknowable area. Such a patent may confer power to block off whole areas of scientific development, without compensating benefit to the public. The basic quid pro quo contemplated by the Constitution and the Congress for granting a patent monopoly is the benefit derived by the public from an invention with substantial utility.But a patent is not a hunting license. It is not a reward for the search, but compensation for its successful conclusion.” (Brenner v. Manson, 383 U. S. 519, 148 U.S.P.Q. (BNA) 689 (1966))

This ruling, however, is considered to represent the “high-water mark” of utility doctrine (Merges (1997)). The recent ruling in re Brana in 1995, which has established that utility for pharmaceutical products can be established by animal testing, seems to depend on an underlying logic conflicting with the above supreme court ruling at least on its face: “FDA approval, however, is not a prerequisite for finding a compound useful within the meaning of patent laws. Usefulness in patent law, and in particular in the context of pharmaceutical inventions, necessarily includes the expectation of further research and development. The stage at which an invention in this field becomes useful is well before it is ready to be administered to humans. Were we to require Phase II testing in order to prove utility, the associated costs would prevent many companies from obtaining patent protection on promising new inventions, thereby eliminating an incentive to pursue, through research and development, potential cures in many crucial areas such as the treatment of cancer.”(In re Brana 51 F. 3d 1560, 34 U. S. P. Q. 2d 1436 (Fed. Cir. 1995))

More recently, utility and enablement requirement has become a big issue in biotechnology area. Its innovation has been driven by scientific progress, so that research based on recent scientific advances has resulted in intermediate results such as identification of gene sequences, which are mainly useful since they enable further research. One of the most famous early cases is the patent application of partial genetic sequences (expressed sequences tags or EST) by NIH (Dr. Craig Venter) in 1991. NIH claimed that these can be used as diagnostic probes, identification of chromosomes, etc, which are uncertain generic utilities. NIH, however, gave up patenting in 1994, when they faced a rejection by USPTO, based on utility and other requirements, as well as strong criticism from scientific and the other circles.

Utility requirement is an important issue in biotechnology industry in the

following contexts.
(1) With regard to genetic sequences such as ESTs and cDNA, there remains a question of how specific utility a firm has to establish in order to be qualified as patents.
(2) Similar points apply to the proteins obtained from genetic sequences. Is the utility estimated based upon computer-based homology credible and substantial enough? Or are the experimental tests necessary?
(3) Can a firm, which has discovered a research tool such as a target protein for screening, also get a patent for the research results such as activating compounds (agonists) or medicaments using the agonistics, which may be obtained from using such research tool? This is the issue of reach-through claim.

The patentability of research results is especially important for firms specialized in research, which are very important part of the U.S. biotechnology industry. Since these firms do not have internal assets to implement downstream research such as clinical testing, patents for intermediate research results are important for them to sell the research outputs or to attract investment money for engaging in downstream research. The head of the leading U.S. biotechnology venture firm states the following: "Some argue that the invention is not complete until the precise biological activity of an individual gene is identified; indeed, there is some indication that the Patent Office intends to apply the new guidelines in this way. This argument ignores the real world utility, described above, associated with the isolation, sequencing and identification of genes and their classification into categories whose general functions are known. If this standard were to apply, then only those companies that adhered to the inefficient, vertically-integrated pharmaceutical industry model would be entitled to patents. This approach would be at odds with the evolution of the pharmaceutical industry, with its attendant efficiencies."(Testimony of Randal Scott, president and chief scientific officer of Incyte Genomics Inc., before the U.S. House Judiciary Subcommittee on Courts and Intellectual Property, July 13, 2000)

Another context where utility can become an issue is concept patent. It is patenting of a general product or business idea, using new technology. The idea is easy to come up, so that it has little role in advancing knowledge, but which has to be used widely in applying new technology. Such concept patent would discourage R&D for discovering application technologies for using new technology, since it enables the patentee to collect royalty, but does not aid R&D at all in terms of knowledge. Such invention may be rejected based on a non-obviousness requirement, but can also be rejected based on the absence of specific utility.

The above discussions suggest the following analytical questions.

(1) What is the economic effect of patentability of intermediate research result?

(2) Under what conditions patentability of intermediate research will improve welfare?

Analysis of these issues would help clarifying why the utility requirement is necessary first of all. People may wonder whether we should eliminate the utility requirement and leave the utility test to the market competition, since business knows utility better than the patent office. It would also indicate how it should be exercised.

1.3 Economic effects of utility standard

There are two important effects of patentability of an intermediate technology. First, patentability of intermediate technology would enhance incentive for engaging in the first stage research competition for discovering intermediate technology, while it can constrain research competition in the D stage. There are two reasons why patentability promotes the R stage of research. Firms can choose to patent the intermediate technology only if patent protection yields higher profit than trade secret. In addition, patentability of an intermediate technology will facilitate the entry by a firm specialized in research (e.g. biotechnology ventures). Our analysis does not explicitly analyze the second aspect. Patentability of intermediate technology constrains research competition in the second stage, since such research infringes the patent of the intermediate technology, although ex-ante licensing if feasible can reduce such negative effect. Whether patentability promotes the overall research or not depends on which effects are more important.

Secondly, patentability of intermediate technology would enhance incentive for disclosure. Unless intermediate technology is patentable, a firm would not voluntarily disclose it, since an intermediate technology has no direct commercial value and it is a source of the competitive advantage in the D stage research competition. However, there are subtle points both in the effect of patentability on disclosure and in the economic effect of disclosure. It is important to note that the intermediate technologies protected by trade secret can spillover to competitors. It may take place through academic publications and contacts among researchers of competing firms, which are important in science-driven innovation. Patentability may not significantly enhance disclosure, if a firm seeks a patent when such spillover risk of trade secret is high.

The disclosure of patented intermediate technology forces competing firms to avoid investment for reinventing the wheel. It is important to note that a firm choosing trade secret may also be able to force such shakeout by announcing discovery without disclosing technical details, as assumed by Green and Scotchmer (1990). Disclosure of intermediate technology may also generate inter-temporal spillover by enabling the entry of competing firms in the D stage research, using the disclosed patented technology. In the case of utility standard, however, the D stage research would infringe the patent of intermediate technology, since the D stage research would use the patented technologies such as new chemicals or gene fragments. Thus, the patent holder of the intermediate technology can potentially block the entry. However, enforcing the patent of an intermediate technology against the follow-up research might be difficult, since research process itself can be kept secret. In this case a firm which protects the intermediate technology by patent also faces competition in the D stage due to spillover. We will incorporate these subtle points in our analysis.

