The Dynamic Effects of Intellectual Property Practices*

by

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This paper analyses various intellectual property practices in a dynamic context. Building on a model of Segal and Whinston (2004), the paper considers the rate of innovation when IP licensing is expected versus when it is not. In each case, innovation returns trade off the immediate value from innovation versus the long-term advantages of incumbency. Licensing enhances the former but reduces the latter relative to no licensing but overall licensing has a positive impact on innovation rates. The paper then turns to consider the impact of other IP practices such as patent breadth, disclosure requirements, experimental use exemptions and protection from expropriation. By utilising a model that considers immediate and future benefits from innovation, it is able to substantially clarify and, in some cases, resolve debates regarding the impact of these practices. *Journal of Economic Literature* Classification Number: O34.

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The impact of intellectual property protection upon the competitive dynamics of an industry, both in terms of entry and innovativeness, has been a focus of considerable attention in economic studies of innovation. Of course, Schumpeter most clearly identified the means by which innovation could at the same time create economic value will destroying the value of existing incumbency. Arrow (1962) demonstrated how established firms would be concerned about raising innovation rates in any industry for this reason while Teece (1987) reminded us of the critical importance of complementary assets held by established firms on the ability of new entrants to earn innovative rents.

In recent times, there has been increased interest in how intellectual property protection itself might influence the evolution of competition and continual innovation in an industry. Gilbert and Newbery (1981) began this literature, demonstrating that incumbency generated increased incentives to secure patents so as to protect incumbency rents from potential entrants. Reinganum (1989) built on this to argue that pre-emption as well as fear of cannibalization of existing incumbent assets would trade-off in incumbent's innovative responses but in any case would be spurred on by increased entrant innovation. Katz and Shapiro (1987) demonstrated how such competition could cause innovation to occur at a socially excessive rate. Finally, Gans and Stern (2000) examined the incentives of incumbents to license innovations from entrants rather than face head to head competition with them providing a set of instances whereby entrant innovation could reduce incumbent innovation incentives. In any case, when such licensing was possible it would reinforce incumbency rather than destroy it in any Schumpeterian sense.

Each of these models are static in a very important sense: the roles of firms in an industry is fixed over time and there is effectively a single innovation race. Specifically, when one firm wins a particular innovation race it does not change the competitive dynamics in subsequent races. In some situations, such as when an entrant always licenses to an incumbent, this may be acceptable. However, when entry actually occurs, the entrant becomes established in subsequent innovation races.[1] For forward looking firms, this change in structure will impact upon all innovation races. Moreover, even when licensing is an equilibrium, it will impact upon off the equilibrium path outcomes that themselves will impact on licensing agreements. As such, a neglect of the role of changed (or potential changes in) technological and market leadership in any industry will hide some potentially important effects of intellectual property protection on innovation in an industry.

To redress this, we extend the model of Segal and Whinston (2005) – hereafter SW – to a context that allows licensing. SW provide a model of continual change in technological and market leadership in any industry for the purpose of analysing the competitive and welfare effects of different exclusionary practices. What they do not explore, however, is the impact of intellectual property protection; in particular, how it relates to the possibility of cooperative agreements between incumbent and entrant such as licensing. Gans, Hsu and Stern (2002) have demonstrated empirically that increased intellectual property protection is associated with greater levels of cooperative agreements between start-up, entrepreneurial firms and established competitors across a variety of industries. Specifically, those cooperative agreements are made at the expense

[1] Hunt (2004) provides a model that captures such dynamic effects but focuses on the design of intellectual property protection – namely, non-obviousness criteria – rather than practices such as licensing that are the focus of this paper.

of product market entry by those smaller firms. This effect has caused some to criticise the scope of current patent protection as harming the competitive process (Boldrin and Levine, 2002).

It appears to be uncontroversial that increased intellectual property protection can facilitate cooperative agreements. One obvious reason is that such protection prevents small firms from being expropriated by established ones when disclosing their ideas (Arrow, 1962; Anton and Yao, 1994). Having such protection also impacts upon the incentives to enter product markets (by preventing imitation). However, Gans, Hsu and Stern (2002) demonstrate that the relative benefit to cooperation is increasing in the degree of IP protection. For that reason, IP protection will facilitate, in some cases, anticompetitive cooperative outcomes.

The impact of this on the rate of innovation is unknown. On the one hand, as SW argue, cooperative agreements tend to raise the 'prize' from an innovation race and hence, spur the rate of innovation. However, that prize can itself impact on the value of incumbency and also on the effective economic life of any innovation created. It is demonstrated in Section 3 that, in equilibrium, the relative value of incumbency when licensing is not possible is much higher than when it is, potentially leading to higher innovation rates. Thus, in the absence of a model of these competing effects, it is not easy to say whether IP protection that facilitates licensing will actually spur innovation rates in an industry.

The contribution of this paper is to explore this by building upon the framework of SW to include the possibility of incumbent-entrant licensing (as in Gans and Stern, 2000), as well as the notion that incumbents have some advantages in exploiting innovative potential. A situation where licensing is not possible (due to a disclosure problem) is compared with a situation where IP protection is such that licensing can be freely undertaken. In this context, it is found that (1) incumbency advantages are indeed weaker under licensing than no licensing but (2) regardless, increased IP protection, improves the rate of innovation in an industry as the incumbency advantage is outweighed by the immediate advantages of licensing on innovative returns.

