INSECURE PROPERTY RIGHTS AND PLANT VARIETIES: THE EFFECT ON THE MARKET FOR SEEDS IN ARGENTINA

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Introduction

During the 1990s, the market for biotechnology in agricultural and pharmaceutical sectors has become an international economic force.[1] Investment in research and development (R&D) of new seed varieties has become a key factor for market success (Kesan, 2000). In the last few decades, the investment in R&D has switched from state sponsored research to more private R&D spending (Fernandez- Cornejo, 2004). At the same time, the market moved towards a strong concentration in a few multinational firms, which now control most of the biotechnological research and development around the world (RAFI, 1999 and Sirinivasan, 2003). These changes are happening at the same time that a revolution on biotechnology is advancing on agriculture and pharmaceutical industries (Fernandez-Cornejo, 2004).

In this new environment, with wide private participation in an international market, the protection of intellectual property rights and its role in shaping the biotech market has been highly debated (Kesan, 2000; Kesan and Janis, 2001; Swanson and Goschl, 2000; Janis and Kesan, 2002; Goldsmith, Ramos and Steiger, 2002; Goldsmith, 2001; Lesser, 1998; Moschini, 2001; Moschini and Lapan, 1997; Rohrbach, Minde and Howard, 2003; Alston and Venner, 2002; Frisvold, Sullivan and Raneses, 2003; Graff, Rausser and Small, 2003 and Diez, 2002). Governments, international organizations, the private sector (firms and farmers), scholars and scientists are discussing the implications of these changes for the market for seeds, and how property rights should be defined and enforced to promote social welfare (Fernandez-Cornejo, 2004). Developed countries have tried to enforce intellectual property rights over new varieties of seeds in developing countries in order to promote and protect the investments made by their companies abroad. On the other hand, developing countries have insisted on maintaining a weak property rights system in order to favor their farmers and obtain new technologies at the lowest possible cost (Goldsmith, Ramos and Steiger, 2002).

[1] "The ISAAA projects that the global market value of transgenic crops will increase from between $4.5 billion and $4.7 billion in 2003, to $5 billion or more in 2005. In 2002, the global market was estimated at $4 billion, representing 15 percent of the $31 billion global crop protection market and 13 percent of the $30 billion global commercial seed market. The ISAAA says the estimated market value is based on the sale price of transgenic seed plus any technology fees that apply." Doris de Guzman, Surge in US Biotech Crops Continues, Chemical Market Reporter, New York, V. 265, I. 15 April 12th 2004, at 13.

Despite the interest on the impact of property rights on R&D on agricultural markets, there have not been many studies on the matter. The creation of effective property rights legislation to promote a high level of R&D, even though this implies the possibility of some monopoly power in the market, is a key instrument for biotechnology in agriculture (Kesan, 2000). Accordingly, property rights should protect the creators of new plant varieties, and they should be enforced (Kesan, 2000). Of course, the scope and definition of rights will depend on the characteristics of the plant to be protected (Cohen and Levin, 1989; Fernandez-Cornejo, 2004).

In this article, we analyze different property rights regimes and their impact on the production of new varieties of soybean and corn in Argentina (Janis and Kesan, 2002). Soybean requires a higher level of protection than corn, given the reproductive characteristics of self-pollinated versus hybrid crops (Janis and Kesan, 2002). As a result, we observe that in countries like the United States, soybean utility patents can protect research, while simple Plant Variety Protection Certificates (PVPCs) may be adequate protection for some crops such as corn (Fernandez-Cornejo, 2004; Janis and Kesan, 2002). However, in Argentina, patent protection is not generally available for plant varieties, and seed producers only have PVPCs according to the guidelines established by the UPOV 78.[2] Given that Argentina is the third world exporter of soybean and one of the main producers of genetically modified soybean, the study of the lack of property rights protection on the soybean market, as compared to the corn market, provides insightful results for the effect of property rights on biotechnology research.