2 Existing literature

In this section we review three paper that we believe our work is most closely related. Grossman and Shapiro (1987) analyzes whether firms support patentability of intermediate technology in the framework of a two-stage race among duopolists, in which the completion of the first stage research is necessary for commencing the second stage research but the first stage research has no commercial value. Based on simulations, they suggest that intermediate patent may be beneficial to the firms ex post (i. e. after the first stage research), but not ex ante, since it intensifies competition. They assume that an intermediate patent requires the competing firm to drop out of the second stage research race, so that the second stage research is monopolized. They ignore the possibility of trade secret protection. They do not analyze welfare.

Scotchmer and Green (1990) analyzes novelty standard with respect to the interim innovation in duopoly competition. The major focus of their analysis is the role of the patent in facilitating disclosure, which accelerates research in their model. They take into account the possibility that a firm chooses trade secret for intermediate technology even if it is patentable. They find that a weak novelty requirement promotes disclosure while it does not undermine ex ante profit significantly, and that the first-to-file regime encourages disclosure more than the first-to-invent regime (see the Appendix how these finding can be carried over to the case of utility standard). It is important to note that utility standard is different from novelty standard in the following two aspects. First, in the novelty case the intermediate technology can have a direct commercial value and can compete with the final innovation, as assumed by Green and Scotchmer (1990), while it does not in the utility case. Second, in the case of the novelty standard, the second innovation may not infringe the first patented intermediate innovation, as assumed by Green and Scotchmer, even if patented. In the utility standard case, the secondary innovation infringes the patented first innovation, since the first innovation provides input to the research in the second stage research. Furthermore, they analyze the issue in a relatively rigid model where the levels of R&D investments are fixed and market structure is duopolies.

Denicolo (2000) analyzes the optimal degree of forward patent protection of the first innovation in the framework of a two-stage patent race. In his model, the patentability of the first stage innovation is assumed and he analyzes the economic effects of the patentability of the secondary innovation and its potential infringement of the first innovation, or the degree of forward protection. He shows that strong forward protection becomes less attractive as the relative profitability of the first innovation increases and the relative difficulty of obtaining it decreases. Although we use and extend his analytical framework, we address a different issue. We analyze the economic consequences of the patentability of the first innovation by comparing the case where the first innovation is patentable under the weak standard of utility and the case where it is not patentable due to the strong standard of utility so that it can only be protected by trade secret. Although the first case is equivalent either to UI (the secondary innovation is unpatentable and infringing) or PI (the secondary innovation is patentable and infringing) in the Denicolo analysis, he has not analyzed the case where first innovation is protected only by trade secret. In addition, we incorporate fixed cost of research in the analysis, since duplicative aspects or economy of scale may be important especially in development stage of research.

3 A Model

In this section we extend the two stage patent race model of Denicolo (2000) in order to analyze the economic effects of the utility standard. We assume free entry in research competition, unless it is constrained by patent, as in Denicolo (2000). We also assume that a firm can protect intermediate technology by trade secret, even if the firm does not choose to protect the intermediate technology by a patent. This assumption is realistic in the analysis of utility standard, since a firm does not directly commercialize the intermediate technology for the general public consumption. The intermediate technology such as a research tool is used only for further research.

A firm which protects the intermediate technology by trade secret faces potential competition of being leap-frogged in the R stage competition. That is, the other firms may (will eventually in the case of Poisson discovery process) discover the same intermediate technology and enter into the D stage research competition. Since we assume that research expenditure in each stage is completely sunk once commenced, there is no reason for a firm to drop out of competition unless it believes that it cannot profitably enter in the D stage research competition. We assume that the firm which protects intermediate technology chooses to force competitors out of research competition by committing a large scale development research, taking advantage of its first-mover position. This is a profit-maximizing conduct when the fixed cost of development research is large. We assume that the intermediate technologies protected by trade secret can spillover to competitors, with a certain probability. For simplicity, we assume that the firm which has discovered an intermediate technology immediately knows that whether it spillovers completely or whether it can be protected completely.

Specifically, firm i chooses research intensity x_{it} for cost of c_t for R&D at stage t, where $t = R$ or $t = D$. Firm i will be the first to succeed at time τ where τ is distributed according to a Poisson process. We assume there is a fixed cost f_t to participate in stage t. If the intermediate technology is patentable, then the patentee can either be the sole developer of final technology or license the intermediate technology to other firms for development. This is equivalent to Denicolo's UI or PI with $v_1 = 0$. (Because it is basic research, there is no value to the intermediate technology itself.)

If the intermediate technology is not patentable, then only the firm that achieved the intermediate technology is immediately able to proceed to the

D stage unless there is spillover. Spillover of the intermediate technology will occur with probability γ. When spillover occurs, the original innovator is unable to prevent others from using the intermediate technology to develop the final technology since there is no patent protection. If there is no spillover, the patentee has some advantage but not complete control - patentee must take into account that other firms may also move onto D stage by their own success. Thus we assume the patentee invests to deter or blockade entry when there is no spillover.

3.1 D Stage investment

We will first analyze the D stage investment behavior under the two patent regimes.

The intermediate technology is Patentable

Even when the intermediate technology is patentable, a firm may prefer to resort to trade secrets if it chooses. This would result in Not Patentable regime of the next section. In this section we will characterize the equilibrium investment when the firm patents. It will be shown later that a firm always prefers to patent if this is legally possible.

When firm has the patented technology, it is able to invest as a monopolist. It chooses x to maximize,

$$\int_0^\infty exp^{-(x+r)\tau} xv d\tau - c_D x - f_D = \frac{xv}{x+r} - c_D x - f_D.$$

The monopoly investment, x_m, is

$$x_m = \sqrt{\frac{rv}{c_D}} - r,$$

and the monopoly profit is,

$$\pi_m = \left(\sqrt{v} - \sqrt{c_D r}\right)^2 - f_D.$$

The equilibrium D stage profit when the intermediate technology is patented is, $\pi_D^P = \pi_m$ and the corresponding investment is $X_D^P = x_m$.

The intermediate technology is Not Patentable

When the intermediate technology is not patentable, there are two subgames after completion of the R stage: one where spillover occurs (with probability γ) and one without. If there is spillover, the firm must compete with new entrants into the D stage. If there is no spillover, the firm must invest to deter entry in case another firm obtains the intermediate technology on its own.