The paper proceeds as follows: in Sections 1 and 2, the basic model is introduced and the equilibrium under no licensing (or competition) is presented. Section 3 then considers the licensing case including a derivation of the licensing fee in a dynamic context. Importantly, this demonstrates that incumbency advantage – even if not forfeited in equilibrium – does impact on innovation benefits in this case. Section 4 then considers alternative IP practices including patent breadth, disclosure requirements, experimental use exemptions and protection from expropriation. The latter is shown to reduce license fees (as it reduces incumbency advantages) but, nonetheless, to stimulate innovation rates as it stimulates the potential for licensing. The former three practices are more difficult to analyse as they improve research productivity as well as changing the direct private benefits from innovation. Nonetheless, in some cases, a clear prediction regarding the impact of these practices on innovation is possible.

1. Model Set-Up

Here we augment the ‘quality ladder’ model of SW to allow a transparent comparison between competitive and cooperative modes of commercialisation.

Consumers

Suppose there is a continuum of infinitely-lived consumers of measure 1. Each consumes a nonstorable and nondurable good. Research and development can result in improved product quality. A product of generation *j*, generates utility for all consumers of $v_j = v + \Delta \cdot j$.

Firms

There are two firms in the industry.[2] Both discount the future at a rate, $\delta \in (0,1)$ and both face no production costs. If the current generation of the product is *j*, I assume that the j-2th generation is in the public domain and can be produced by any firm. The j^{th} and j-1th generations are patented and can be produced by their patent-holder or licensee. Clearly, if these are the same firm, then that firm can charge a price of 2Δ to consumers and still capture the entire market. On the other hand, if they are not the same firm, then the leader (who holds the production rights to *j*) can serve the whole market for a price of Δ; being constrained by competition from the holder of the production rights to the previous generation[3]

At any particular juncture, we distinguish between the current market (and technological) leader in the industry – the incumbent – and others – the entrants. An incumbent by definition holds the production rights (via patent or license) to the current (j^{th}) product generation. Moreover, in so doing, I assume that the incumbent has an advantage in commercialising the next generation of product (*j*+1). This is modeled by assuming that any entrant would have to incur sunk costs of *f* in order to produce

[2] SW demonstrate that these results readily generalise to the case of *N* firms.
[3] In contrast, SW assume that the current technological (and market) leader is always different from the previous one and so that price charged is always Δ.

generation j+1. The basic idea is that the act of producing the j^{th} product generation gives the incumbent a competency in producing the $j+1^{th}$ generation. However, that advantage can only be maintained if the incumbent continues to produce the current generation. If an entrant were to enter and sink costs f, that entrant would have the advantage for the next generation and the incumbent would lose any advantage – becoming just another entrant for any future competition. As we will see, this creates a value for incumbency that impacts upon the nature of competitive dynamics.

It is assumed that only entrants engage in innovation.[4] Let $\phi_i \in [0,1]$ be the R&D intensity – literally the probability that firm i generates an innovation in the current period. $c(\phi_i)$ is the cost of R&D where $c(.)$ is a non-decreasing, strictly convex function.

Timeline

In each period, all entrants select their R&D intensity. Then nature determines who (if any) has innovated and who among that set is awarded a patent. The patent holder then faces a choice. It can enter into production of the product generation by sinking costs, f, or it can negotiate with the current incumbent.[5] We assume that such negotiations take the Nash bargaining form where the incumbent and entrant both have equal bargaining power.[6] In contrast, when licensing is not possible, the patent holder faces no choice and must enter.

A final subtle case occurs when the innovator has very insecure property rights – at the extreme, none at all. In this situation, it faces expropriation if it engages in

[4] This is also assumed by SW. They extend their model to a general case where all firms invest but given the complexity of the analysis there, I restrict attention to the simple case throughout this paper.
[5] This is a common presumption in innovative industries; see Teece (1987).
[6] In a non-cooperative bargaining model, Gans and Stern (2000) show that this outcome is the upper bound on the entrant's bargaining power when IP protection is potentially weak and the incumbent can invest in 'work around' technologies.

bargaining and imitation if it enters the product market. This will be a significant impact the resulting outcomes if more than one entrant innovates in any given period.

2. No Licensing Case

I begin with the case where licensing is simply not possible but otherwise an entrant holds strong IP over its innovation. For simplicity, as noted earlier, we assume that there is only one entrant. In the infinite-horizon dynamic game, I confine our attention to Markov perfect equilibria using SW's dynamic programming approach. For this purpose, let V_I be the expected present value of profits of the incumbent firm at the beginning of any given period and V_E those of any given potential entrant. Given that innovation results in entry, these values will satisfy:

$$V_I = \Delta + \delta V_I + \phi\delta(V_E - V_I) \qquad \text{(VI)}$$

$$V_E = \delta V_E + \phi(\Delta - f + \delta(V_I - V_E)) - c(\phi) \qquad \text{(VE)}$$

for any given symmetric R&D intensity, ϕ.