In order to analyze the effects of insecure property rights in research and development in agriculture, we develop a theoretical model in which the producer of a new variety faces partial excludability and appropriation in the market. This inventor produces two different varieties of plants (corn and soybean). This particular setup allows us to address the effect of insecure property rights on one variety, soybean, and how this has an effect on the production of the other variety, corn. This cross effect inside the production process of seed companies has not been addressed in the literature,

[2] *See* Section IV (explaining the legal protection in Argentina).
"Monsanto's 1995 application for a patent for Roundup Ready soybeans in Argentina was rejected. Monsanto appealed the decision, and an Argentine court overturned the rejection. Monsanto has petitioned

and we find it to be very important for research and development decisions. From this model, we obtain a series of empirical implications: First, the price and quantity of new varieties will depend on the level of property rights in the market. Second, the quality of the new varieties will have a positive impact on prices and quantities offered, but a negative effect on quantity demanded. Third, the level of investment in the new varieties will depend positively on the definition of property rights and the research effort. Fourth, changes in the level of property rights protection or research effort in one of the markets will have an inverse relationship with the quality of the new variety in the other market.

We use the case study of Argentina, and the United States, to evaluate the empirical implications of our theoretical model. We find that the market for soybean and corn seeds in Argentina operate according to our theoretical model. In addition, we find that both domestic and foreign seed producers respond in a similar fashion to market incentives. The implementation of PVPCs according to the UPOV 78 guidelines could provide enough protection for corn seeds, which need a lower level of legal property rights protection, but they are completely ineffective to protect soybean innovation. According to what our model predicts, this bias in the enforcement of property rights generates an over-production of corn seeds and under-provision of soybean seeds, even though Argentina has become one of the main producers of soybeans in world markets.

This article is organized as follows. The second section presents a description of agricultural markets for corn and soybean in Argentina. The third section presents the theoretical model. The fourth section describes the evolution of intellectual property rights in Argentina and its comparison to the United States. The fifth section presents empirical evidence regarding the effect of legislation on research and development of new varieties, and the market for seeds in Argentina in comparison to the United States. Finally, we present our conclusions.

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for reconsideration of the patent application; as of December 1999, the application was pending." GAO, 2000, at 6.

Argentina's Soybean and Corn Markets

Argentina is an important actor in international agricultural markets.[3] During the 1990s, the liberalization of the country provided a new impetus to agriculture, and soybean was one of the crops that were grown the most (Schnepf, Dohlman and Bolling, 2001).

Graph 1: Hectares Planted with Corn and Soybean

Since the 1978/79 season, the area planted with soybean had steadily increased (graph 1).[4] The total growth from 1978 to 2003 reached 669%, while total production went from 2.5 million metric tons to 35 million metric tons in 2003. During the same period, the area planted with corn stayed almost constant, declining 6.5%, but production increased by 72.9% because of the improvements in yield. The boom in the production of soybean has propelled Argentina into the spotlight in international markets. Total production of corn represented just 2.6% of total world production for the period 1999-2000 to 2001-2002. Nonetheless, total exports were 11.5% of total world exports (see Table 1).

In the case of soybean, Argentina represented 15.2% of total world production, and has share in world markets of 11.2% of total exports (see Table 2). As a result, both crops occupy an important position in the agricultural sector of the country and in international markets.

The importance of Argentina in the international markets for corn and soybean is also found in the market for seeds (see Table 3). The domestic market in Argentina for seeds occupies the 8th position in the world and can be compared with other seed markets

[3] "However, in the past decade two Southern Hemisphere competitors—Argentina and Brazil—have begun to tap more deeply into their own vast array of agricultural resources. Spurred by economic policy reforms, private investment (much of it from external sources) has been pouring into their agricultural sectors, applying cutting-edge technologies to historically underdeveloped production, marketing, and processing sectors. As a result, crop area and yields have been expanding rapidly, generating sharp increases in production. This output expansion, in turn, has translated into strong gains in global competitiveness in several commodity markets important to the United States, most notably soybeans and its products." Schnepf and Dohlman, 2001, at 1.

