

The Economic Incentive to Innovate in Plants: Patents and Plant Breeders' Rights

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Abstract

The exclusivity conferred to inventors by intellectual property rights (IPRs) provide an *ex ante* incentive for innovation, but the resulting market power yields an *ex post* inefficiency (because it limits use of the innovation). Strong IPRs may also affect innovation by limiting access of proprietary knowledge in research aimed at new inventions and discoveries, which raises the question of whether IPRs should have an experimental use or research exemption (RE) provision. This chapter sets up a model to study some effects of a RE provision by comparing two IPR systems that are available for plants: utility patents and so-called plant breeders' rights (PBRs), which in the USA are implemented by the 1970 Plant Variety Protection Act (PVPA). Whereas PBRs allow for an RE, the US patent law does not have a statutory RE.

The differences related to the RE provide the sharpest distinctions between patents and PBRs. The simple model and preliminary analysis presented in this chapter suggest that the RE inevitably weakens the *ex ante* incentive for private firms to innovate. Thus, when research is very costly and/or risky, as may be the case with pre-breeding germplasm development, an IPR system centred on the features of standard PBRs may not deliver the desired innovation incentive for private firms. Conversely, when research and development (R&D) costs are low, relative to the potential returns, the RE may be desirable because it ensures a larger pool of innovators in follow-up inventions.

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Moschini, G., and Yerokhin, O., "The Economic Incentive to Innovate in Plants: Patents and Plant Breeders' Rights," in J.P. Kesan, ed., *Agricultural Biotechnology and Intellectual Property: Seeds of Change*, CAB International, 2007 (pp.190-203).

1. Introduction

Economics has long emphasized the market failures that beset the competitive provision of innovations (Arrow, 1962). Creative and inventive activities produce intangible assets that can be quite costly to obtain, that may be extremely valuable to society at large, but that can be copied and/or imitated very easily. Intellectual property rights (IPRs) such as patents, copyrights and trademarks—allowing the producers of new and/or original work to assert (limited) exclusive ownership on the outcome of their efforts—can provide a solution to the incentive problems that arise in this context. But, the solution provided by IPRs displays a quintessential second-best nature (Langinier and Moschini, 2002). *Ex ante*, the profit opportunities made possible by the exclusivity conferred by IPRs provide a critical incentive for private research and development (R&D) activities. But *ex post*, because IPRs confer a degree of monopoly power, they introduce a novel source of distortions in the economy by restricting the use of innovations (which typically have the nature of a public good). This leads to the basic trade-off between static and dynamic efficiency illustrated by Nordhaus (1969), which implies that weak IPRs may provide insufficient incentive, but strong IPRs may inefficiently restrict the use of an innovation. Thus, the form and extent of the optimal IPR system is still an open question.

The fact that most innovations are not produced in isolation, but rather are often derived from the existing stock of possibly proprietary knowledge, adds a new dimension to the analysis of IPRs. In particular, to provide adequate incentives for innovation, IPRs should offer protection not only from imitation but also from future inventions that will compete with the protected product (Scotchmer, 1991). This is especially critical in a sequential and cumulative innovation context, such as that characterizing the case of biotechnology's "research tools," or the case when successive innovations can be viewed as a quality ladder. The possibility of granting patents with a so-called leading breadth that is sufficiently large can, in principle, provide sufficient protection. But then it is not clear whether the competitors' research activities themselves, which in the case of cumulative innovation unavoidably rely on the use of existing (proprietary) knowledge, should be viewed as infringing. To put it another way, the question is whether IPRs should contemplate a well-defined "experimental use" or "research exemption" provision. Such a provision would clearly weaken the exclusivity conferred by IPRs, thereby affecting the incentive to innovate. At the same time, it is quite plausible that restricting the

“experimental use” of proprietary technology could overly restrict future improvements on an innovation and be suboptimal from the social point of view. So far there has been no systematic attempt to investigate this question and relate it to the relevant features of the specific cumulative research process under consideration.

In this chapter we will focus on the research exemption to compare and contrast the innovation incentives provided to plant breeders by two alternative IPR instruments: utility patents, and so-called plant breeders’ rights (PBRs), which in the United States are implemented by the 1970 Plant Variety Protection (PVP) Act. PBRs allow the use of others’ proprietary germplasm when breeding new varieties. This research exemption provision stands in sharp contrast with the stronger type of protection granted by utility patents. As was confirmed by the Court of Appeals for the Federal Circuit in *Madey v. Duke*, the U.S. patent law does not envision a statutory research exemption (Eisenberg, 2003). Also, because the innovation process of interest (plant breeding) is a quintessential sequential endeavor, the dynamic incentive issues related to the availability of a research exemption (or lack thereof) take on a central role. In what follows we first discuss the main features of PBRs and patent systems for the problem at hand. The economic impacts of PVP have been the object of many empirical studies, which we briefly review. The assessment that they yield is (perhaps inevitably) largely inconclusive. This motivates us to pursue a more theoretical approach. The simple model that we develop, rooted in the quality ladder models of sequential innovation, permits a first investigation of the different innovation incentives that flow from PVP and patent protection. We find that the presence of a research exemption inevitably weakens the firms’ *ex ante* incentive to innovate.