The equilibrium level of R&D intensity is given by the following set of equations:

$$\phi \in \arg\max_{\varphi\in[0,1]} \{\varphi(\Delta - f + \delta(V_I - V_E)) - c(\varphi)\}$$

Following SW, we let W denote the "innovation prize." In this case,

$$W = \Delta - f + \delta(V_I - V_E) \qquad \text{(IB)}$$

so that an entrant is effectively solving:

$$\phi \in \arg\max_{\varphi\in[0,1]} \{\varphi W - c(\varphi)\} \qquad \text{(IS)}$$

Given the convexity of $c(.)$, this gives an "innovation supply" relationship between the quantity of R&D (ϕ) and its price (W). As we will see, with all cases considered below, all that changes is how W is determined while the (IS) relationship itself is otherwise stable. The convexity of R&D costs means that ϕ is non-decreasing in W.

Solving (VI), (VE) and (IB) simultaneously, we have:

$$V_I = \frac{fr\delta\phi^2 - \Delta(1+\delta(-1+(1+\phi)\phi)) + \phi\delta c(\phi)}{(-1+\delta)(1+\delta(-1+2\phi))} \qquad \text{(VI-Comp)}$$

$$V_E = \frac{\left(f(1+(-1+\phi)\delta) - (1+\phi\delta)\Delta\right)\phi + (1+(\phi-1)\delta)c(\phi)}{(-1+\delta)(1+\delta(-1+2\phi))} \qquad \text{(VE-Comp)}$$

$$W = r\frac{(1+\phi\delta)(\Delta - f) + \delta(f + c(\phi))}{1+\delta(-1+2\phi)} \qquad \text{(IB-Comp)}$$

The last equation describes the "innovation benefit" relationship between R&D intensity and the level of the innovation prize (W). Any level of ϕ that jointly satisfies (IS) and (IB-Comp) is a stationary equilibrium of the R&D game.

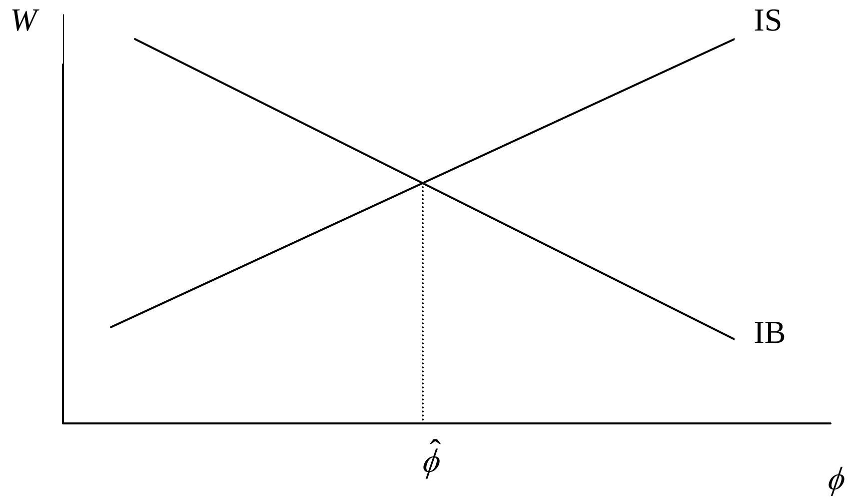
Figure 1 depicts the equilibrium outcome.[7] The equilibrium rate of innovation, , occurs where the (IS) and (IB) curves intersect.[8] At this stage, it is useful to note that the equilibrium level of R&D will be non-decreasing in δ, non-decreasing in Δ, non-increasing in f.[9] Basically, the first two changes cause the IB curve to shift outwards while the remaining change causes it to shift inwards. The IS curve is unchanged by another of these parameters.

[7] For convenience these are drawn as straight lines.

[8] The IB curve may not be monotonic. SW demonstrate, however, that the same qualitative analysis holds whether it is monotonic or not. For that reason, I simplify the graphical exposition for the more familiar downward sloping case.

[9] This can be seen by taking the derivative of W in (IB-Comp) with respect to each variable and applying Theorem 1 of Milgrom and Roberts (1994) on the corresponding set of equilibria.

Figure One: Equilibrium under Competition



3. Licensing with Strong IP

I now turn to consider licensing when the innovator has strong IP protection.[10] I will continue to assume here that entry is credible ($\Delta \geq f$). In this case, in negotiations with a patent holder, the incumbent earns $2\Delta - \tau + \delta V_I$ from licensing for a fee of τ but otherwise expects to earn δV_E (as entry occurs and the incumbency advantage is lost). The innovator expects to earn $\tau + \delta V_E$ from licensing and $\Delta - f + \delta V_I$ otherwise (as it gains an incumbency advantage from entry). It is easy to see that licensing is preferred to not licensing because:

$$\underbrace{2\Delta - \tau + \delta V_I + \tau + \delta V_E}_{\text{Joint Payoff from Cooperation}} = 2\Delta + \delta(V_I + V_E)$$
$$\geq \Delta - f + \delta(V_I + V_E) = \underbrace{\delta V_E + \Delta - f + \delta V_I}_{\text{Joint Payoff from Competition}}$$

[10] SW briefly note, a model with long-term exclusive contracts with customers, that licensing might increase the prize from innovation but do not model the license fee itself. As such, they cannot capture the difference between the licensing and no licensing cases.