[4] See, Secretaria de Agricultura y Pesca de la Nacion (SAGyP), at www.mecon.gov.ar (providing statistical information on the Argentine agricultural sector).

in developed countries. Finally, Argentina has been one of the early adopters of genetically modified crops, especially in soybean and corn. Since 1996, the government approved the use of genetically modified seeds, and farmers have been adopting Roundup Ready soybean and Bt corn extensively.[5]

Given the importance of Argentina in the markets for corn and soybean, an analysis of the incentives for research and development that property rights legislation generates is meaningful to better understand market behavior in general. As a result, in the next section, we develop a theoretical model to understand the incentives seed producers face in the market.

Table 1: International Trade, Corn Exports

Table 2: International Trade, Soybean Exports

Table 3: Estimated Values of Commercial Markets for Seed

The Model

There are several works that have addressed the impact of property rights on the market for seeds. The issue of how excludability and appropriation generate incentives for research and development in agriculture has also been studied (Alston and Venner, 2002). In this section, we develop an economic model considering a private firm that considers investing in developing two new varieties of seeds A and B (for example, corn and soybean). If this firm successfully develops a new variety, this firm is assumed to have a monopoly on the intellectual property rights for these varieties. However, we assume that the appropriation of these rights in the market is imperfect. This assumption is very important for markets of self-pollinating seeds where the cost of reproduction of the genetically modified technology is almost non-existent, such as reproduction of

[5] "U.S. and Argentine farmers have readily adopted Roundup Ready soybean and Bt corn seeds since their market introductions –with adoption rates for Roundup Ready soybeans seeds particularly high." GAO, 2000, at 7. United States General Accounting Office (GAO), "Biotechnology: Information on Prices of Genetically Modified Seeds in the United States and Argentina". GAO, 2000, at 7.

soybean seeds. For other seeds, like corn, the hybrid technology provides a higher degree of protection, even with a lower degree of legal property definition and enforcement.

Further, we assume that this firm will operate in different periods of time. In the first period, the firm has to decide how much to invest in developing both varieties having into account all the usual costs and the research effort needed to produce the new seed varieties. Furthermore, we assume that the level of property rights in the market will be a factor in determining the optimal investment. We also assume that the development of different varieties is complementary since resources spent in developing one variety could be useful to develop a different one. Accordingly, we are establishing a relationship in the research and development process between varieties. This particular characteristic of the model tries to capture the characteristics of real life investment processes wherein there are many complementarities among research processes. For example, human capital, specific knowledge and techniques as well as different productive factors can be used indistinctly in the invention process of various seed varieties. Finally, we assume that in the second period, the seed producer will introduce new varieties into the market and obtain monopoly profits depending on the level of property rights protection in the specific market for each variety.

In order to solve our model, we start by finding the optimal result for the commercialization of the new varieties in the second period. We work backwards because the expected profits to be obtained once the variety is traded will be taken into account during the research and development stage. Then, we will consider the maximization problem for the seed producer in the first period, when the investment in the new varieties is to be decided. We assume that this seed producer acts as a monopolist for the market of their new varieties and that the company invests in a new variety in the first period and sells this new variety in subsequent periods. Accordingly, the quality of the new variety in the first period can be represented as,

$$A = A(s, H, X) \qquad (1)$$

where s is the effort devoted to produce a new variety, H is the previous investment in knowledge used to develop the variety and X is a series of different factors that determine the quality of the new variety.

Without loss of generality, we assume that this firm produces two different kinds of seed varieties, i.e., soybean and corn. Accordingly, the demands for the new varieties of corn and soybean in the second period are the following,

$$q_A = Q(A_A, p_A)$$
$$q_B = Q(A_B, p_B) \qquad (2)$$

The demand of each variety depends positively on the quality, A_A and A_B, which are determined in the first period, and negatively on the market price, p_A and p_B.