We start with the case of no spillover. The firm chooses x to deter entry. An entrant's profit when it invests x_e is,

$$\pi_e = \int_0^\infty exp^{-(x_e+x+r)\tau} xv d\tau - c_D x - f_D = \frac{x_e v}{x_e + x + r} - c_D x_e - f_D, \qquad (1)$$

v is the value of the final technology. The entrant will invest to maximize this profit, given x. That is, x_e satisfies the first order condition,

$$\frac{\partial \pi_e}{\partial x_e} = v \frac{x+r}{x_e + x + r} - c_D = 0.$$

The incumbent will produce x so profit (1) will be zero even when the entrant profit maximizes. The entry deterrent output, x_b is,

$$x_b = \frac{(\sqrt{v} - \sqrt{f_D})^2}{c_D} - r.$$

This is decreasing in fixed cost, f_D. $x_b \geq x_m$ for

$$\sqrt{f_D} \leq \sqrt{v} - \sqrt{\sqrt{r c_D v}}.$$

This condition also guarantees $\pi_m \geq 0$. The equilibrium profit with entry deterrence will be,

$$\begin{aligned}\pi_b &= v - (\sqrt{v} - \sqrt{f_D})^2 - c_D r \left(\frac{v}{(\sqrt{v} - \sqrt{f_D})^2} - 1 \right) - f_D \\ &= 2\sqrt{f_D}(\sqrt{v} - \sqrt{f_D}) - c_D r \left(\frac{v}{(\sqrt{v} - \sqrt{f_D})^2} - 1 \right).\end{aligned}$$

Profit is increasing in f_D. Larger f_D reduces the entry deterrent investment level making it closer to the monopoly level.

If there is spillover, there are n firms (the number determined in equilibrium) in D stage competition. Firm i's profit when its investment is x_i is,

$$\pi_i = \int_0^\infty exp^{-(\sum_{j=1}^n x_j + r)\tau} x_i v d\tau - c_D x_i - f_D = \frac{x_i v}{\sum_{j=1}^n x_j + r} - c_D x_i - f_D. \quad (2)$$

First order condition for profit maximization is,[7]

$$\frac{\partial \pi_i}{\partial x_i} = v \frac{\sum_{j \neq i} x_j + r}{x_i + \sum_{j \neq i} x_j + r} - c_D = 0. \quad (3)$$

There will be an incentive to invest a positive amount when this marginal profit is positive at $x_i = 0$ which will hold if $v > c_D r$.

In symmetric equilibrium with free entry, profit given by (2) should equal 0 and $x_j = x$ for all j. Equations (2) and (3) become

$$\frac{xv}{nx + r} - c_D x - f_D = 0,$$
$$\frac{(n-1)x + r}{(nx + r)^2} v - c_D = 0.$$

The two equations characterize the equilibrium investment and number of firms.[8] The equilibrium investment is

$$x_0 = \frac{\sqrt{f_D v} - f_D}{c_D}.$$

Ignoring the integer problem, we have the equilibrium number of firms engaged in D stage investment,

$$n_0 = \sqrt{\frac{v}{f_D}} - \frac{c_D r}{\sqrt{f_D v} - f_D}.$$

Number of firms is decreasing in both costs. The total investment is,

$$X_0 = n_0 x_0 = \frac{v - \sqrt{v f_D}}{c_D} - r.$$

Note that $x_b \to X_0$ as $f_D \to 0$. Entry deterrence is impossible if there is no

[7] All summation hereafter will be for $i = 1, \ldots, n$ unless noted $j \neq i$ which is for $j = 1, \ldots, i-1, i+1, \ldots n$.

[8] We first derive the relationship,

$$(nx + r)^2 = \frac{x^2 v}{f_D}.$$

fixed cost. The equilibrium profit when there is spillover is 0. Straightforward calculation yields,

Lemma 1.

$$x_m < x_b < X_0, \quad \pi_m > \pi_b.$$

The equilibrium D stage profit when the intermediate technology is not patentable is,

$$\pi_D^N = \gamma 0 + (1-\gamma)\pi_b. \tag{4}$$

This is less than π_m.

Lemma 2. *The firm will always patent the intermediate technology if it is patentable. That is,* $\pi_D^P > \pi_D^N$.

3.2 R stage investment

General solution of R stage

We derive a general solution for R stage when the payoff to the winner from the D stage is π_D and loser gets nothing. Firm i's expected payoff when it invests x_i and other firms invest x_j is

$$\pi_i = \frac{x_i \pi_D}{x_i + \sum_{j \neq i} x_j + r} - c_R x_i - f_R. \tag{5}$$

First order condition for profit maximization is,

$$\frac{\partial \pi_i}{\partial x_i} = \frac{\sum_{j \neq i} x_j + r}{x_i + \sum_{j \neq i} x_j + r} \pi_D - c_R = 0. \tag{6}$$

There will be an incentive to invest a positive amount when this marginal profit is positive at $x_i = 0$ which will hold if $\pi_D > c_D r$.

In symmetric equilibrium with free entry (5) should equal 0 and $x_j = x$ for all j. Equations (5) and (6) become

$$\frac{x\pi_D}{nx + r} - c_R x - f_R = 0,$$
$$\frac{(n-1)x + r}{(nx+r)^2} \pi_D - c_R = 0.$$

The two equations characterize the equilibrium investment and number of firms.

The equilibrium investment is

$$x_R = \frac{\sqrt{f_R \pi_D} - f_R}{c_R}. \tag{7}$$

In order for this to be positive (interior solution), profit from the next stage must be sufficiently large, $\pi_D > f_R$. Investment is decreasing in both marginal and fixed costs and increasing in D stage profit π_D. Ignoring the integer problem, we have the equilibrium number of firms engaged in R stage investment,

$$n_R = \sqrt{\frac{\pi_D}{f_R}} - \frac{c_R r}{\sqrt{f_R \pi_D} - f_R}.$$

Number of firms is also decreasing in both costs. Dependence on D stage profit is more subtle,

$$\frac{\partial n_R}{\partial \pi_D} \gtreqless 0 \quad \Leftrightarrow \quad (\sqrt{\pi_D} - \sqrt{f_R})^2 \gtreqless c_R r.$$

The aggregate investment, X_R, is always increasing in D stage profit:

$$X_R(\pi_D) = n_R x_R = \frac{\sqrt{\pi_D}}{c_R}\left(\sqrt{\pi_D} - \sqrt{f_R}\right) - r, \tag{8}$$

if $\pi_D > f_R$ and $X_R = 0$ otherwise. This together with Lemma 1 highlights how investment is increased in one stage at the cost of reducing it in the other.