2. Plant Breeders’ Rights, Patents, and the Research Exemption

PBRs in the United States are defined by the 1970 PVP Act, whereby the U.S. Department of Agriculture (USDA) can issue PVP certificates. Varieties claiming a PVP certificate must be new and must satisfy requirements of distinctiveness, uniformity, and stability. The protection offered by PVP certificates is similar to that provided by patents, including the standard 20-year term, with two major qualifications: there is a research exemption, meaning that protected varieties may be used by others for research purposes (e.g., to develop other new varieties); and there is a “farmer’s privilege,” that is, seed of protected varieties can be

saved by farmers for their own replanting (but farmers are prohibited from reselling protected seeds).

The international coordination of PBRs is the prerogative of the International Union for the Protection of New Varieties of Plants (UPOV, after its French spelling). The latest UPOV convention (1991) allows countries to provide protection for new varieties with both PVP certificates and utility patents and allows (but does not require) countries to permit farmers to save protected seeds for replanting. A major development with UPOV 1991 was the introduction of the notion of “essentially derived variety” (EDV). The perceived problem, at the time, was the imbalance between the protection offered by patents and PBRs, in particular the interaction of the two modes. Specifically, the developer of a patented transgenic trait (often a single gene transformation) would have the option of inserting it into others’ varieties covered by PBRs by way of the traditional research exemption, but, in turn, the owner of that variety could not access the trait-improved variety because of the patent on the trait (Roberts, 2002).

The notion of EDV strengthens the rights of the initial variety owner by establishing that the principle that that his/her approval, and profit sharing, would be required for marketing the EDV (e.g., the initial variety plus the gene of interest). Thus, the EDV notion is a significant development vis-à-vis the research exemption attribute of PBRs. But it should be clear that the notion of EDV does not invalidate the standard breeders’ exemption, because no authorization whatsoever is required for using others’ varieties protected by PBRs (unlike what applies if the variety is patented) (Jördens, 2002).

In addition to PBRs, plant innovators can rely on a few other instruments to assert their intellectual property, including trade secrets, the use of hybrids (provided parent lines can be protected), so-called genetic use restriction technologies (still under development), and specific contractual arrangements, such as the bag-label contracts that are common in the United States (Boettiger, VanDusen, Graff, Pardey, and Wright, 2004). Perhaps most important, in the United States plant breeders can also protect their innovations by filing utility patents. The landmark 1980 U.S. Supreme Court decision in *Diamond v. Chakerabarty* opened the door for patent rights for virtually any biologically based invention, if obtained through human intervention. And, in its 2001 ruling in *J.E.M. Ag Supply, Inc. v. Pioneer Hi-Bred International, Inc.*, the U.S. Supreme Court held that plant seeds and plants themselves (both

traditionally bred or produced by genetic engineering) are patentable under U.S. law (Janis and Kesan, 2002).

As noted earlier, the U.S. patent law does not have a statutory research exemption (apart from the provision governing pre-approval testing of generic drugs allowed for by the Hatch-Waxman Act of 1984). An exception to patent infringement liability when the purpose of the activity is mere experimentation has long been thought to exist, but existing case law (culminating with the *Madey v. Duke* decision noted earlier) has made it clear that such a defense could only be construed very narrowly (Miller, 2003). Hence, a plant breeder that elects to rely on patents can prevent others from using the protected germplasm in rivals' breeding programs. That is not possible when the protection is afforded by PVP certificates. Of course, the standards for obtaining a patent are higher, in principle, because to be patentable an innovation must, among other things, be *novel* (not constituting part of the prior art) and involve an inventive step (i.e., it must be *non-obvious*), two attributes that are not required for PVP protection.

The differences in the degrees of protection conferred by patents and PVPs for plant innovations are somewhat more challenging in an international context. The drive to harmonize patent protection long pursued by the World Intellectual Property Organization, received a considerable boost by the TRIPS (trade-related aspects of intellectual property rights) agreement of the World Trade Organization (Moschini, 2004). Yet, there is no uniformity across national jurisdictions with respect to the research exemption. Some countries' patent laws are like those of the United States in that they do not envision an explicit research exemption or experimental use exception for patents (e.g., Australia), whereas others do have an explicit recognition that some experimental use is allowed (e.g., Japan and the European Union) (Straus, 2002; Advisory Council on Intellectual Property, 2004).

Conversely, in many countries the main available protection for plant innovations is offered by PBRs. Indeed, under TRIPS it is not mandatory for a signatory country to offer patent protection for plant and animal innovations, as long as a *sui generis* system is available. Thus, elsewhere in the world, access to patents for plant innovations is often not available (Otten, 2003). That is certainly the case for most developing countries, where PBRs, in the blueprint provided by UPOV, are more commonly used for plant varieties. But even in European countries, where plant innovations are included in the patentable subject matter,

somewhat anachronistically, plant varieties *per se* are explicitly not patentable by the statute of the European Patent Office (Fleck and Baldock, 2003).

Given that patents and PBRs appear to offer a different level of IPR protection, and that the possibility for plant breeders to avail themselves of either protection differs across countries, it is of foremost interest to ascertain the differences in innovation incentives that countries offer.

