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# Assessing the Impact of Intellectual Property Rights in the Plant/Seed Industry

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# 1 Introduction

Evolution in science such as recent developments in biotechnology creates new challenges for patent regimes, leads to reforms in laws and regulations, and has led to the creation of property rights where none existed before. New property rights imply new avenues of rents for firms and new types of strategic behavior. Intellectual property rights, by giving inventors monopoly rights to their inventions, provide economic incentives for research and development. In exchange for the monopoly rights inventors reveal the methods behind their invention, which helps further the public good by fostering cumulative invention while imposing a cost on the company from revealing their secrets. This work models firm decisions of whether to patent their technologies or keep trade secrets in a nash bargaining framework and then uses recent changes in the intellectual property laws in the plant and seed industry as well as key agronomic differences between corn and soybeans to investigate the validity of the model.

The present exponential growth in biotechnological research is one of the byproducts of changes in intellectual property rights for living organisms. The new paradigm in biotechnology patenting started after the landmark Supreme Court *Diamond vs Chakrabarty* [1980] decision that allowed the patenting of life forms. This decision opened the door to the patenting of plants and animals as standard utility patents. In the case of plants certain forms of property rights, for plant seeds the Plant Variety Protection Act (PVPA) and for tubular form plants the Plant Protection Act (PPA), were already in place before this landmark case was decided, but they granted weaker property rights than utility patents. Both of these acts had limits on the extent of property rights that were not true of standard utility patents.

New property rights also imply increased uncertainty in the interpretation of laws. In such a dynamic scenario where laws and interpretations of them are changing rapidly, firms need to be strategic in their patenting decisions, such that they can extract maximum rents from their rights. Such strategic behavior of firms has been captured in the literature on patent lengths and breadths (for example: Gilbert and Shapiro, 1990). Our goal in this paper is to explore two other important aspects of strategic patenting behavior: [1] The impact of uncertainty in patent acceptance, [2] the implications of patenting rules on the intellectual portfolio choice between patents and trade secrets. In this paper we explore these two issues using patenting data on patenting in plants.

This Supreme Court decision created a menu of choice in plant intellectual property rights for agricultural biotechnology firms. For seeds firms with new research ideas they could either apply for a PVPA or PUP or they could apply for both. Such menu choice in intellectual property rights is unique to plants. A theoretical model by Hopenhayn and Mitchell (2001) suggests that a menu approach in patenting with different levels of property rights can lead to intensive level of strategic patenting behavior by firms leading to socially sub-optimal investments in property rights. Our study will explore this issue of availability of menu choice in plant patenting and its implications for strategic firm behavior based on the already existing theoretical literature.

The chronology of patent law changes allow us to also explore the behavior of biotechnology firms in plants. Chronologically, in the case of plant patents the regulations, litigations and decisions significantly strengthened the property rights available for plants. The following are the most significant decisions and regulation changes on plant patenting: [1] Diamond vs. Chakrabarty [1980], [2] ex-parte Hibberd [1985], [3] J.E.M. Ag Supply v. Pioneer Hi-Bred International [2000]. We explore strategic behavior of firms in patenting given these events using event study methodology.

Preliminary evidence from the data shows that the introduction of stronger property rights in plants after the ex-parte Hibbard decision of 1985 caused an increase in both PVPA and utility patent property rights in plants. Some of this increase clearly comes from the uncertainty in which would be the strongest form of property, but some may also represent strategic behavior by companies. Some evidence of property rights uncertainty as the driving force behind the increases in property rights protection comes from the drop in PVPA applications after the JEM Ag Supply decision implied that anything that could receive a PVPA could also receive a utility patent.

## **1.1 Literature review**

This work fits in a now large literature that seeks to understand the effects of changes in regulations and research technologies on the rate of innovation and patenting. Kortum and Lerner (1997) investigate whether the tremendous growth in US patents starting in the early 1980's can be attributed to rule changes that strengthened patents or to increases in innovation. They conclude that the "jump" in patent production is due to innovation and improvements in the management of research rather than to changes in patenting

laws. Hall and Ziedonis (2001) in contrast found that changes in patent laws had a significant impact in patenting strategies of firms in semiconductor industries and led to ‘patent portfolio races’ among capital-intensive firms, but it also facilitated entry by specialized design firms. These findings imply that stronger patenting rules are likely to lead to more strategic behavior by firms, but not necessarily more innovation. Using Japanese patent data before and after the 1988 patent reforms Sakakibara and Branstetter (2001) find no evidence to link the stronger patent rights with increased R&D investment or innovation.