Proposition 1. *Patentability of the intermediate technology increases R stage research investment but reduces D stage investment.*

The equilibrium investments when the intermediate technology is patentable, X_R^P, and when not patentable, X_R^N can be found by substituting the appropriate equilibrium profits from D stage, π_D^P and π_D^N. We make the following observation:

Proposition 2. *When the intermediate technology is not patentable, spillover must be unlikely and costs (f_R and c_R) small for there to be investment in the intermediate technology. That is,*

$$X_R^P > 0 \quad \Leftrightarrow \quad \sqrt{(1-\gamma)\pi_b} \geq \frac{\sqrt{f_R}}{2} + \sqrt{c_R r + \frac{f_R}{4}}.$$

We can also identify the minimum level of D stage profit to guarantee R stage activity,

Corollary 1. *In order for there to be positive R stage investment, D stage profit must be sufficiently high. That is, π_D must satisfy*

$$\pi_D \geq \frac{f_R}{2} + rc_R\sqrt{f_R}\sqrt{c_R r + \frac{f_R}{4}}.$$

4 Welfare

The value v is the private value for the firm. To the society as whole, there is an additional value s. Given aggregate investment X,

$$P(X) = \frac{X}{X+r},$$

is the "adjusted probability" of innovating (Denicolo (2000)). It discounts the value according to the delay which is distributed according to a Poisson process. The expected welfare is,

$$W(X_R, X_D) = P(X_R)\left\{P(X_D)(v+s) - c_D X_D - f_D\right\} - c_R X_R - f_R.$$

Social optimal investments, X_D^S and X_R^S are,

$$X_D^S = \sqrt{\frac{(s+v)r}{c_D}} - r,$$
$$X_R^S = \sqrt{\frac{r\left\{P(X_D^S)(s+v) - c_D X_D^S - f_D\right\}}{c_R}} - r.$$

In equilibrium, profit is bit down to zero at the beginning of the game, both for firms in R stage competition and for firms that enter at D stage. Welfare with and without patentability of the intermediate technology are,

$$W^P = P(X_R^P)P(X_D^P)s,$$
$$W^N = P(X_R^N)\left\{\gamma P(X_0) + (1-\gamma)P(x_b)\right\} s.$$

Using (4) and Lemma 1, the adjusted probabilities for each stage is , for any γ,

$$P(X_R(\pi_D^N)) = P(X_R((1-\gamma)\pi_b)) < P(X_R(\pi_D^P)) = P(X_R(\pi_m)),$$
$$\gamma P(X_0) + (1-\gamma)P(x_b) > P(X_D^P) = P(x_m).$$

From Lemma 1, $P(X_R^N)$ is decreasing in γ while $\gamma P(X_0) + (1-\gamma)P(x_b)$ is increasing in γ. Greater spillover benefits society at the D stage but it has an adverse effect on R stage investment. We are able to identify situations where patentability of the intermediate technology is beneficial and not beneficial to society.

Proposition 3. *When the first or second stage of research is expensive (high fixed costs f_D, f_R or marginal costs c_D, c_R), relative to the value of the final patent, v, patentability of the intermediate technology tends to increase welfare.*

Proof. Under such circumstances patentability can increase the chance that a firm engages in research first of all. It can enhance the probability of the success of the R stage research significantly. Given that a firm can recover investment in R stage research only from the commercialization value of the D stage research, not only high cost of R stage research but also high cost of D stage research tends to favor patentability of the intermediate technology. □

Proposition 4. *Patentability of intermediate technology always improves social welfare when spillover is very large. That is, there is always a level γ^P such that for all $\gamma \geq \gamma^P$,*

$$W^P > W^N.$$

Proof. There is always a $\gamma > 0$ such that

$$P(X_R^P)P(X_D^P) = P(X_R((1-\gamma)\pi_b))P(X_0). \tag{9}$$

For any γ,

$$P(X_R((1-\gamma)\pi_b))P(X_0) > P(X_R((1-\gamma)\pi_b))\left\{\gamma P(X_0) + (1-\gamma)P(x_b)\right\}.$$

We define γ^P as the γ that satisfies (9). □

This is independent of the fixed costs but of course there are restrictions such as (13) that we assume always hold.

Proposition 5. *The ratio W^N/W^P is (i) decreasing in c_R and (ii) decreasing in f_R.*

Proof. We define the adjusted probability by

$$P(X) = \frac{X(\theta)}{X(\theta) + r},$$

where $X(\theta)$ means X is a function of parameter θ (e.g., $\theta = \pi_D$ in (8)). Then,

$$\frac{dP(X_R)}{d\theta} = \frac{dX_R}{d\theta}\frac{r}{(X_R + r)^2}.$$

Given that $\frac{dP(X_D)}{d\theta} = 0$, we have the following:

$$\frac{d\ln(W^N/W^P)}{d\theta} = \frac{dP(X_R^N)/d\theta}{X_R^N} - \frac{dP(X_R^P)/d\theta}{X_R^P}$$

Using (8),

$$\frac{dX_R}{dc_R} = -\frac{X_R + r}{c_R}.$$

Thus, we have

$$\frac{dP(X_R)}{dc_R} = -\frac{r}{c_R(X_R + r)}.$$

Since $X_R^N < X_R^P$, we have $-dP(X_R^N)/dc_R > -dP(X_R^P)/dc_R > 0$. It follows that

$$\frac{d\ln(W^N/W^P)}{dc_R} < 0.$$

Similarly,

$$\frac{dX_R}{d\sqrt{f_R}} = -\frac{X_R + r}{\sqrt{\pi_D} - \sqrt{f_R}},$$

so that

$$\frac{dP(X_R)}{d\sqrt{f_R}} = -\frac{r}{(\sqrt{\pi_D} - \sqrt{f_R})(X_R + r)}.$$

Since $X_R^N < X_R^P$ and $\pi_D^N < \pi_D^P$, we have $-dP(X_R^N)/d\sqrt{f_R} > -dP(X_R^P)/d\sqrt{f_R} > 0$. □

The social welfare depends on the product of the adjusted probability of D stage success and that of R stage success. As a result, when the probability R stage success becomes high due to lower research cost of that stage (low c_R and low f_R), it becomes more efficient to encourage the expansion of the D stage. Since patentability reduces the D stage adjusted probability, non-patentability becomes more advantageous. The proposition implies that patentability should be rejected when the intermediate technology covers a mere “idea” easy to come up with but its development is relatively much more costly. Something like a utility standard.