2.1 The Economic Effects of Plant Breeders' Rights

The question of whether the PVP Act has had a positive effect on the breeding efforts and quality of new plant varieties in the United States has received a lot of attention in the literature. One of the first studies in this area was the one conducted by Perrin, Hunnings, and Ihnen (1983). These authors conducted a 1980 survey of 127 seed companies designed to obtain data on research expenditures from 1960 to 1979 for the purpose of investigating increases in the research expenditures on non-hybrid crops after the enactment of the PVP Act. It turned out that there was a moderate increase in investment in soybeans and cereals in that period, which was, however, substantially smaller than the increase in expenditures in the hybrid corn sector, even though hybrid varieties were not protected under the PVP Act. This study also used soybean variety test results from the mid-1960s up to 1979 to see if there was an impact on the rate of improvement in yields of soybean varieties. A positive but not statistically significant effect was found.

Butler and Marion (1985) combined a survey of breeders with data on PVP certificates and found that the PVP Act had had an impact on private investment only in wheat and soybeans, while public investment did not change. In a follow-up study, Butler (1996) reached a similar conclusion, which was once again confirmed in a USDA (1995) study of new crop varieties. Additionally, the study documented an increase in both PVP certificates and utility patents for new plants starting in the early 1970s.

In a more recent study, Alston and Venner (2002) investigated whether the PVP Act had a positive effect on wheat breeding efforts. Results of their survey suggest that investment in wheat breeding remained at the same level before and after introduction of the PVP Act. They also found no evidence of an increase in wheat yields throughout the period.

An interesting analysis of PVP in an international context is given in Srinivasan (2004). This paper uses data on grants of PVP certificates in a cross-section of 13 developed

countries observed over periods of up to nine years to investigate whether stronger IPRs for plant varieties lead to higher R&D expenditures and PVP grants, and if stronger PVP protection leads to significant exchange of plant varieties between countries. The analysis suggests that stronger IPRs will increase R&D and PVP grants. Hence, there might be a positive effect of strengthening protection in countries with weaker IPRs in this area. As to international transferability of varieties, it is at its highest level within Europe, where significant harmonization of PVP regimes has taken place. The same author (Srinivasan 2003) used PVP renewal data from selected European countries to estimate the private values of holding a PVP certificate on a new variety. It turned out that the distribution of private values is quite skewed, with a large number of certificates yielding no return to their owners. Also, for new agricultural crops the mean private value of a PVP certificate ranged from \$156 in the Netherlands to around \$1,364 in Germany, suggesting that the value of PVP protection to private breeders is moderate at best.

There is a separate strand in this literature that attempts to investigate the economic effect on plant breeding of the so-called farmer's privilege. For example, Pray and Basant (1999) conducted interviews with Indian breeders and found that the farmers' privilege has a significant negative effect on the appropriation rate of economic benefits of new varieties. Hansen and Knudson (1996) developed a model for testing whether seed suppliers try to capture some of the benefits from future saved seed by pricing their varieties accordingly and found statistically significant evidence of such appropriation in the soybean market. They conclude that the farmers' privilege does not decrease the incentives to invest in development of new varieties or their improvements.

In conclusion, the foregoing empirical studies provide scant empirical evidence on the hypothesis that the PVP Act had a positive effect on plant breeding in the United States. However, these findings are not conclusive because of the nature of the studies that delivered them. It is by no means clear that these studies have controlled for all variables that can potentially influence plant genetic improvement in the long run. The main difficulty in evaluating the effects of the PVP Act, which has not been overcome in the empirical literature, is the impossibility of disentangling the impact of the PVP Act from the many potential confounding factors that may work in either direction. In particular, in these empirical studies it is unclear whether the alternative to PBRs ought to be construed as one with weaker IPR protection (e.g., no IPRs for plants) or one of stronger IPR protection (e.g.,

patents instead of PBRs). The former seems to be, at least implicitly, the hypothesis of many of the earlier analyses, but the latter is arguably the more pressing policy question (as emphasized by the current TRIPS debate that contrasts *sui generis* systems with a patent system).

In any event, it is clear that the extant empirical evidence does not address the problem at hand, i.e., the possible different strengths of the incentive to innovate provided by PBRs and patents. To gain some insight into the effects of the research exemption, therefore, we now turn to a theoretical analysis.

3. Modeling Cumulative and Sequential Innovations

The recognition that inventions are typically the springboard for further innovations has long been noted in the analysis of the economics of IPRs (Scotchmer, 1991). When innovation is cumulative, the first inventor will not necessarily be compensated for his contribution to the social value created by the subsequent inventions, which adds another dimension to the task of designing an efficient IPR regime. Scotchmer (2004) distinguishes between three main types of cumulativeness of the innovation process: (i) an initial innovation leading to several next-generation innovations; (ii) a higher-level innovation that requires several first-generation innovations as inputs, and (iii) a quality-ladder innovation process in which each invention builds on the previous generation of the same product and serves as a basis for further improvements.

The theoretical models of cumulative innovation follow roughly the same taxonomy and can be viewed as belonging to the two broad classes. The first class is represented by two-period models that are meant to capture the first two types of cumulativeness. These models typically deal with the problem of the transfer of profits from successful application of a given patented innovation to the original inventor(s). The second class is comprised of models that attempt to model the quality ladder type innovation process in the explicitly dynamic setup.

One of the first models to analyze the division of profits between the first- and second-generation inventors was Green and Scotchmer (1995). The main question addressed in the paper is how patent breadth and patent length should be set in order to allow the first inventor to cover his cost, subject to the constraint that the second-generation innovation is profitable. The optimal policy depends on the type of licensing agreements available, but in

general the model implies that patents should last longer when the firms pursuing the first and second innovations are different (as opposed to the case in which a single firm develops both innovations).