In a market with perfect enforcement of intellectual property rights, the seed producer will have no problems in maximizing total profit and exploiting its market power. Nonetheless, the markets for varieties are not perfect, and appropriation is not perfect. As we will analyze later in our model, in the market for corn varieties, intellectual property rights are easier to enforce as compared with soybean because of the characteristics of the seeds. Corn is a hybrid crop and reproduction from a newly created variety is not technologically attractive. As a result, corn seed producers can protect property rights in their own technology for producing the new variety, and simple PVPCs offer adequate legal protection. However, in the case of soybean, self-pollination allows free copying of new varieties. As a result, a more strict definition and protection of property rights like plant patents and utility patents are needed for effective legal protection. The setup of our model will help us understand how these differences in property rights protection determine market results and the investment incentives for seed producers.

In the second period, the seed producer will maximize the following profit function with respect to the price of corn (A) and soybean (B),

$$\pi = \delta p_A q_A + \gamma p_B q_B - e(q_A, q_B) \qquad (3)$$

where $e(q_A,q_B)$ is the commercialization cost of the new varieties;
δ and γ are the degree of appropriation the seed company has in the market for each seed. We assume that $\gamma \in [0,1]$ and $\delta \in [0,1]$. That is, if any of these parameters are close to zero, that means that intellectual property protection and enforcement is very weak since the company cannot obtain any profits from releasing the new varieties in the market. Otherwise, if δ and γ are equal to one, then intellectual property protection and enforcement is perfect, and the company will obtain full monopoly profits from the seed market in the absence of non-infringing alternatives. Replacing the demand equations into the profit function, the firm will maximize profits with respect to the price of both seed varieties

$$\pi = \delta p_A q_A(p_A) + \gamma p_B q_B(p_B) - e(q_A(p_A), q_B(p_B)) \tag{4}$$

the first order conditions are,

$$\begin{aligned} \frac{\partial \pi}{\partial p_A} &= \delta\left(q_A + p_A \frac{\partial q_A}{\partial p_A}\right) - \frac{\partial e}{\partial q_A}\frac{\partial q_A}{\partial p_A} = 0 \\ \frac{\partial \pi}{\partial p_B} &= \gamma\left(q_B + p_B \frac{\partial q_B}{\partial p_B}\right) - \frac{\partial e}{\partial q_B}\frac{\partial q_B}{\partial p_B} = 0 \end{aligned} \tag{5}$$

From these conditions, we can obtain the prices (p_A^*, p_B^*) and quantities (q_A^*, q_B^*) at equilibrium. These variables will depend on the level of intellectual property rights (IPR) in the market and on the parameters of the model. As we can see, in this stage the price and quantities offered in each market do not depend on each other. That is, we assume that the markets for seeds can be separated by the seed producer.

First period investment

In the first period, the seed producer will determine the research effort and resources devoted to provide a new variety. In particular, the producer will be interested in producing a variety of seed at a quality level that maximizes profits. Accordingly, the

profit function in the first period takes into account the market profit in the second period plus all the costs associated with the development of the new varieties.

$$\Pi_A = e^{-pt} p_A^* q_A^* - c(\delta, s_A(A_A), A_A, A_B, b)$$
$$\Pi_B = e^{-pt} p_B^* q_B^* - c(\gamma, s_B(A_B), A_A, A_B, b) \quad (6)$$

where the prices and quantities are derived from the maximization problem in the second period. The seed producer will maximize the present value of profits with ρ being the discount rate. The cost function depends on the effort level associated with each variety s_A and s_B, the quality of each seed, which can be associated with previous knowledge and other specific factors for each seed, and finally, b, which is a cost of entering the market for new varieties. In this case, we assume that the firms will adjust the level of effort s for each variety accordingly to the level of intellectual property protection and enforcement in the market. As a result, we assume that the level of property rights protection will positively influence the level of effort. Another assumption is that because the varieties can use common knowledge, the factors that determine the level of investment in one variety will have an impact on the other variety. The first order condition for profit maximization is given by,

$$\frac{\partial \Pi_A}{\partial A_A} = e^{-\rho t}\left[\frac{\partial p_A^*}{\partial A_A} q_A^* + \frac{\partial q_A^*}{\partial A_A} p_A^*\right] - \frac{\partial c}{\partial A_A} = 0$$
$$\frac{\partial \Pi_B}{\partial A_B} = e^{-pt}\left[\frac{\partial p_B^*}{\partial A_B} q_B^* + \frac{\partial q_B^*}{\partial A_B} p_B^*\right] - \frac{\partial c}{\partial A_B} = 0 \quad (7)$$