A number of observers of patenting, particularly in the biological sciences, have suggested that patenting rules and overlapping claims have generated a “patent thicket” that has impeded innovation and made the R&D process more costly (Rai, 2001; Rai, 1999). Rai (2001) for example, argues that broad patents especially on upstream platform technologies represent a threat to competition and the cumulative process of innovation in the biopharmaceutical industry. A recent court ruling in *Maye v. Duke University* (Oct. 2002) greatly contracts the research exemption rules on US patents especially for universities making this patent thicket potentially more of a problem.

Such concerns of a patent thicket have raised questions as to whether there might be reasons to legislate a greater research exemption in US patenting laws. Does intellectual property with a research exemption have sufficient value to companies that it can foster innovation? Or does the research exemption make imitation too easy and reduce the value of intellectual property to zero? The plant science industry provides a useful place to test the effects of such a research exemption since among the multiple types of intellectual property available to companies in the plant sciences industry are ones that have a research exemption (Plant Patents and Plant Variety Protection Certificates).

While much of the theoretical literature has focused on varying rules within the realm of intellectual property rights (patent length, breadth, etc.), recent empirical evidence has pointed to the importance of company secrets in company strategies. Cohen, Nelson, and Walsh, for example, find that firms in the 1990’s were likely to rely more heavily on company secrets than were firms in the 1980’s. This type of empirical evidence is not well described by current models of patenting, since they typically ignore the option to keep a company secret rather than apply for a patent. An exception is the model of firm R&D strategies put forth by Bulun and Moschini in which firms choose whether to patent or keep a trade secret based on the returns

and the probability of losing a trade secret. We build on that model but in order to capture the changing intellectual property regimes include both a probability of having a patent denied and the externalities that come from a firm revealing its research in a patent.

Such choices between company secrets and intellectual property are particularly salient in the plant science industry where “closed pedigree” plant breeding in hybrids was developed in the 1940’s and 1950’s to respond to the lack of intellectual property rights in plant seeds. With the Plant Variety Protection Act and subsequent court rulings, seed companies have access to a full panoply of intellectual property much greater than in other industries.

## 1.2 Description of the Game

In this paper we first examine firms ex-ante decision problem to apply for any form of property rights through patents or to keep trade secret. Next we develop a model where firm chooses between different forms of property rights and keeping trade secrets. Compared to recent literature our model makes the following innovation. We assume that probability that a patent is granted is less than one. We also assume that there is a loss from the patent application process. The motivation for this assumption comes from the fact that in a patent application a firm needs to reveal the methods behind the innovation. As a result whether the firm’s patent is accepted or not firm faces certain loss from this revelation. When comparing strategies of patenting with different length or scope, this revelation loss is constant, but when comparing patents to trade secrets the revelation loss could be important.

## 1.3 Benefits under different regimes:

The benefit structure in this game is similar to the one in Bulut and Moschini (2003).

The social benefit of a product innovation:

$$SB = \int_0^{\infty} b e^{-rt} dt = \frac{b}{r} \quad (1)$$

The benefit from trade secret will be based on a hazard rate  $z$ . So the benefit from a secret is expressed as:

$$FB_s = \int_0^{\infty} u e^{-(z+r)t} dt = \frac{b}{z+r} = \frac{r}{z+r} SB = \gamma(z) SB \quad (2)$$

The benefit for the firms in patenting will be for a finite time period (patent length). If the patent application process reveal some trade secrets. We assume that this loss is a fraction of the benefits from keeping trade secrets. So, the benefit for the firm for successful application can be stated as:

$$FB_{pt}^A = \int_0^T be^{-rt} dt = \left(1 - e^{-rT}\right) \frac{b}{r} = \delta^T SB - lFB_S \quad (3)$$

where  $0 < l < 1$ . This can also be expressed as:

$$FB_{pt}^A = SB \left( \delta^T - l\gamma \right) \quad (4)$$

On the other hand from the failure of application leads to a loss of:

$$FB_{pt}^R = -l\gamma SB \quad (5)$$

## 1.4 Ex-Ante Probability

As mentioned before we assume that the any firm's application for patent may get rejected. As a result, the expected pay-off will be based on the probability of success and failure. Lets probability of success with patent application is  $p$ .