In Scotchmer 1996, the focus is again on the division of profits between creators of a basic invention and those who apply it: if the application infringes on prior art, can patenting be optimal from the social point of view? The paper argues that it cannot, because in that case the second inventor has less bargaining power when negotiating a licensing agreement with the patent holder, who in turn is more willing to invest in research and develop the basic invention. A similar problem was studied by Matutes, Regibeau, and Rockett (1996). In this paper the authors similarly argue that the first-generation inventor should be given enough incentives to innovate. In particular, it might make sense to give the inventor an exclusive right to develop a particular application of her invention, while all other applications can be developed and patented by other firms. The second type of cumulativeness, when several first-generation products give rise to the single application, is exemplified by special types of inventions called research tools. These are inventions that derive their market value from their use in applied research. The problem of division of profit in this context is discussed in Koo and Wright (2002).

Most of the models previously mentioned seem to provide theoretical support for strong patent protection when innovation is cumulative. There are however some notable exceptions in the literature. In particular, Denicolò (2000) has shown that if one allows for R&D races in each of the two periods (as opposed to assuming that each firm can have at most one idea) and rules out the possibility of *ex ante* agreements, one can obtain a different conclusion. His model emphasizes the fact that the cumulative nature of the invention process results in the divergence between social and private payoffs from innovation, which in the absence of *ex ante* sharing agreements would make the case for strong forward protection less appealing. Denicolò and Zanchettin (2002) compare two tools for providing forward protection, the novelty requirement and leading breadth (the minimum size of quality improvement that makes a follow-on innovation non-infringing), and conclude that the leading breadth requirement is, in general, more conducive to the invention process than the novelty requirement, which gives too much blocking power to the first inventor.

The second class of models deals with dynamic models of repeated innovation in which each firm will periodically assume the role of follower or leader. Hence, the main

question here is not the division of profits between first and second innovators but rather how to increase total profits while minimizing monopoly distortions. O'Donoghue, Scotchmer, and Thisse (1998) present a model of cumulative innovation in which firms sequentially improve each other's products. The main object of their analysis is leading breadth—protection against new, improved products. The authors show that zero leading breadth will lead to underinvestment in R&D from the social point of view; that is, only innovations of a relatively larger size are implemented, while it would be socially optimal to implement smaller innovations as well. This result is due to the short expected life of the patent, since any new innovation will take over the market when the leading breadth requirement is absent from the model.

Another model of this type is described in O'Donoghue 1998, the main focus of which is the patentability requirement—the minimum threshold innovation size required to receive a patent (see also Hunt, 2004). This should be contrasted with leading breadth, in which a patent can be obtained but then the patentee must obtain a license. The conclusion of this study is similar to the one reached in O'Donoghue, Scotchmer, and Thisse (1998), namely, that the patentability requirement can stimulate R&D investment and increase dynamic social welfare.

4. A Model of Cumulative Innovation for Plant Breeding

The model of research exemptions that we want to construct is related to the second strand in the literature previously discussed. In particular, we want to construct a simple model of innovation that captures some salient features of plant breeding. Plant breeding is a lengthy and risky endeavor that consists of "... developing new varieties through the creation of new genetic diversity by the reassembling of existing diversity..." (International Seed Federation, 2003). Thus, the process is both sequential and cumulative, because new varieties would seek to maintain the desirable features of the ones they are based on while adding new attributes. As such, a critical input in this process is the starting germplasm, and that in turn is critically affected by whether or not one has access to the successful varieties of others, that is, whether or not there is a research exemption. But in a dynamic context, of course, the quality of the existing germplasm is itself the result of (previous) breeding decisions, and so it is directly affected by the features of the IPR regime in place. Industry views on the matter highlight the possibility that freer access to others' germplasm will create little

incentive for pre-breeding germplasm enhancement, such as widening the germplasm diversity base by introducing exotic germplasm (Donnenwirth, Grace, and Smith, 2004).

In the stylized model that we consider in this paper, we imagine two firms that are competing to develop a new variety along a particular development trajectory. At time zero both firms have access to the same germplasm and, upon investing an amount c , achieve success with probability p . Thus the R&D process is costly and risky. Given one success, the firms then have the option to pursue the next improvement, again upon paying an initial cost c and with a probability p of a successful outcome for each firm. Whether or not both firms can attack the next innovation stage depends on the IPR regime (which we define subsequently). But, following Bessen and Maskin (2002), we assume that each firm's outcome is independent of the other and that whenever both firms fail to achieve the next innovation no further innovation is possible. Note that we are thus capturing the sequential nature of plant breeding, as well as the notion of what breeders sometimes call "path dependency" (Donnenwirth, Grace, and Smith, 2004), whereby successive improvements along a given path greatly benefit from the initial breakthrough.