From these conditions, we can obtain the optimal level of quality for each variety, A_A^* and A_B^*, as a function of the level of effort (s_A,s_B), the IPR protection in the market (δ,γ), the fixed cost of entering the market (b), and other parameters of the model.

If we assume linear demand functions and cost functions, we have the following model:

$$
\begin{aligned}
q_A &= Q(A_A, p_A) = \frac{A_A}{B} - \frac{p_A}{B} \\
q_B &= Q(A_B, p_B) = \frac{A_B}{D} - \frac{p_B}{D} \\
e(q_A, q_B) &= e(q_A + q_B) \\
c_A(\delta, s_A(A_A), A_A, A_B, b)) &= \frac{(s_A + \delta)\left(A_A + A_B - b\right)^2}{2} \\
c_B(\gamma, s_B(A_B), A_A, A_B, b)) &= \frac{(s_B + \gamma)\left(A_A + A_B - b\right)^2}{2}
\end{aligned}
\tag{8}
$$

The cost function for the first period investment is divided in two according to the number of new varieties. For variety A, the cost depends on the minimum research effort necessary to obtain the new variety (s_A) plus an extra research effort that depends on the security of property rights (δ). Accordingly, the firm will provide extra seed quality in those markets that have secure property protection, while the research effort will decrease in insecure markets. Finally, in each cost function, we include the research expenses on the other variable (A_B), which has a positive effect on the development of variety A. For example, the seed company can use the same investment, like capital, human resources, knowledge and development with respect to one variety in the development of a different variety.

Based on these functions, first, we solve the maximization problem for the second period of market competition, obtaining the following optimal prices and quantities:

$$
\begin{aligned}
q_A &= \frac{\delta A_A - e}{2\delta B} \qquad & p_A &= \frac{\delta A_A + e}{2\delta} \\
q_B &= \frac{\gamma A_B - e}{2\gamma D} \qquad & p_B &= \frac{\gamma A_B + e}{2\gamma}
\end{aligned}
\tag{9}
$$

As we can see, the price and quantity of equilibrium for both varieties depend on the quality of the seed and also on the extent of IPR protection in the market. In general, higher IPR protection will imply higher prices, and correspondingly, lower quantity of equilibrium, while higher quality of seeds will increase both prices and quantities of equilibrium. Similar to the results from Alston *et al.,* higher IPR protection will have two

effects on the market (Alston and Venner, 2002). On one side, for any given price, higher property rights protection will increase the quality of the variety, and as a consequence, the quantity demanded will increase. On the other hand, because of the higher IPR protection, for any given quantity, the seed producer will be willing to increase market prices. This increase in prices will decrease the demand for the new variety. Accordingly, the introduction of more secure intellectual property rights will have two different effects. First, a positive impact on prices which will increase because of the monopoly power. Second, the the quantity of equilibrium can increase or decrease depending on whichever effect is bigger, i.e., the increase in quantity because of the better quality compared to the decrease in quantity demanded because of the higher price (Alston and Venner, 2004).