## 1.5 The patent game with two firms

We assume symmetric firms such that they have the R&D research output for patent, and the probability of success in the application process is independent for each firm. As a result probability of success of firm 1 does not impact the probability of success of firm 2. And if both the firms gets approved then they share the total monopoly rent equally. In matrix form the game can be stated as:

		Firm j	
		Property Rights	Trade Secret
Firm i	Property Rights	$\Pi_i^{pt,pt}, \Pi_j^{pt,pt}$	$\Pi_i^{pt,s}, \Pi_j^{pt,s}$
	Trade Secret	$\Pi_i^{s,pt}, \Pi_j^{s,pt}$	$\Pi_i^{s,s}, \Pi_j^{s,s}$

So, the expected payoff can be stated as:

- Expected payoff of each firm when both firms chooses patent:

$$\Pi_i^{pt,pt} = p(1-p)FB_{pt}^A + (1-p)FB_{pt}^R + p^2 \left( \frac{\tilde{A} FB_{pt}^A}{2} + \frac{FB_{pt}^R}{2} \right) \quad (6)$$

This can also be stated as:

$$\Pi_i^{pt,pt} = SB - p(1-p) \delta^T - \gamma l - (1-p)l\gamma + p^2 \frac{\delta^T}{2} - l\gamma \quad (7)$$

2. Expected payoff of firm  $i$  when firm  $i$  chooses patent and firm  $j$  chooses trade secret:

$$\Pi_i^{pt,s} = pFB_{pt}^A + (1-p)FB_{pt}^R \quad (8)$$

Similarly we can simplify the expression as:

$$\Pi_i^{pt,s} = SB - p \delta^T - \gamma l - (1-p) \gamma l \quad (9)$$

3. Expected payoff of firm  $i$  when firm  $i$  chooses trade secret and firm  $j$  chooses patent:

$$\Pi_i^{s,pt} = (1-p) \frac{FB_s}{2} + pFB_{pt}^R \quad (10)$$

This expression here can be expressed as:

$$\Pi_i^{s,pt} = SB - (1-p) \frac{\gamma}{2} - pl\gamma \quad (11)$$

4. Expected payoff when both the firms decide to keep trade secret:

$$\Pi_i^{s,s} = \frac{FB_s}{2} = SB \frac{\gamma}{2} \quad (12)$$

**Proposition 1** In this game (patent, trade secret) or (trade secret, patent) are not pure strategy Nash equilibrium.

Proof. In this game  $\Pi_i^{pt,pt} > \Pi_i^{s,pt}$  and as a result each firm will have an incentive to deviate from any of the pure strategy Nash equilibrium mentioned above. ■

Now to explore pure strategy Nash equilibrium (PNE) there are two interesting Nash equilibrium from the perspective of our research. They are [(Patent, Patent): PNE\_1] and [(Trade Secret, Trade Secret): PNE\_2]. In this symmetric game for PNE\_1 the following condition should hold:

$$\Pi_i^{P,P} \geq \Pi_i^{TS,P} \quad (13)$$

and for PNE\_2 the condition will be:

$$\Pi_i^{TS,TS} \geq \Pi_i^{P,TS} \quad (14)$$



**Lemma 2** (1) if  $\gamma \leq \frac{p\delta^T(2-p)}{(1+2l)(1+p)}$  then (patent, patent) is the PNE; [2] if  $\gamma \geq \frac{2p\delta^T}{1+2l}$  then (trade secret, trade secret) is the PNE; [3].for  $\frac{p\delta^T(2-p)}{(1+2l)(1+p)} \geq \gamma \geq \frac{2p\delta^T}{1+2l}$  any there exist only mixed strategy equilibrium.

Proof. The proof [1] and [2] are strait forward and based on solving condition (13) and (14). In the case of [3] we know from proposition 1 that the (patent, trade secret) and (trade secret, patent) can not be pure strategy Nash equilibrium. So, any intermediate  $\gamma$  the equilibrium should be mixed strategy equilibrium. ■

To explore PNE\_1 and PNE\_2 outcome we define two threshold. At  $\gamma_{s,s} = \frac{2p\delta^T}{1+2l}$  each firm is indifferent between the PNE\_2 outcome and applying for patents, and at  $\gamma_{pt,pt} = \frac{p\delta^T(2-p)}{(1+2l)(1+p)}$  each firm is indifferent between maintaining equilibrium PNE\_1 and deviating to trade secret. The two threshold can also be stated as  $\gamma_{pt,pt} = \frac{\gamma_{s,s}(2-p)}{2(1+p)}$ . Given that  $\frac{(2-p)}{2(1+p)} < 1$  suggest for certain values of  $\gamma$  neither (patent, patent) and (trade secret, trade secret) will be Nash equilibrium.