5 Compulsory Licensing

In this section we analyze the effects of compulsory licensing. If there is compulsory licensing, the patentee must license the technology to all firms that want to engage in D stage R&D.

We will refer to the winner of the R stage as the Leader or patentee and the other firms in D stage competitions as the Followers or the licensees. There are n Follower firms. If one of the Followers wins the D stage, Leader gets half of the value of the innovation.

Leader's profit is,

$$\pi_L = \frac{x_L v + \sum_{i=1}^{n} x_i \frac{v}{2}}{x_L + \sum_{i=1}^{n} x_i + r} - c_D x_L - f_D. \tag{10}$$

A Follower firm i' profit is,[9]

$$\pi_i = \frac{x_i \frac{v}{2}}{x_L + \sum_i x_i + r} - c_D x_i - f_D. \tag{11}$$

The first order conditions of maximization are,

$$\begin{aligned} \frac{v(x_L + \sum_{j \neq i} x_j + r)}{2(x_L + \sum x_i + r)^2} - c = 0, \\ \frac{v(\frac{\sum x_j}{2} + r)}{(x_L + \sum x_j + r)^2} - c = 0. \end{aligned} \tag{12}$$

In symmetric (among Followers) equilibrium, $x = x_j$, $\forall j = 1 \dots n$. It is easy to show $x_L = x + r$. Substituting this relationship into (11) with the zero profit condition and (12), we have

$$\begin{aligned} \frac{x}{2((n+1)x + r)} - c_D x - f_D = 0, \\ \frac{v(\frac{nx}{2} + r)}{(n+1)x + r} - c_D = 0. \end{aligned}$$

[9]If the firm obtains a patent, the technology becomes public information and any firm is technologically able to attempt to develop the final technology. It is arguable that information contained in a patent is sufficient to use the patented technology just as effectively as the patent owner. However it seems if the intermediate technology is gene fragments, this is possible. If the intermediate technology is a chemical entity and the final technology is clinical testing, some ex-ante licensing agreement between patent owner and another firm would be necessary and such a contract would be feasible. We restrict our analysis to situations where other firms will be equally competent.

We solve for x and n by first deriving

$$(x_L + nx + r)^2 = x\sqrt{\frac{v}{2f}}.$$

The equilibrium investment and number of follower are,

$$x_F = \frac{\sqrt{\frac{f_D v}{2}} - f_D}{c_D},$$

$$n_\ell = \frac{2}{x_F}\left\{\frac{c_D(x_F)^2}{2f_D} - r\right\} = \sqrt{\frac{v}{2f_D}} - 1 - \frac{2c_D r}{\sqrt{\frac{f_D v}{2}} - f_D}.$$

The total Follower output should be positive, $n_\ell x_F > 0$. This requires,

$$\sqrt{v} - 2\sqrt{c_D r} > \sqrt{2f_D}. \tag{13}$$

This condition will also guarantee $X_0 > 0$. The equilibrium investment of the leader is $x_L = x_F + r$. The equilibrium total investment when there is compulsory licensing, $X_\ell = x_L + n_D^P x_F = (n+1)x_F + r$ is,

$$X_\ell = \frac{v - \sqrt{2f_D v}}{2c_D} - r.$$

Using $x_L = x_F + r$, (10), and (11), we obtain the following relationship between patent owner's equilibrium profit, π_L, and equilibrium profit of the Followers, π_F,

$$\pi_L - \pi_F = \frac{v}{2} - c_D r.$$

The left hand side is actually π_L since follower profit is 0 in equilibrium. When the intermediate technology is patentable and compulsory licensing, this is the equilibrium D stage profit that R stage winner gets,

$$\pi_\ell = \frac{v}{2} - c_D r.$$

This is independent of the fixed cost f_D.

Lemma 3. *The following relationships always hold, for all f_D satisfying (13),*

$$x_m < X_\ell < x_b < X_0, \quad \pi_m > \pi_\ell > \pi_b \quad .$$

Proof. The only non trivial part is relationship between π_ℓ and π_b. Define λ

and β by

$$\frac{v}{2} = \lambda c_D r, \quad \sqrt{f_D} = \beta\sqrt{v}.$$

(13) implies that $\lambda > 2$ and $0 < \beta < \frac{1}{\sqrt{2}} - \frac{1}{\sqrt{\lambda}}$. Doing the appropriate substitution,

$$\pi_\ell - \pi_b = \frac{v}{2}\left\{1 - 4\sqrt{f_D}(\sqrt{v} - \sqrt{f_D})\right\} - c_D r\left\{2 - \frac{v}{(\sqrt{v} - \sqrt{f_D})^2}\right\} = c_D r\Delta,$$

where

$$\Delta = \lambda(1-2\beta)^2 + \frac{1}{(1-\beta)^2} - 2. \tag{14}$$

This is minimized when π_b is maximized by β^* that satisfies,

$$\frac{\partial \pi_b}{\partial \beta} = c_D r\left\{2\lambda(1-2\beta) - \frac{1}{(1-\beta)^3}\right\} = 0.$$

Substituting this into (14),

$$\Delta = \lambda(1-2\beta)(3-4\beta) - 2.$$

This will be positive when

$$\beta \leq \hat{\beta} \equiv \frac{5\lambda - \sqrt{\lambda^2 + 16\lambda}}{8\lambda}.$$

When $\beta = \hat{\beta}$,

$$\frac{\partial \pi_b}{\partial \beta} = c_D r\left\{-4\frac{\lambda^2(\lambda^2 + 88\lambda - \lambda^{\frac{3}{2}}\sqrt{\lambda+16} - 16\sqrt{\lambda}\sqrt{\lambda+16} - 32)}{(3\lambda + \sqrt{\lambda}\sqrt{\lambda+16})^3}\right\}.$$

This is negative for $\lambda > 2$ and shows that the $\beta^* < \hat{\beta}$ and it means $\Delta > 0$ at β^*. Since β^* minimizes Δ, it be $\Delta > 0$ for any β. □

This and (4) implies,

$$X_\ell < X_D^N \quad \textit{and} \quad \pi_\ell > \pi_D^N.$$

Even if there is compulsory licensing, a firm will want to patent the intermediate technology. On the other hand, such licensing must always be compulsory. Because the innovation is a Poisson process, the licensor does not gain from multiple firms engaging in D stage.