Note, cooperation avoids the dissipation of monopoly rents and the sunk costs of entry ($2\Delta - (\Delta - f)$). However, for the incumbent it means preserving the incumbency advantage ($\delta(V_I - V_E)$) while for the innovator cooperation means forfeiting it. This is something the innovator needs to be compensated for.

Given this, using the Nash bargaining solution the license fee is simply $\tau = \frac{3}{2}\Delta - \frac{1}{2}f + \delta(V_I - V_E)$. In this case, the innovation prize is: $W = \tau$. Thus, as in the case of competition, under cooperation the (IB) curve includes a factor based on the value of incumbency advantage. Even though this is never lost in equilibrium, nevertheless, entrant innovators can still appropriate this in negotiations over the license fee.[11] The (IS) relationship remains the same as the no licensing case. As such, the equilibrium outcome will look similar to Figure 1.

In the licensing case, the equilibrium continuation payoffs are:

$$V_I = 2\Delta + \delta V_I - \phi\tau \qquad \text{(VI)'}$$

$$V_E = \delta V_E + \phi\tau - c(\phi) \qquad \text{(VE)'}$$

Notice that, along the equilibrium path, incumbency involves a continual flow of monopoly profits (2Δ) peppered by the payment of license fees to preserve technological (and market) leadership. In contrast, potential entrant returns are governed by the period earnings from license fees over the economic life of the patent.

Solving for (VI)', (VE)' and $W = \tau$ simultaneously gives:

$$V_I = \frac{-f\phi(1-\delta) + \Delta((3\phi - 4)(1-\delta) - 4\delta\phi) + 2\phi\delta c(\phi)}{-2(1-\delta)(1+\delta(-1+2\phi))} \qquad \text{(VI-Coop)}$$

[11] Of course, this would not be possible if product market entry were not credible. Note, however, this does not require the innovator to exercise this entry option, merely to facilitate it (see also Anton and Yao, 1994).

$$V_E = \frac{-\left(f(-1+\delta)+(3+\delta)\Delta\right)\phi + 2(\delta(\phi-1)+1)c(\phi)}{-2(1-\delta)(1+\delta(-1+2\phi))} \qquad \text{(VE-Coop)}$$

$$W = \frac{f(-1+\delta)+(3+\delta)\Delta + 2\delta c(\phi)}{2(1+\delta(-1+2\phi))} \qquad \text{(IB-Coop)}$$

Note that the resulting equilibrium level of R&D is non-decreasing in Δ, non-increasing in *f* but does not have a monotonic relationship with respect to δ.

The equilibrium rates of innovation under licensing and no licensing can now be readily compared. It is easy to see, given the upward sloping (IS) curve, that the rate of innovation will be higher where the prize (*W*) is higher. That is, licensing will result in a higher innovation rate if *W* as defined by (IB-Coop) is higher than that defined by (IB-Comp) for any given level of ϕ.[12]

In comparing (IB-Coop) with (IB-Comp), there are two factors to consider: the immediate benefit from the current innovation and the on-going benefit from an incumbency advantage. Under licensing, the immediate benefit from the current innovation is $\frac{3}{2}\Delta - \frac{1}{2}f$ whereas the returns from entry under no licensing are $\Delta - f$. Thus, an innovator is able to gain more value under licensing because it is able to threaten the incumbent with the loss of monopoly profits and appropriate these without incurring sunk entry costs. In effect, the license fee is the half of sum of industry profits under monopoly (2Δ) and those under entry ($\Delta - f$) whereas under no licensing the innovator appropriates all of industry profits under entry. As industry profits under monopoly exceed those following entry, the prize under licensing is higher.

[12] That is, $\frac{f\left(1-(1-2\phi)\delta\right)+\Delta\left(1+(1-2\phi)\delta\right)}{2(1+\delta(-1+2\phi))} > 0$.

Countering this are future benefits. Under both licensing and no licensing, the innovator appropriates the value of the incumbency advantage ($V_I - V_E$). However, for any given δ, that advantage is greater under no licensing than it is under licensing. To see this, note that:

$$V_I - V_E = \frac{\Delta + c(\phi) - \phi(\Delta - f)}{1 - \delta(1 - 2\phi)} \qquad \text{(IA-Comp)}$$

$$V_I - V_E = \frac{2\Delta + c(\phi) - \phi(3\Delta - f)}{1 - \delta(1 - 2\phi)} \qquad \text{(IA-Coop)}$$

The effective discount on that advantage is determined in the same way under both cases as is the desire to maintain monopoly profits (2Δ) and avoid R&D costs if forced to become an entrant (c). However, the advantage is also driven by the consequences of entry. In the no licensing case, this is the expected immediate return to entry ($\phi(\Delta - f)$) whereas in the licensing case, this is the fact that successful innovation causes the entrant to earn a license fee and for the incumbent to forgo that license fee. This has a net impact of $\phi(3\Delta - f)$ on the incumbency advantage. In effect, the returns to an entrant are higher under licensing and hence, the relative value of incumbency is lower.