Also note that the relationship between  $\gamma$  and  $p$  is monotonic and positive and between  $\gamma$  and  $l$  is monotonic and negative in the case of PNE\_2. In the case of PNE\_1, the relationship between  $l$  and  $\gamma$  is still monotonic and negative. But  $\gamma$  and  $p$  has a much more complex nonlinear relationship. To explore we concentrate on the threshold level, that is  $\gamma = \frac{p\delta^T(2-p)}{(1+2l)(1+p)}$ . At the threshold

$$\frac{d\gamma}{dp} = \frac{\delta^T}{1+2l} \cdot \frac{2-p(p+2)}{(1+p)^2} \quad (15)$$

The sign of (15) will depend on the term  $2-p(p+2) \leq 0$ . If we solve it then in this game until  $p = 0.7325$   $\frac{d\gamma}{dp} > 0$  and if  $p > 0.7325$  then  $\frac{d\gamma}{dp} < 0$ . This result suggest that if the probability of getting patent goes up then the threshold for PNE\_1 will initially go up but it will decrease at a high probability ceteris paribus. Intuitively at a high probability, both firms' expectation to get the patent goes up. As a result probability that they are going to get the patent jointly also increases, hence each firm's expectation of being the sole monopolist decreases. This is due to the fact that the (patent, patent) outcome generates more externalities for each firm. If a firm applies for patent then the firm not only needs to take into account that the firm might lose the patent application to the other firm but also the firm might have share the benefits of the patent. Where as in PNE\_2 outcome of the firm does not generate any externalities.

## 1.6 Model's Implications

In this model we assume following variables the policy makers can impact,  $r$ ,  $T$ ,  $p$ , and  $l$ . On the other hand the only variable that the firm can impact is  $z$ . In the case of  $r$  and  $T$  the reasoning for this assumption is obvious. In the case of  $p$  and  $l$  in reality firms can also have some influence. By choosing patent breadth firm can influence the probability of getting an specific application approved and also determine the level of information revealed. In this paper we assume that there is only one patent breadth that a firm can choose. One way firm can influence firm can influence hazard rate is through mergers and acquisition.

Results of simulating the equilibria in this model

### 1.6.1 A Brief History of Patenting of Plants

Up until the end of the twentieth century, US utility patent statutes were understood to exclude patents on living organisms. The intellectual property needs/demands of the plant and seed propagation industry led to a number of intellectual property rules to allow intellectual property on plants despite this exclusion. After a series of complaints by nursery owners, the US Congress created the Plant Patent Act (PPA) in 1930 to allow intellectual property protection of asexually propagated plants, which are those that propagate by cuttings rather than seeds. Over the years the court traditions construed this law quite strictly to apply only to asexual propagation and that infringement only occurs when from the actual taking of shoots or plant material is proven but cannot be proven merely by genetic similarity (Janis and Kesan, 2001).

In 1970 Congress created the Plant Variety Protection Act (PVPA) which allowed intellectual property protection of plants propagated by seeds. While similar to utility patent statutes, the PVPA has a research exemption and a farmer use exemption. The research exemption allows the use of PVP protected seeds in research, while the farmer exemption allows farmers to replant from PVP protected seeds he grew the previous year, "bin-run seeds". It does, however, exclude the farmer selling those seeds to other farmers, a practice commonly called "brown-bag seeds".

In 1980, the Supreme Court stepped into the fray with its 5 to 4 decision on *Diamond v. Chakrabarty*, which held that genetically modified bacteria could be patented within the scope of the US patent statutes. This decision, which was the linchpin to the explosion of biotechnology patents in the late 1980's and 1990's,

was not clarified as being applicable to plants until 1985 when in *ex-parte* Hibberd, a utility patent application for a type of corn seed, the patent office's board of appeals concluded that Chakrabarty did apply to plants. Note that utility patent statutes have higher levels of standards for novelty and utility than the PVPA and have neither a farmer or researcher exemption, such that farmers cannot "bin-run" seeds with utility patents and researchers cannot use them without license. Also because of the US patent office infrastructure in publicizing patent application contents the utility patents provide much more exact information for the public domain.