Each successful innovation embeds all previous ones, thus reflecting the fact that breeding is a cumulative process whereby each new variety builds on the previous ones, and it is worth an additional Δ , per period, to society. What a success is worth to the innovator, however, depends on the IPR regime and on the possible constraining effects of competition among innovators. We make the simplifying assumption that only the best product is sold in this market, but what the owner can charge is the marginal value over what the competitor can offer (i.e., we assume Bertrand competition). For example, if two firms have achieved n and m innovation steps, respectively, with $m > n$, the firm with m steps will be the one selling any product and will make an *ex post* per-period profit of $(m - n)\Delta$. As for IPRs, here we consider two regimes. For simplicity, the protection offered by both IPR regimes lasts forever (the more realistic alternative of a finite patent life adds nothing to the economic analysis but would make the exposition more cumbersome). The first regime, labeled as "full patent" (FP), does not allow a research exemption. The second regime, labeled "research exemption" (RE), allows it (thus, the RE regime reflects the attributes of a PBR system).

Our ultimate goal is to compare incentives to innovate in an industry consisting of two firms and characterized by these two distinct IPR modes of protection. However,

before proceeding to the direct comparison of these regimes, it is useful to analyze the incentive to innovate for a firm that has no competitors. This special case is useful in what follows, and also allows us to introduce the rest of the notation and the method of analysis. Thus, let V_0^M denote the present expected value (at time zero) of the flow of profits to the (monopolist) firm. Assuming that the firm invests in every period in which it has an investment opportunity (i.e., after each successful innovation), V_0^M satisfies the following recursive relation:

$$V_0^M = -c + p \left(\frac{\Delta}{1-\delta} + \delta V_0^M \right)$$

where $\delta \in (0,1)$ denotes the discount factor ($\delta \equiv 1/(1+r)$, say, where r is the interest rate), such that we have

$$V_0^M = \frac{p\Delta - c(1-\delta)}{(1-p\delta)(1-\delta)}$$

Note that the present value V_0^M is positive if and only if

$$\frac{\Delta}{c} > \frac{(1-\delta)}{p} \equiv t_M.$$

Also, if this condition holds, the firm will choose to invest in every period.

4.1 Patent Protection Mode

As noted, we assume that patents are of infinite length and with breadth defined by the innovation step (worth Δ). If the two firms (firm A and firm B, say) both invest c at time zero, four possible outcomes are possible: only firm A is successful, only firm B is successful, both are successful, and neither is successful. If neither succeeds, the R&D contest ends. If both succeed, priority is assigned randomly with equal probability to either firm, such that we have a unique winner of the first stage of the R&D contest. With the full patent protection, we assume that the winner of the first stage is the only one that can attack the next research stages. As with Bessen and Maskin (2002), a critical assumption for this characterization is that licensing is not possible. Hence, the first firm to obtain a patent will become a monopolist starting from date one (from which the previous present-value discussion therefore applies). This implies that at time zero both firms will race to obtain this dominant position.

When both firms are involved in the first-stage R&D contest, the probability that either one is the sole winner is $q \equiv p(1-p) + 0.5p^2 < p$. In such a situation, a firm that invests in the first period, and keeps investing if it is the winner of that stage as long as there is an investment opportunity, has a present value V_0^{FP} that satisfies

$$V_0^{FP} = -c + q \left(\frac{\Delta}{1-\delta} + \delta V_0^M \right)$$

Thus, we have

$$V_0^{FP} = \frac{\Delta p(2-p) - c(1-\delta)(2-\delta p^2)}{2(1-\delta)(1-\delta p)}$$

Under the assumption of risk neutrality, both firms will invest in period zero if $V_0^{FP} \geq 0$, that is, if

$$\frac{\Delta}{c} \geq \frac{(1-\delta)(2-\delta p^2)}{p(2-p)} \equiv t_{FP}$$

Note that $t_{FP} > t_M$; that is, competition to be the only firm in the industry in period one dissipates some of the incentive to innovate in period zero by lowering the probability of reaching stage one. Also, whenever $\Delta/c \geq t_{FP}$, so that both firms invest in the initial investment game, then $\Delta/c > t_M$. Hence, the firm that wins the initial innovation contest (thereby becoming a monopolist) will keep investing in follow-up improvements (as assumed in the derivation of V_0^{FP}). If $t_M < \Delta/c < t_{FP}$ then there are two pure-strategy Nash equilibria (a firm will invest provided the other does not) and, perhaps more interesting, there is also a (symmetric) mixed-strategy equilibrium in which each firm randomizes between investment and no investment (and earns a zero expected initial payoff).

4.2 Research Exemption Mode

Introducing research exemption in this model is equivalent to making any innovation (improvement of the existing product or variety) non-infringing. In such a situation a success by any one of the firms is a sufficient condition for both firms to be able to invest in the next period. In what follows we present a simplified analysis by assuming that only two strategies are available to each firm: invest in every period (*I*) and never invest (*N*). In other words, each firm can either enter the market and try to innovate in each period or stay out of

the market altogether. Let $V_{0,j}^{RE}(s^A, s^B)$ denote the payoff (as of period zero) to firm j ($j = A, B$) when the two firms choose strategies (s^A, s^B) in every period at which there is an investment opportunity. Clearly, $V_{0,A}^{RE}(I, N) = V_{0,B}^{RE}(N, I) = V_0^M$, $V_{0,j}^{RE}(N, N) = 0$ ($j = A, B$), $V_{0,B}^{RE}(I, N) = V_{0,A}^{RE}(N, I) = 0$, and $V_{0,A}^{RE}(I, I) = V_{0,B}^{RE}(I, I) \equiv V_0^{RE}$. That is, a firm that chooses to stay out of the R&D contest gets a payoff of zero, and a firm that enters the competition alone gets the monopolist's payoff V_0^M calculated earlier. Finally, when both firms engage in R&D at every date at which there is a research opportunity, then they each have the same expected present value, which is labeled V_0^{RE} .