The discount rate weights these two effects. Not surprisingly, when there is complete discounting (δ = 0), it is clear that W is higher when licensing occurs. When there is no discounting, maximum weight is placed on the incumbency advantage in the prize. However, even in this case, the difference between (IB-Coop) and (IB-Comp) becomes $\frac{\Delta}{2\phi} - \frac{\Delta - f}{2}$. Notice, that even if $\phi = 1$, this is positive. As such, the following has been demonstrated:

Proposition 1. *The equilibrium innovation rate is higher under licensing than no licensing.*

Basically, the marginal improvement in the incumbency advantage under no licensing never outweighs the immediate benefits from licensing the current innovation.

In this model, the difference between monopoly and competition in the product market amounts to a difference in who earns surplus in that market. Under monopoly, it is the firm. Under competition, the consumers earn the marginal improvement from the new generation of product. Hence, the consequences are distributional and only the rate of innovation matters for social welfare.

In general, however, this will not be the case and monopoly will involve on-going deadweight losses. In this regard, Proposition 1 demonstrates that the rate of innovative activity will be higher as a result of licensing but social welfare may be lower. Thus, there is a traditional trade-off – similar to that in patent policy (Nordhaus, 1969) – between the on-going costs of the preservation of monopoly versus the higher rate of product innovation. To be sure, surplus from these is being passed to consumers as old generations become competitive but the rate at which that occurs is slowed.

4. Impact of IP Practices

With a model that analyses technological competition under product market competition and cooperation respectively, it is now possible to evaluate the impact of various IP practices. These involve aspects of patent policy that have received much attention in the academic and policy literature including the breadth of patent protection, disclosure requirements, exemptions for experimental use and general protection against expropriation of innovators. Each of these is dealt with in turn paying attention to the competitive and cooperative commercialisation modes as they arise.

Minimum Inventive Step

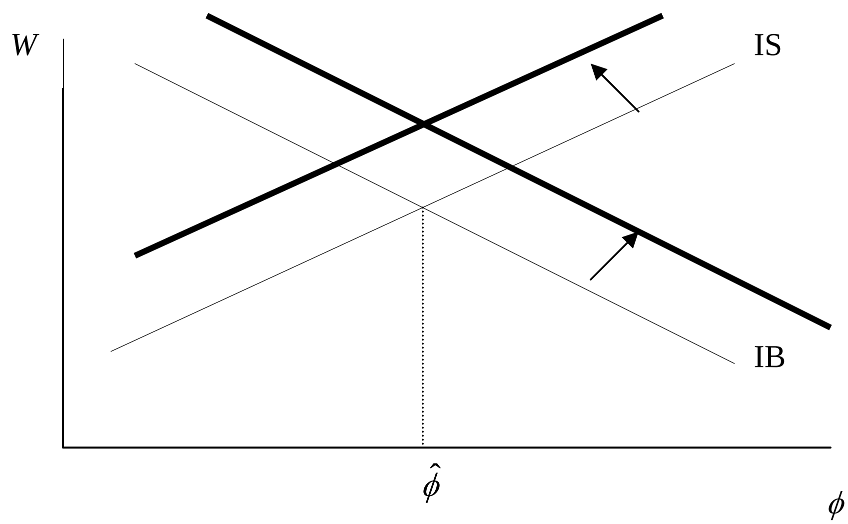
The first practice to be analysed is the requirement of a 'minimum inventive step' in order to secure a patent right and not infringe previous patent holders. Practically, this is how the breadth of patent protection is established. It is generally thought that while a broader patent protects innovators by expanding the economic life of an innovation, it also makes it more difficult for future innovators. These two effects can be captured in the dynamic model here.

To see this, suppose that for the patent on a previous generation (j-1) not to be infringed, the step-up in quality must be above a certain threshold. This threshold is denoted by Δ and the strength of that threshold is modeled as the minimum R&D expenditure of achieving a probability, ϕ, that that threshold is reached in the current period. This minimum expenditure is a function, $c(\phi, \Delta)$, and it is non-decreasing in both of its arguments. Thus, Δ is a measure of "leading breadth" as defined by O'Donoghue, Scotchmer and Thisse (1998).

Having a higher minimum inventive step protects the patent holder of the current product generation by extending the effective economic life of their IP. It does this by making it more costly for entrants to innovate over the next generation. At the same time, the increased distance between it and the previous two generations, in equilibrium, allows the patent holder or licensee as the case may be, to charge higher prices to consumers. Thus, regardless of whether licensing is possible or not, the prize from innovation activity is increasing in Δ.

However, at the same time, an increase in Δ may alter the marginal cost of R&D activity. If this occurs, then it will shift IS as well as IB; making it ambiguous whether increased IP protection will raise the rate of innovation in the industry (see Figure 2).