Social welfare with patentability and compulsory licensing is,

$$W^{\ell} = P(X_R(\pi_{\ell}))P(X_{\ell})s.$$

The advantage of compulsory licensing is that increase investment in D stage compared to just patentability. However the draw back is that it reduces investment in R stage. Comparison with patentability is independent of size of spillover. How it compares to No Patentable is very similar to comparison with Patentability.

Proposition 6. *Patentability of intermediate technology always improves social welfare when spillover is very large. That is, there is always a level* γ^{ℓ} *such that for all* $\gamma \geq \gamma^{\ell}$,

$$W^{\ell} > W^{N}.$$

Proof. Define γ^{ℓ} as

$$P(X_R(\pi_{\ell}))P(X_{\ell}) = P(X_R((1-\gamma^{\ell})\pi_{\ell}))P(X_0)$$

Since for any γ,

$$P(X_R((1-\gamma)\pi_{\ell}))P(X_0) > P(X_R((1-\gamma)\pi_{\ell}))\left\{\gamma P(X_0) + (1-\gamma)P(X_{\ell})\right\},$$

the Proposition follows. ☐

5.1 General share compulsory licensing

If the government were able to set the division of profit between patentee and license, what should it be ? We denote by α the share of v that the patentee gets when a competitor succeeds in the D stage. Aggregate output is,[10]

$$X_D(\alpha) = \sqrt{(1-\alpha)v}\left(\frac{\sqrt{(1-\alpha)v} - \sqrt{f_D}}{c_D}\right)^2 - r,$$

and the equilibrium patentee profit is, Licensees' profits is bit down to 0 in equilibrium.

The even division of previous section is when $\alpha = \frac{1}{2}$. Monopoly profit is $\pi_m = \pi_D(\alpha_m)$, where α_m is the smallest α such that $nx_F = 0$. When there is spillover, $\alpha = 0$, i.e., $X_0 = X_D(0)$. Perfectly competitive, compulsory licensing,

[10] Derivation is in the Appendix.

and monopoly can be explained by extent of patentee market power, α. The difference between entry deterrence and other regimes cannot be explained by difference in market power only.

Lemma 4. *There are two critical values, $\underline{\alpha}_b < \overline{\alpha}_b < \frac{1}{2}$ such that*

1. $X_D(\underline{\alpha}_b) = x_b$ *and* $\pi_D(\underline{\alpha}_b) < \pi_b$
2. $\pi_D(\overline{\alpha}_b) = \pi_b$ *and* $X_D(\overline{\alpha}_b) < x_b$.

Proof. Definitions of $\pi_D(\alpha)$ and $X_D(\alpha)$ are,

$$X_D(\alpha) = x_L + nx_F,$$
$$\pi_D(\alpha) = \frac{x_L + \alpha n x_F}{x_L + nx_F + r} v - c_D x_L - f_D$$

x_L and nx_F are also functions of α. There is α_b such that $X_D(\alpha_b) = x_b$. Using $\pi_F = 0$,

$$\begin{aligned}
\pi_D(\alpha_b) &= \frac{x_L + \alpha n x_F}{x_b} - c_D x_L - f_D \\
&= \pi_D(\underline{\alpha}_b) + n\pi_F \\
&= \frac{x_L + \underline{\alpha}_b n x_F + (1-\underline{\alpha}_b) n x_F}{x_b} - c_D(x_L + nx_F) - f_D - nf_D \\
&= \frac{x_b}{x_b + r} - c_D x_b - f_D - nf_D
\end{aligned}$$

$= \pi_b - nf_D < \pi_b$.

The rest follows from the fact that $X_D(\alpha)$ is decreasing in α and $\pi_D(\alpha)$ is increasing in α. □

By requiring share of $\overline{\alpha}_b$ to the patentee, it is possible to have the firm patent the intermediate technology for any level of spillover. Lower share increases total investment in the D stage. It is possible to offer smaller shares by adjusting to level of spillover.

6 Reference

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Appendix

Incentive for disclosure and ex-ante incentive for engaging in research in Green and Scotchmer (1990) Model

One important economic effect of weak utility standard for patentability is to encourage disclosure of intermediate research, which would help avoid spending duplicative research and enhance research efficiency. The weak standard also affects ex-ante incentive for engaging in research competition, which is significantly affected by the availability of trade secret protection. This appendix gives a sketch of how the framework of Green and Scotchmer (1990) can be used to shed light on these issues in the case of utility standard. This analysis assumes that the patent of an intermediate technology still allows the entry of a competitor in the development stage competition, resulting in the ex-post license when it is successful as in the case of compulsory licensing case. In addition, it assumes the interim profit which the first innovator can get in the case of novelty standard if he chooses to patent its discovery can be ignored relative to the final profit, due to low interest rate.

We can derive the following three main conclusions, which is stated as a comparison between utility and novelty standards. First, the incentive for disclosure is stronger in the case of weak utility standard than in the case of weak novelty standard. The payoff of patenting is larger for the first innovator (firm A). Unlike with the novelty standard, firm A can obtain a half of the commercialization revenue by patenting in the case of utility standard, even if it has failed in the second innovation, since the latter infringes the former. The profitability of choosing trade secret for firm A declines with the first-to-invent regime (Figure 1). This is because the laggard in the first innovation (firm B) is more likely to stay in research competition since the profit which it can obtain if it successfully catches up (by finishing first innovation) is larger. On the other hand, the payoff for firm A does not change when it chooses the trade secret strategy. Thus, firm A is more likely to patent and disclose the intermediate technology).

The similar conclusion applies to the first-to-invent regime (Figures 1 and 2). As with the first-to file regime, by the patenting strategy, firm A can obtain a half of the commercialization revenue in the case of utility standard, even if it has failed in the second innovation. When firm A chooses trade secret strategy in the case of utility standard, the payoff for firm B is not affected, but firm A can still obtain part of the revenue even if firm B is successful in both innovations. This is because the second innovation infringes the first innovation, unlike the case of the novelty standard. The first effect dominates the second effect, so that firm A is more likely to patent and disclose the intermediate technology.

Secondly, the first-to-file regime encourages disclosure more than the first-to-invent regime in both weak utility standard case and weak novelty standard case, although the reasons are a bit different. In both cases the first innovator A is assumed to successfully counter-patent when the competitor B catches up and attempts to patent, with first-to-invent. In the case of weak utility standard, firm A can receive licensing revenue from firm B, even if firm A chooses trade secret initially and firm B leap-frogs firm A, only with first-to-invent. Firm A can still monopolize the market even if firm B succeeds only in the catching-up with the first innovation. In the case of weak novelty standard, the first innovator can monopolize the market even if firm A chooses trade secret initially and firm B succeeds in the first stage of innovation, only with first-to-invent. Thus, in both cases, first-to-invent enhances the profitability of trade secret.