Even with our simplifying assumption that firms use the same strategy in every period, the characterization of V_0^{RE} is not straightforward. This is because the return to a "success" depends on where the rival stands on the ladder of quality improvements. For example, the winner of the first innovation stage (firm A, say) can charge Δ (because that is all that the innovation is worth). But under the RE regime both firms can then participate in the next innovation stage. If firm A wins the second stage as well, then this firm can charge 2Δ for the (twice improved) product. But if it is firm B that wins the second stage, this firm can charge only Δ because of our Bertrand competition assumption (given that firm A still owns the first innovation). Hence, what each firm can expect to earn in each period depends on two state variables (the highest number of innovation steps patented by the two firms), and as the time horizon progresses there is an infinite number of configurations of these state variables, the probability distribution of which is implicitly defined by the initial stochastic assumptions (each firm has an independent probability of success equal to p).

Accounting for the number of all possible histories leading to a particular state configuration (m, n) , where m and n denote the highest number of innovation steps achieved by firms A and B, respectively, it is possible to obtain the present value of the stream of expected profit of the two firms. The derivation of this result is somewhat lengthy and it is omitted. But it can be shown that the present value V_0^{RE} can be written as

$$V_0^{RE} = \frac{q\Delta}{(1-\delta q)(1-\delta)} - \frac{c}{(1-2\delta q)}$$

where, again, $2q \equiv [1 - (1-p)^2] > p$ is the probability that at least one firm is successful in a given stage.

From the initial (time zero) perspective, the R&D investment contest in which each firm chooses between I and N can be represented as a static game with the payoff matrix given in Table 1. Several Nash equilibria are possible here. First, (I, I) is a Nash equilibrium if $V_0^{RE} \geq 0$. Second, (I, N) and (N, I) are both Nash equilibria if $V_0^{RE} \leq 0$ and $V_0^M \geq 0$. Finally, (N, N) is a Nash equilibrium if $V_0^M \leq 0$. Note that $V_0^{RE} \geq 0$ holds if and only if

$$\frac{\Delta}{c} \geq \frac{(1-\delta q)(1-\delta)}{q(1-2\delta q)} \equiv t_{RE}.$$

Thus, the equilibrium of the static game as previously defined will depend on the value of the benefit-cost ratio Δ/c . If Δ/c is such that $0 < \Delta/c < t_M$, no firm will invest. If $t_M < \Delta/c < t_{RE}$ then there are two pure-strategy Nash equilibria, (I, N) and (N, I) (and also a mixed-strategy equilibrium in which each firm randomizes between I and N , earning the expected initial payoff of zero). Finally, if $t_{RE} < \Delta/c$, the unique Nash equilibrium is (I, I) with both firms receiving a payoff equal to V_0^{RE} .

Because $q = 0.5p(2-p) < p$, it is verified that the threshold levels derived in the foregoing satisfy the following inequalities:

$$0 < t_M < t_{FP} < t_{RE}.$$

Based on these inequalities we can already conclude that the RE mode provides weaker *ex ante* incentives to invest than does the FP regime. That is, for a given R&D cost c , there is a range of the benefit parameter Δ where the FP regime can support two firms in the (initial) R&D contest, each earning positive returns, whereas the RE mode cannot. Specifically, this outcome happens whenever $t_{FP} < \Delta/c < t_{RE}$.

Furthermore, from the *ex ante* payoff formulae derived earlier we also conclude that

$$\frac{\partial V_0^{FP}}{\partial \Delta} = \frac{q}{(1-\delta p)(1-\delta)} > \frac{q}{(1-\delta q)(1-\delta)} = \frac{\partial V_0^{RE}}{\partial \Delta}$$

Thus, not only does the FP model provide an R&D incentive for a range of Δ where the RE mode does not, but the *ex ante* returns to the firms increase faster with Δ under FP than under RE. In other words, $V_0^{FP} \geq V_0^{RE}$, where the inequality holds strictly whenever

$\Delta/c > t_{FP}$. Hence, in our setting a firm would never prefer weaker patent protection over stronger patent protection (unlike what may happen, for example, in the Bessen and Maskin, 2002, framework). This result, illustrated in Figure 1, shows the behavior of the firms' *ex ante* expected profit for a range of the benefit/cost ratios.

We should note, before closing, that some limitations of our simplified analysis are readily apparent. Specifically, our identification of Nash equilibria does not address the question of whether such equilibria are “*subgame perfect*.” In other words, limiting our consideration to strategies that entail the same action at every period in which there is an investment opportunity is, admittedly, restrictive. Whereas this limitation of the analysis can be overcome, the more rigorous game-theoretic approach that is required is not pursued here but is left for future research.