Figure Two: Expanding the Minimum Inventive Step



In the licensing and no licensing cases, an increase in Δ will result in an increase in innovative activity if:

$$r\left(1+\phi\delta+\delta\tfrac{\partial c}{\partial\Delta}\right) > (1-\delta(1-2\phi))\tfrac{\partial^2 c}{\partial\phi\partial\Delta} \qquad \text{(Comp)}$$

$$r\left(3+\delta+2\delta\tfrac{\partial c}{\partial\Delta}\right) > 2(1-\delta(1-2\phi))\tfrac{\partial^2 c}{\partial\phi\partial\Delta} \qquad \text{(Coop)}$$

for all feasible ϕ. Clearly, if Δ only affects fixed R&D costs and not marginal cost, IP protection will accelerate the rate of innovation. Where it impacts upon marginal costs, it could do so to such an extent, that a sufficiently high inventive step may stifle innovation

Disclosure Requirements

Another IP practice that can impact on the rate of innovation and competitive dynamics are requirements to disclose "know-how" that accompany the grant of IP protection (such as patents). The primary benefit of such rights is to facilitate the accumulation of knowledge by making it easier for others to innovate based on the original technology. In this model, this effect can be represented by a shift in the cost of R&D activity. Specifically, let *d* be a parameter that captures the amount of disclosure required and $c(\phi, d)$ the resulting R&D cost. It is assumed that the total and marginal costs are non-increasing in *d*.

In this situation, a change in *d* will impact on both the IS and IB curves. Innovation supply is increased by a higher *d*, as this lowers the overall cost of innovating. However, this very cost also impacts upon *W* with a reduction reducing the innovation benefit under both licensing and no licensing. In each case, a value of incumbency is not performing innovation and hence, not incurring those costs. For this reason, if those costs fall, the benefit of avoiding them also falls; reducing the incentive to innovate.

In the non-licensing case, an increase in disclosure (*d*) will lead to more innovation if: $\delta \frac{\partial c}{\partial d} > (1-\delta(1-2\phi)) \frac{\partial^2 c}{\partial \phi \partial d}$. Notice that under complete discounting (δ = 0), this condition is always satisfied as the cost of innovation is reduced but there is no detriment to the incumbency advantage. However, if disclosure only affects fixed R&D costs, then this condition will not be satisfied and greater disclosure will lead to less innovation. As the following example demonstrates, however, the opposite could easily be the case.

Example: *It is useful to explore this in a simple example. Suppose that* $c(\phi, d) = \frac{1}{2}(c-d)\phi^2$ *where* $c > d > 0$. *In this case, the equilibrium level of innovation under competition is:*

$$\hat{\phi} = \frac{1}{3(c-d)\delta}\left(\delta(\Delta - f) - (c-d)(1-\delta) + \sqrt{\left(\delta(\Delta - f) - (c-d)(1-\delta)\right)^2 + 6(c-d)\delta(\Delta - f(1-\delta))}\right)$$

It is straightforward to demonstrate that this is increasing in d.

Turning now to the licensing case, when disclosure is automatic, the entrants continuation profits, $V_E(d)$, are determined by:

$$V_E(d) = \delta V_E(d) + \phi_L \tau - c(\phi_L, d) \quad \text{(VEd)}$$

This is also the profits for an entrant who is a previous innovator (and has licensed that innovation) when disclosure is not automatic; as such an entrant is presumed to have to disclosed to itself. In contrast, if the entrant was not the previous innovator (i.e., it is a displaced incumbent), then when there is no disclosure,

$$V_E = \delta V_E + \phi\tau - c(\phi) \quad \text{(VE)'}$$

For the incumbent, continuation profits are still as in (VI)'. Given this, the licensing fee when there is no disclosure becomes: $\tau = \frac{3}{2}\Delta - \frac{1}{2}f + \delta(V_I - \frac{V_E + V_E(d)}{2})$. The final term arises because if there is no licensing agreement, the displaced incumbent will not be as efficient an innovator as the entrant. Thus, the license fee is higher than that achieved under disclosure; i.e., $\tau = \frac{3}{2}\Delta - \frac{1}{2}f + \delta(V_I - V_E(d))$.

Given that a licensing agreement is always signed, the innovator is always a firm with the disclosures from the previous innovation. As such, under licensing, requiring disclosures does not change the IS curve. It does, however, shift the IB curve as the prize from innovation is reduced when disclosure is required. Thus, in contrast to the competition case, under cooperation, requiring disclosure *always* reduces the rate of innovation.

Of course, in many situations, technological competition involves a hybrid of these outcomes. When there are many entrants, even under licensing, requiring disclosure will cause the IS curve to shift to the right. As such, even though this reduces the prize from licensing, by improving R&D efficiency and stimulating the intensity of competition, automatic disclosure may increase the overall rate of innovation.

This sheds considerable light on the debate regarding the impact of requiring publication of patent applications on the incentives for R&D. In particular, 26 Nobel prize winners in economics argued that change in patent application procedure in the US in 2000 that required the publication of pre-grant patent applications, would be harmful to small inventors (Modigliani, 2001). While it is the case that such publication reduces the prize from innovation, when there are many competing researchers, this also improves its productivity and this can outweigh any standard detriment.