Thirdly, the patentability of intermediate technology under a weak standard is unlikely to reduce the ex-ante profit in the case of utility standard too . This is because firm A can secure licensing revenue even if the second firm succeeds earlier in completing the second stage of research, only if intermediate technology is patented. If firm A finds that disclosure of intermediate research reduces its profit, it can choose trade secret, as in the case of novelty standard. With first-to-invent, patentability of intermediate technology enhances the profit of firm A, since it can get the licensing revenue even if firm B leap-frogs firm A, only if the intermediate research is patentable. With first-to-file, as in the case of novelty standard, firm A would earn less when it chooses trade secret protection in the case of weak standard than it would in the case of strong standard (Figure 3), since firm B is now less likely to exit from research competition.

General patentee share α

α is the share of v that the Leader will get if a Follower succeeds in the D stage. The Follower will get $(1-\alpha)v$.

D Stage investment

Leader's profit is,

$$\pi_L = \frac{vx_L + \alpha \sum_{i=1}^n x_i}{x_L + \sum_{i=1}^n x_i + r} - c_D x_L - f_D.$$

A Follower firm i' profit is,

$$\pi_i = \frac{(1-\alpha) v x_i}{x_L + \sum_i x_i + r} - c_D x_i - f_D. \tag{15}$$

The first order conditions of maximization are,

$$v\frac{(1-\alpha)\sum x_j + r}{(x_L + \sum x_i + r)^2} - c_D = 0,$$
$$v(1-\alpha)\frac{x_L + \sum_{j\neq i} x_j + r}{(x_L + \sum x_j + r)^2} - c_D = 0.$$

In symmetric (among followers) equilibrium, $x = x_j$, $\forall j = 1 \dots n$. Thus the two first order conditions and the zero profit condition on (15) become, we have

$$v\frac{(1-\alpha)nx + r}{(x_L + nx + r)^2} - c_D = 0,$$
$$v(1-\alpha)\frac{x_L + (n-1)x + r}{(x_L + nx + r)^2} - c_D = 0,$$
$$\frac{(1-\alpha)vx}{(x_L + nx + r)} - c_D x - f_D = 0,$$

We first solve for x and n by first deriving

$$\frac{x^2}{(x_L + nx + r)^2} = \frac{f_D}{(1-\alpha)v}.$$

Follower's investment is

$$x = \frac{\sqrt{(1-\alpha) f_D v} - f_D}{c_D}.$$

Leader's investment is

$$x_L = x + \frac{\alpha}{1-\alpha} r.$$

Total D stage investment is,

$$X_D(\alpha) = \sqrt{(1-\alpha)v}\left(\frac{\sqrt{(1-\alpha)v} - \sqrt{f_D}}{c_D}\right)^2 - r.$$

This is decreasing in α. Leader is the only firm that makes positive profit in equilibrium. The equilibrium D stage profit is,

$$\pi_D(\alpha) = \pi_L - \pi_F = \alpha v - \frac{\alpha c r}{1-\alpha}.$$

This is increasing (decreasing) for $\alpha < \tilde{\alpha}$ ($\alpha > \tilde{\alpha}$) and is maximized at $\alpha = \tilde{\alpha}$ where $\tilde{\alpha}$ satisfies $(1-\tilde{\alpha})^2 = \frac{cr}{v}$.

We need to determine α_m such that $X_D^P = X_D(\alpha_m)$. The share α_m is the minimum level of Leader's share of Follower's success that makes it unprofitable for the Follower to enter. That is, when $\alpha = \alpha_m$, $xn = 0$. Since

$$nx = \frac{c_D x^2}{f_D} - \frac{r}{1-\alpha},$$

α_m satisfies

$$\left(\sqrt{(1-\alpha)v} - \sqrt{f_D}\right)^2 = \frac{r c_D}{(1-\alpha)}.$$

One can show that there will be a $z > 0$ that satisfies

$$(z\sqrt{v} - \sqrt{f_D})^2 = \frac{r c_D}{z^2}.$$

One can also show $\alpha_m < \tilde{\alpha}$ and $\alpha_m \to \tilde{\alpha}$ as $f_D \to 0$. α_m is the share the minimum share of Leader that will blockade D stage entry if there is no fixed cost. When there is fixed cost, entry is deterred at a smaller share, α_b.

R stage

The R stage total investment is restatement of (7),

$$X_R(\alpha) = \frac{\sqrt{\pi_D(\alpha)}(\sqrt{\pi_D}(\alpha) - \sqrt{f_R}) - c_R}{c_R}.$$