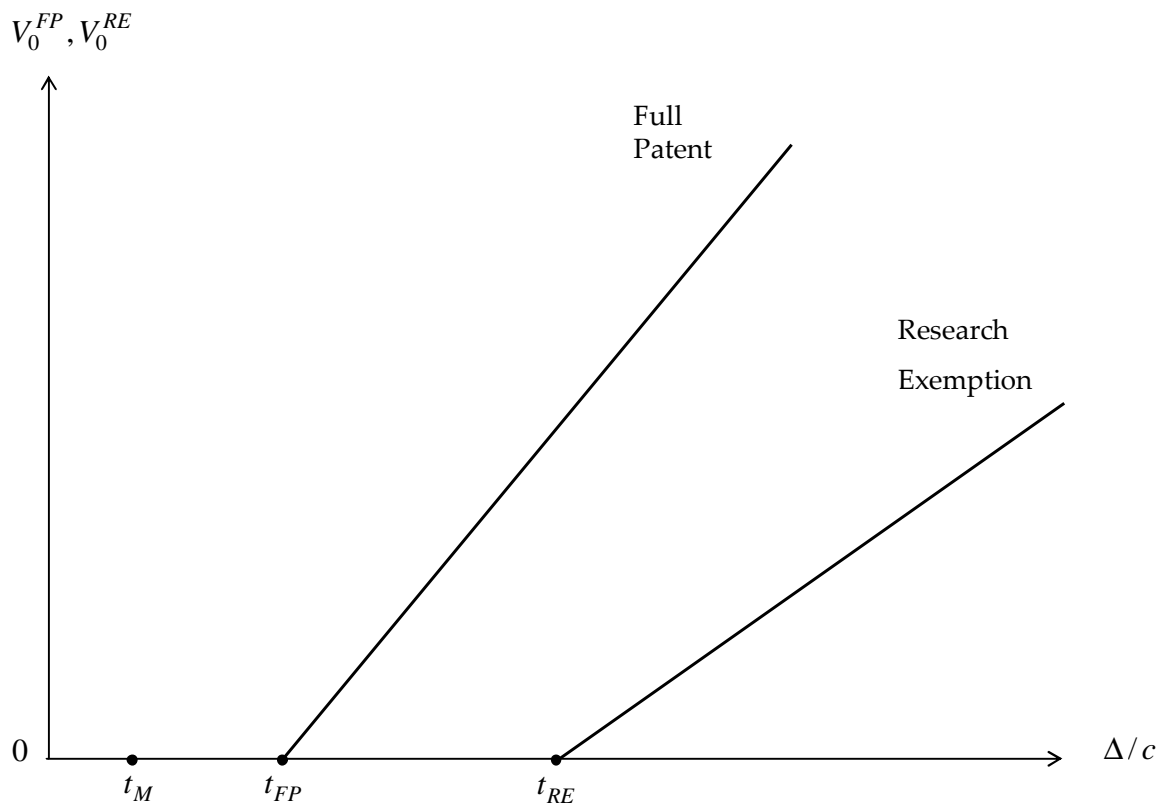
5. Conclusion

In the United States, IPR protection for plants can be secured through either utility patents or protection certificates under the PVP Act of 1970. A crucial difference between these two modes of protection concerns the so-called research exemption: PVP certificates allow it, whereas patents do not. When innovation is sequential and cumulative, as is the case in plant breeding, the economic implications of the research exemption are not completely understood. The simple model and preliminary analysis presented in this paper suggest that the research exemption inevitably weakens the *ex ante* incentive for private firms to innovate. Although in this paper we have not explicitly considered the welfare implications, from society's perspective, of the two modes of protection analyzed, the private incentive effects that we have uncovered allow some interesting conclusions. When R&D costs are low, relative to the potential returns, the reduced incentives may be immaterial, and the research exemption may be desirable because it ensures a larger pool of innovators for follow-up inventions. But when research is relatively costly and/or risky, as is arguably the case with pre-breeding germplasm development, an IPR system centered on the features of standard PBRs (i.e., allowing for a fairly liberal research exemption) does not deliver the desired innovation incentive for private firms.

Table 1. Payoff matrix of the R&D game with a “research exemption”

		Firm B	
		<i>I</i>	<i>N</i>
Firm A	<i>I</i>	V_0^{RE} , V_0^{RE}	V_0^M , 0
	<i>N</i>	0 , V_0^M	0 , 0

Figure 1. *Ex ante* payoff to firms under the two IPR regimes



References

- Arrow, K. (1962). "Economic Welfare and the Allocation of Resources for Innovation," in R.R. Nelson, ed., *The Rate and Direction of Inventive Activity*, Princeton, NJ: Princeton University Press.
- Advisory Council on Intellectual Property. (2004, February). Patents and experimental use (Issues Paper). Canberra: Australian Government.
- Alston, J., & Venner, R. (2002). The effects of the US PVPA on wheat genetic improvement. *Research Policy*, 31(4), 527-542.
- Bessen, J., & Maskin, E. (2002). Sequential innovation, patents, and imitation (Working Paper). Boston: Research on Innovation.
- Boettiger, S., VanDusen, E., Graff, G.D., Pardey, P.D., & Wright, B.D. (2004). Intellectual property rights for plant biotechnology: International aspects. In P. Christou & H. Klee (Eds.), *Handbook of plant biotechnology*. New York: John Wiley & Sons Ltd.
- Butler, L.J. (1996). Plant breeders rights in the US: update of a 1983 study. In J. Vam Wijk & W. Jaffe (Eds.), *Intellectual property rights and agriculture in developing countries* (pp. 17-33). Amsterdam: University of Amsterdam.
- Butler, L.J., & Marion, B.W. (1985). Impacts of patent protection in the US seed industry and public plant breeding (North Central Regional Research Bulletin no. 304). Madison, WI: University of Wisconsin, Madison.
- Denicolò, V. (2000). "Two-Stage Patent Races and Patent Policy," *RAND Journal of Economics*, 31(3), 488-501.
- Denicolò, V., & Zanchettin, P. (2002). "How should forward patent protection be provided?" *International Journal of Industrial Organization*, 20(6), 801-27.
- Donnenwirth, J., Grace, J., & Smith, S. (2004). Intellectual property rights, patents, plant variety protection and contracts: A perspective from the private sector. *IP Strategy Today*, 9, 19-34.
- Eisenberg, R.S. (2003,14 February). Patent swords and shields. *Science*, 299, 1018-1019.
- Fleck, B., & Baldock, C. (2003, October). Intellectual property protection for plant-related inventions in Europe. *Nature Reviews – Genetics*, 4, 834-838.
- Green, J., & Scotchmer, S. (1995). On the division of profit in sequential innovation. *RAND Journal of Economics*, 26(1), 20-33.