The model here generates an empirically testable implication regarding the impact of the *American Inventors Protection Act* of 1999. It should have led to reduced levels of patenting over time in industries with little technological competition and greater levels of patenting in other industries.[13]

Experimental Use

There has been recent discussion as to whether some use of patented inventions for the purpose of experiments or research may be subject to an exemption from infringement claims (Elkman, 2004). There is a notion of this in US case law (Eisenberg, 1989) and an explicit treatment in legislation in the UK.

Little has been written directly on this issue in economics. Green and Scotchmer (1995) consider licensing in the context of sequential innovation and, in particular, whether such licensing should be permitted ex ante or ex post. Their model is suggestive of a notion that an experimental use exemption may benefit initial innovators. The basic

[13] Johnson and Popp (2003) provide an empirical analysis of some of the underlying assumptions in the Nobel prize winner's arguments but not a direct test of the impact of the Act itself.

idea is that this exemption makes it difficult for second generation innovators to commit not to utilise the innovation in experiments. When they innovate, the initial innovators can hold them up something not possible if experimental use must be negotiated.

The model here can be modified to consider this issue. In many respects, the ability to use past innovations in experiments has a similar effect as disclosure; by reducing the costs of future innovations (so I maintain that notation here). However, while the above model considered whether disclosures should be mandated or not – something similar to whether experimental use is permitted or not – the experimental use policy must be evaluated against the proper alternative; in this case licensing the initial innovation for experimental use.

Suppose that, prior to beginning research, an entrant can approach the innovator of the last generation (assuming they are not the same person) and license the use of that technology for experimental use. The two parties bargaining over the use of that innovation for research purposes until the next generation technology appears; i.e., that license covers all subsequent R&D towards the next generation of technology (regardless of how many periods it takes). As such, suppose that each expects that the incumbent and entrant payoffs following that next innovation are V_I and V_E.

Consider first the case where innovation licensing is not possible and competition is expected (i.e., there is no licensing of the innovation itself in the product market). Also suppose that each expects agreements to be reached in the future. Then, should they agree to an experimental use license, the incumbent's and entrant's continuation payoffs are determined by:

$$V_I(\phi_L) = \Delta + \delta V_I(\phi_L) + \phi_L \delta (V_E - V_I - 2\tau_e)$$

$$V_E(\phi_L) = \delta V_E(\phi_L) + \phi_L\left(\Delta - f + \delta(V_I - V_E + 2\tau_e)\right) - c(\phi_L, d)$$

where τ_e is the license fee for experimental use. Alternatively, if they do not agree, those payoffs become:

$$V_I(\phi) = \Delta + \delta V_I(\phi) + \phi\delta(V_E - V_I - 2\tau_e)$$

$$V_E(\phi) = \delta V_E(\phi) + \phi\left(\Delta - f + \delta(V_I - V_E + 2\tau_e)\right) - c(\phi)$$

Solving and comparing, the parties will agree to an experimental use license if $V_I(\phi_L) + V_E(\phi_L) \geq V_I(\phi) + V_E(\phi)$ or:

$$\underbrace{(\phi_L - \phi)}_{>0}(\Delta - f) \geq \underbrace{c(\phi_L, d) - c(\phi)}_{?}$$

A simple revealed preference argument demonstrates that this inequality always holds. Thus, it is always mutually profitable to enter into an experimental use license.

What this means is that the prize from innovation is increased by $2\tau_e$ if there is no experimental use exemption (shifting the IB curve outwards) while the R&D costs are the same regardless. That is, because a license for experiment use will always be granted, entrants innovate with a technology based on $c(\phi, d)$ regardless. This means that not having an experimental use exemption will accelerate the rate of innovation.

When both parties expect the innovation to be licensed to the incumbent firm the issues are somewhat subtler. In this case, an experimental use license will only be agreed upon if $c(\phi_L, d) \leq c(\phi)$. If this condition holds, then an experimental use exemption would reduce the rate of innovation; just as it would under competition. On the other hand, if it does not hold, then the entrant would choose the rate of innovation according to:

$$\max_{\varphi} \varphi\tau - c(\varphi, d) \text{ where } \tau = \tfrac{3}{2}\Delta - \tfrac{1}{2} f + \delta(V_I - V_E)$$

when there is no experimental use exemption and according to:

$$\max_{\varphi} \varphi\tau - c(\varphi, d) \text{ where } \tau = \tfrac{3}{2}\Delta - \tfrac{1}{2} f + \delta(V_I - \tfrac{V_E + V_E(d)}{2})$$

if there is. As such, the trade-off is the same as when disclosures are mandated. An experimental use exemption only reduces the prize from innovative activity – shifting the IB curve to the left – and reducing the rate of innovation.

Thus, the model here yields a clear prediction regarding the impact of an experimental use exemption on the rate of innovation; regardless of how an innovation may be commercialised, it reduces it.

Protection from Expropriation

IP laws can also protect start-up firms from expropriation through the unauthorised exploitation of trade secrets in a commercial context. The classic case of this arises from disclosures made in licensing negotiations that following a breakdown in those negotiations are used commercially by the established firm in competition with the start-up (Arrow, 1962; Anton and Yao, 1994; Gans and Stern, 2003).