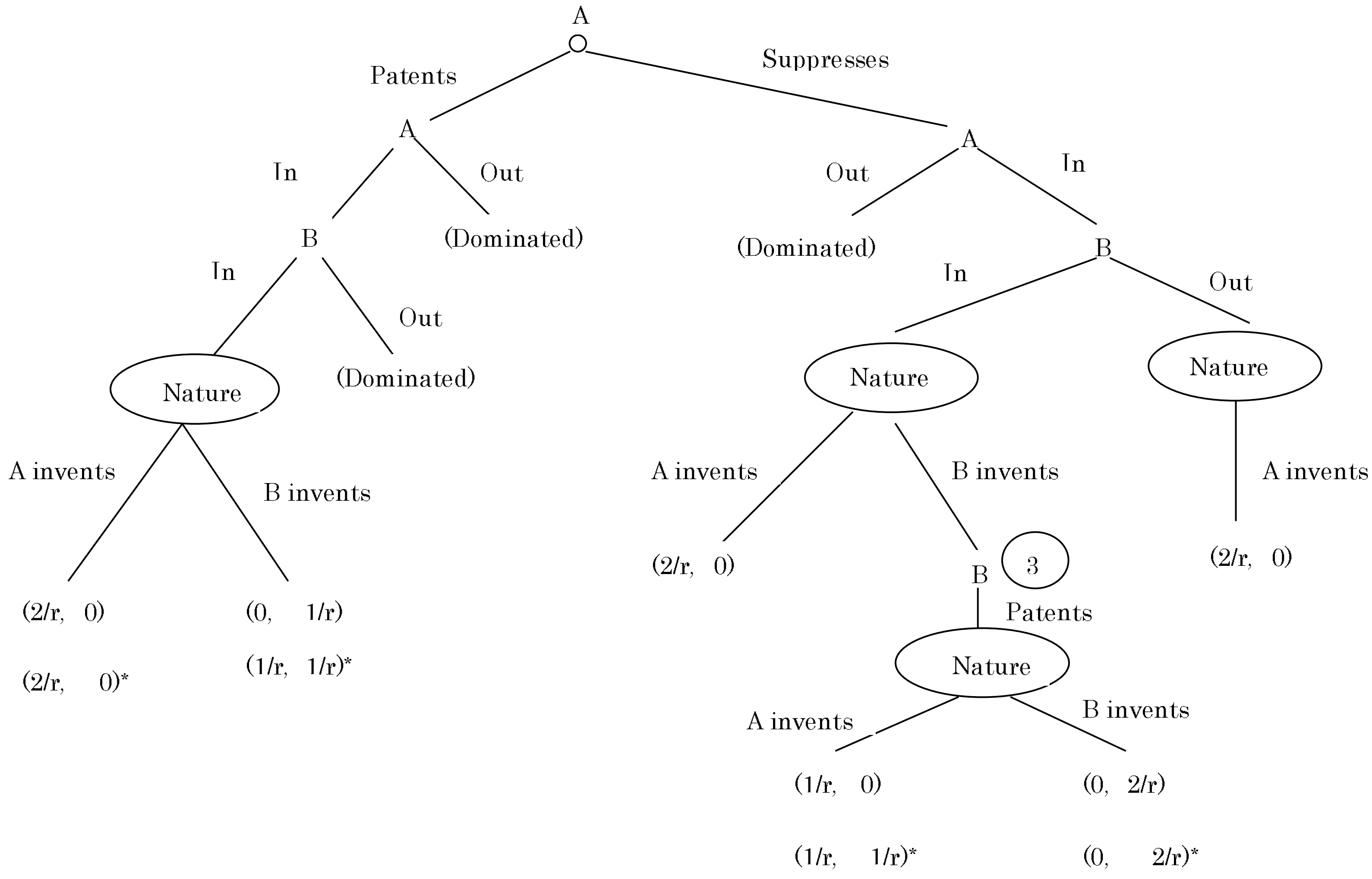
Welfare

Welfare for any share α is,

$$W(\alpha) = P(X_R(\alpha))P(X_D(\alpha))s,$$

where $P(X) = \frac{X}{X+r}$ is the adjusted probability. This is concave in α for $X_R(\alpha) > 0$. $W(0) = 0$ for α so small that $\pi_D(\alpha) = 0$.

Figure 1: The Patent Game for First-to-file with Weak Standard (Novelty vs. Utility



Note * represents the payoff for utility standard.

Figure 2: First-to-invent (Novelty vs. Utility standard)

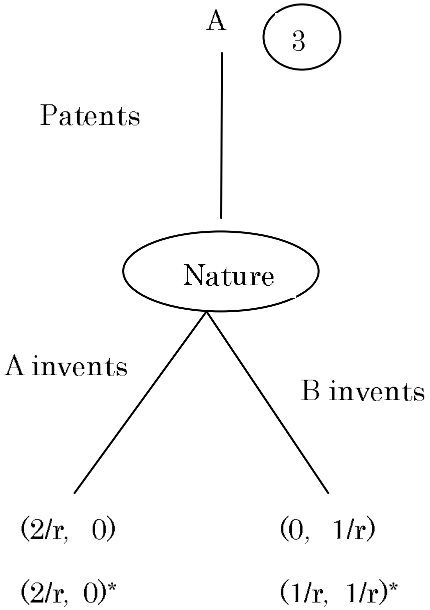
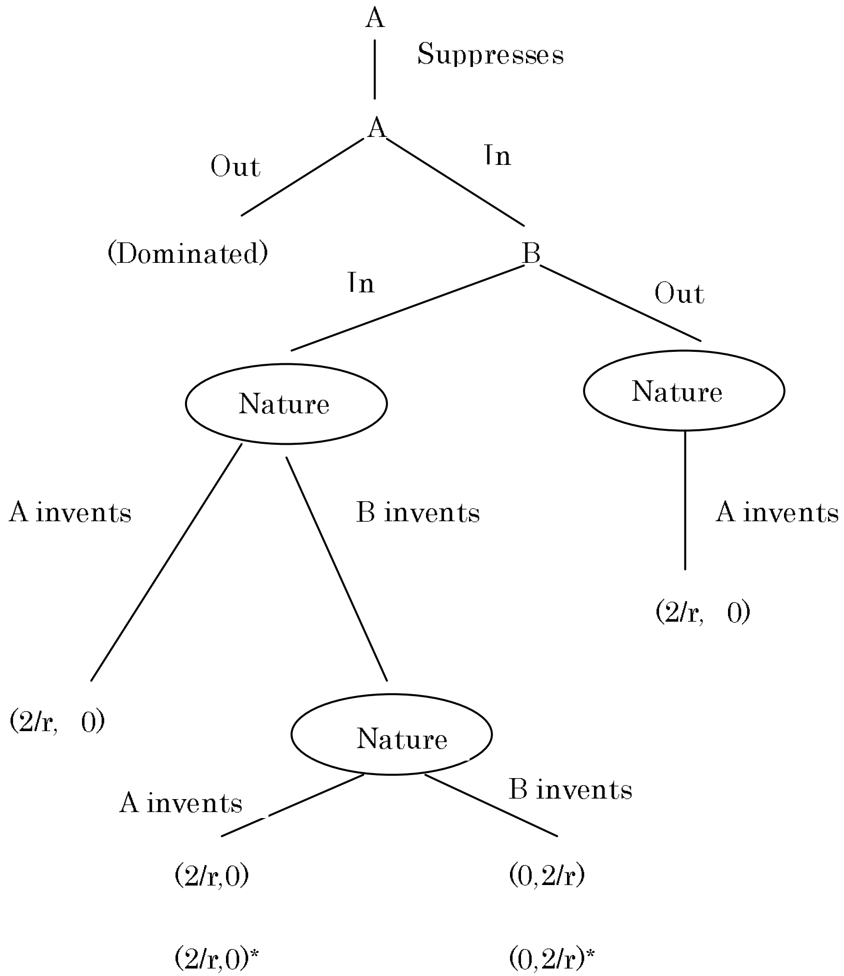


Figure 3: The Patent Game for First-to-file with Strong Standard (Novelty vs. Utility standard)



Note * represents the payoff for utility standard.