- International Seed Federation. (2003, June). ISF view on intellectual property. Bangalore, ME.
- Hansen, L., & Knudson, M. (1996). Property right protection of reproducible genetic material, *Review of Agricultural Economics*, 18, 403-414
- Hunt, R.M. (2004). "Patentability, Industry Structure, and Innovation," *Journal of Industrial Economics*, LII(3), 401-425.
- Janis, M.D., & Kesan, J.P. (2002). Intellectual property protection for plant innovation: Unresolved issues after *J.E.M. v. Pioneer*. *Nature Biotechnology*, 20, 1161–1164.
- Jördens, R. (2002, October). Legal and technological developments leading to the symposium: UPOV's perspective. WIPO-UPOV Symposium on the Co-existence of Patents and Plant Breeders' Rights in the Promotion of Biotechnology Developments, Geneva.
- Koo, B., & Wright, B.D. (2002). Economics of patenting a research tool (EPTD Working Paper No. 88). Washington, DC: International Food Policy Research Institute.
- Langinier, C., & Moschini, G. (2002). The economics of patents. In M.F. Rothschild & S. Newman (Eds.), *Intellectual property rights in animal breeding and genetics*. New York: CABI Publishing.
- Matutes, C., Regibeau, P. & Rockett, K. (1996). Optimal patent design and the diffusion of innovations. *RAND Journal of Economics*, 27, 60-83.
- Miller, J. (2003). Sealing the coffin on the experimental use exception. *Duke Law & Technology Review*, 0012.
- Moschini, G. (2004). Intellectual property rights and the World Trade Organization: Retrospect and prospects. In G. Anania, M. Bohman, C. Carter, & A. McCalla (Eds.), *Agricultural policy reform and the WTO: Where are we heading?* Aldershot, UK: Edward Elgar Publishing.
- Nordhaus, W.D. (1969). *Inventions, growth and welfare: A theoretical treatment of technological change*, Cambridge, MA: MIT Press.
- O'Donoghue, T. (1998). A patentability requirement for sequential innovation. *RAND Journal of Economics*, 29(4), 654-679.
- O'Donoghue, T., Scotchmer, S., & Thisse, J. (1998). Patent breadth, patent life, and the pace of technological progress. *Journal of Economic and Management Strategy*, 7, 1-32.

- Otten, A. (2003, October). Plant biotechnology developments in the international framework. WIPO-UPOV Symposium on Intellectual Property Rights in Plant Biotechnology, Geneva.
- Perrin R.K, Hunnings, K.A, & Ihnen, L.A (1983). Some effects of the US Plant Variety Protection Act of 1970 (Economic Report 346). Raleigh, NC: Dept. of Economics and Business, NC State University.
- Pray, C.E., & Basant, R. (1999, June). Agricultural research and technology transfer by the private sector in India. Working paper No. 1999-06-03, Indian Institute of Management, Ahmedabad
- Roberts, T. (2002, October). Plant variety rights: The breeder's exemption. WIPO-UPOV Symposium on the Co-existence of Patents and Plant Breeders' Rights in the Promotion of Biotechnology Developments, Geneva.
- Scotchmer, S. (1991). "Standing on the shoulder of giants: Cumulative research and the patent law," *Journal of Economic Perspectives*, 5, 29-41.
- Scotchmer, S. (1996). Protecting early innovators: Should second-generation products be patentable? *RAND Journal of Economics*, 27, 322-331.
- Scotchmer, S. (2004). *Innovation and Incentives*, Cambridge, MA: The MIT Press.
- Srinivasan, C.S. (2003, August). Assessing economic returns from farmer's rights. Contributed paper, 25th International Conference of Agricultural Economists, Durban, South Africa.
- Srinivasan, C.S. (2004). Plant variety protection, innovation and transferability: Some empirical evidence. Working Paper, Department of Agricultural and Food Economics, University of Reading. Reading, UK.
- Straus, J. (2002, October). Measures necessary for the balanced co-existence of patents and plant breeders' rights—A predominantly European view. WIPO-UPOV Symposium on the Co-existence of Patents and Plant Breeders' Rights in the Promotion of Biotechnology Developments, Geneva.
- U.S. Department of Agriculture. (1995). AREI updates: New crop varieties—Intellectual property rights spur development of new crop varieties (USDA Publication No. 14). Washington, DC: U.S. Department of Agriculture, Natural Resources and Environment Division, Economic Research Service.