To see the effects of this, following Gans, Hsu and Stern (2002), we consider a situation where, if it approaches the incumbent, the entrant faces a probability, ρ, that key disclosures will be made that would allow the incumbent to introduce the same product generation into the market without the consent of the entrant. However, if this were done, the entrant may be able to enforce its IP rights; although this too was uncertain. Suppose that the probability those rights are enforced is θ. This is a measure of the strength of IP protection in this context.

If a disclosure is made and IP rights are not enforced, it is easy to see that the entrant would receive no license payments and would also not find it worthwhile to incur the sunk costs of entry and compete head to head with the incumbent. That is, it would face no immediate product market advantage or an advantage to incumbency as both it and the incumbent would have competencies in managing the next product generation (and competing for licenses).

In contrast, if no disclosure occurs or if IP rights are enforced, the entrant can negotiate a license fee under the terms considered for the model of Section 3. This occurs with probability $\lambda \equiv 1-\rho(1-\theta)$. Thus, the equilibrium, the continuation payoffs and innovation prize will satisfy:

$$V_I = 2\Delta + \delta V_I - \phi\lambda\tau \qquad \text{(VI)}$$

$$V_E = \delta V_E + \phi\lambda\tau - c(\phi) \qquad \text{(VE)}$$

$$W = \lambda\tau = \lambda\left(\tfrac{3}{2}\Delta - \tfrac{1}{2} f + \delta(V_I - V_E)\right)$$

where here *r* is interpreted more generally as the probability of being rewarded priority in any IP dispute. Solving these simultaneously, we have:

$$V_I = \frac{4\Delta(-1+\delta) + \lambda\phi\left(f(-1+\delta) + \Delta(3-7\delta) + 2\delta c(\phi)\right)}{-2(1-\delta)(1+\delta(-1+2\lambda\phi))} \qquad \text{(VI)''}$$

$$V_E = \frac{-\left(f(-1+\delta) + (3+\delta)\Delta\right)\lambda\phi + 2(1+\delta(-1+\phi\lambda))c(\phi)}{-2(1-\delta)(1+\delta(-1+2\lambda\phi))} \qquad \text{(VE)''}$$

$$W = \frac{\lambda\left(f(-1+\delta) + (3+\delta)\Delta + 2\delta c(\phi)\right)}{2(1+\delta(2\lambda\phi - 1))} \qquad \text{(IB-Coop)'}$$

Notice, however, that these will only be relevant for λ sufficiently high. If $\lambda \leq \frac{2(\Delta - f)}{3\Delta - f}$, it is better for the entrant to avoid negotiations and compete in the product market. In this situation, the equilibrium payoffs as derived in Section 2 will become relevant.

How does the equilibrium rate of innovation change with λ? First, note that:

$$\frac{\partial(V_I - V_E)}{\partial\lambda} > 0 \Rightarrow (3+\delta)\Delta - (1-\delta)f + 2\delta c(\phi) < 0$$

This condition never holds. Thus, reducing the possibility of expropriation reduces the incumbency advantage from innovation and also the license fee, τ, itself. Intuitively, expropriation causes a delay in the effective rate of destruction of an incumbency advantage by delaying the need for the incumbent to pay a license fee. This simultaneously raises the value to the incumbency and lowers the expected value of the innovator.

However, raising λ increases the likelihood of trade. Overall, the impact will be:

$$\frac{\partial W}{\partial\lambda} = \tau + \lambda\frac{\partial\tau}{\partial\lambda} \geq 0 \Rightarrow (3+\delta)\Delta - (1-\delta)f + 2\delta c(\phi) \geq 0$$

It is easy to see that this condition always holds. As such, improving the prospects for successful licensing by preventing expropriation always improves the rate of innovation even though that reduces the license fee itself.

5. Conclusion and Future Directions

The rate of innovation in an industry is driven both by the prize innovators receive from innovating and the productivity of R&D itself. IP practices potentially impact on each of these things and hence, it is often difficult to assess what the impact of a particular practice will be on innovation. This paper has clarified these issues by providing a dynamic model of innovation that can encompass commercialisation paths based both on competition and cooperation (i.e., licensing).

In particular, many IP practices impact on both the immediate benefit to an innovative firm as well as the benefits from future positioning in innovative races (i.e., the incumbency advantage). For example, a license agreement has immediate benefits in terms of the saving of duplicative sunk costs and the preservation of monopoly profits. However, it also diminishes incumbency advantages relative to the competitive case. Nonetheless, this paper demonstrated that one effect outweighed the other and licensing would always increase innovation rates. Similarly, protection of expropriation even though it reduces the incumbency advantage component of licensing, by encouraging licensing itself, raises innovation rates.

When an IP practice impacts on research productivity, as it does when patents are narrower, disclosure is required, and innovations are used in experiments, the effects may be more ambiguous. Nonetheless, the model here has identified some conditions that will drive the relationship between these practices and innovation rates thereby offering testable implications for policy-makers.

Of course, the model here is a simple one. There is only a single innovating firm in any period, innovations do not enhance firm productivity persistently, there is no consideration of long-term R&D capabilities and the model ignores social costs from monopoly. These are considerations that could be useful to add in future work; especially those that consider particular IP practices in more detail.

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