Thus after 1985 plant seed producers had two methods to protect their intellectual property a PVP and a plant utility patent (PUP) and could even apply for protection on both of the seeds. The issue of joint protection using both PVP and PUP was resolved in December 2001 by the Supreme Court decision *J.E.M. Ag Supply Inc. v. Pioneer Hi-Bred Int'l Inc.* which held that concurrent protection under the PVPA and the utility patent statutes was fine.

This history of intellectual property rights has created a number of different regimes for plant seed producers. The first regime which lasted until 1970 had no available intellectual property except for keeping company secrets. In this period corn seed producers developed closely guarded "closed pedigree" seeds that only partially protected their germplasm from use by rivals. After 1970 they had the option of applying for PVPs for their seed varieties. In 1985 utility patents were added to the intellectual property rights portfolio, but with some uncertainty as to their validity when concurrent with a PVP. In 2001 this uncertainty was resolved.

### **1.6.2 Corn and Soy Market Features:**

Corn and soybeans represent the two most important crops in the US seed market with the 2001 corn crop being worth \$19 billion and the 2001 soybean crop worth \$12 billion (USDA, 2002). Not surprisingly a large portion of the private research dollars for seed development are in these seeds and have been the major crops to receive intellectual property protection with just under 1/3 of all the PVPs issued out of the hundreds of crops eligible have been for either corn or soybean varieties. The corn and soybean markets are both dominated by the same two firms Monsanto and Pioneer/Dupont which in 1997 accounted for 56% of the corn seed sales and 38% of the soybean seed sales (Hayenga, 1998).

While these two seed products are globally similar, some key differences in the corn and soybean agronomics and markets imply different firm strategies with respect to research and development as well as marketing strategy. It is these key differences that will help identify the validity of some of the theoretical model's propositions.

A key agronomic difference between corn and soybeans is that corn hybrids if replanted the following year with saved seed will not produce reasonable yields while soybeans can be replanted. Thus soybeans have more durable good properties than corn for which new seed needs to be purchased every year. Typically one could expect in soybeans the seeds sold to cover roughly three quarter of the national acres with the remainder planted in saved seed. Thus the overall size of the corn market is much larger and farmers make decisions about seeds each year rather than perhaps every other year.

This every year demand for hybrid corn seed as well as the larger overall size of the corn acreage planted has meant that more research dollars have gone into corn research than soy. In addition greater marketing and advertising efforts as well as brand/variety proliferation is present in corn seed than in soybeans. In part because of these higher levels of technological change, marketing, and variety proliferation farmers tend to change their corn seed variety every 2 years while in soybeans the turnover is every 4 or 5 years. Thus the effective life of a soybean variety from a company's point of view is about twice as long as that of a corn seed variety.

## **1.7 Empirical Evidence**

Figure 1 shows the growth in intellectual property rights in plants including plant patents, plant variety protection certificates, and plant utility patents from 1976 to 2001. There is clearly dramatic and steady growth overall during this time period with 1,496 intellectual property grants for plants in 2001 being more than 11 times the 128 granted in 1976.

Figure 2 shows the growth in PVPs and PUPs. One can see that after an initial spurt in PVP grants, the levels held relatively constant until another increase at the end of the 1990's. PUP grants, non-existent before 1985 did not really start to take off until the mid 1990's at which point they experienced a growth spurt which ended in 1999 with some retrenchment.

Figure 3 shows the importance of corn and soybean varieties among PUPs, demonstrating that in the

early years corn PUPs were the dominant type of PUP. Corn shows a growth spurt starting in the early 1990's and retrenchment after 1999. Soybean PUPs lagged a few years behind corn varieties, but follow a similar pattern to those of corn though at a lower overall level.

Figure 4 shows the growth of intellectual property rights in corn and soybeans showing both PUPs and PVPs. One sees immediately that soybean PVPs were applied for and granted soon after the new intellectual property rights became available in 1970. Meanwhile in corn there were no corn PVPs until the early 1980's at which point they started to grow rapidly to the level of soybean PVPs.