In order to calculate the optimal investment in the first period, we replace the optimal values for prices and quantities in the profit function (6). Taking derivatives with respect to A_A and A_B, equalizing to zero and solving, we obtain the following optimal investment:

$$A_A = \frac{2B\left[(s_A+\delta)A_B-(s_A+\delta)b\right]}{e^{-pt}-2B(s_A+\delta)}$$
$$A_B = \frac{2D\left[(s_B+\gamma)A_A-(s_B+\gamma)b\right]}{e^{-pt}-2D(s_B+\gamma)} \qquad (10)$$

Solving for A_A and A_B, we obtain the optimal level of quality for both varieties:

$$A_A = \frac{2B(s_A+\delta)b}{2D(s_B+\gamma)+2B(s_A+\delta)-e^{-pt}}$$
$$A_B = \frac{2D(s_B+\gamma)b}{2D(s_B+\gamma)+2B(s_A+\delta)-e^{-pt}} \qquad (11)$$

Figure 1 shows the reaction functions for the optimal levels of quality in each variety. Assuming everything else is constant, an increase in the quality of variety B decreases the quality of variety A because the producer has to allocate the common resources between both varieties. As a result, in order to increase the quality of one of the varieties, the firm

has to decrease the resources allocated to the other one. The optimal level of investment, and consequently, quality of varieties, is reached when both curves cross. At this level, the seed producer company is generating two varieties with a quality level that maximizes profits.

From the optimal quality of each variety, equation (11), we can observe that an increase in the level of apropiability in the market of the given variety will increase the level of quality and investment in this variety. Nonetheless, this increase in appropriability will decrease the level of investment in the other variety since now it is more profitable to invest resources for research and development in the first one. This result is very important, since we show that insecure property rights have an impact not just on the specific market for a given variety, but also on the market for other varieties produced by the seed company. As Figure 2 shows, an increase in intellectual property rights protection in the market for new variety A produces an increase in the investment in variety A and a decrease in the level of investment in variety B, given that the level of appropriability in this market is kept constant. Observe that if the increase in appropiability is the same in both markets, then the firm would increase the quality of both varieties in the same proportion. Changes in the minimum level of effort to produce a given quality will have the same effect as changes in appropriability. Similarly, an increase in the minimum level of investment to access the market, the level of excludability, b, will produce an increase in the level of investment in both varieties.

Figure 1: Reaction Functions of Research and Development in New Varieties

Figure 2: Effect of a Change in Property Rights on Research and Development

Summarizing, the level of quality of a given seed depends positively on its own market appropriability, entry costs and research effort, while it depends negatively on the market appropiability and research effort of other varieties produced by the seed company. As a result, we have established a relationship between property rights in markets and incentives for research and development, and also the effect that these factors have on R&D in other varieties.

Case Study: Property Rights in Argentina and the United States

From the model in the previous section, we have the following implications for market results that we will test with a case study of the markets in Argentina: First, increases in market appropriation will increase investment in all varieties only if the increase in appropriation is similar for all market varieties. Second, if the changes in appropriation affect just the market for one variety, then investment for this variety should increase, while investments for other varieties should decrease. Third, more secure intellectual property rights will lead to higher market prices for new seeds and higher quantity of new seeds. Nonetheless, the actual quantity sold in the market should decline if the effect on quantity of improved quality is smaller than the negative effect on quantities from higher prices. Finally, we should observe productivity gains for higher investment in varieties with more secure property rights.

Accordingly, in this section, we provide a description of how the regulatory system has evolved in Argentina. Based on the evolution of the regulation and the incentives it has generated over time, we use this empirical evidence to evaluate our theoretical model. We use the United States regime as a standard for comparison with Argentina.

Seed Protection in the United States

In order to analyze the Argentine case, we should take into account the main characteristics of what we meant by an environment in which property rights are well-enforced. Thus, we take the case of property rights protection in the United States as such an example, and as our point of comparison with Argentina (Janis and Kesan, 2002).

The intellectual property rights protection regime in the United States is one of the friendliest in the world for biotechnology inventors (Janis and Kesan, 2002 and Fernandez-Cornejo, 2004). Seed producers can protect their inventions with a range of IP regimes—PVP certificates[6], the Patent Act of 1952[7] as in the case of any utility patent,

[6] "Plant variety protection is also know a fixture of U.S. law, the U.S. PVPA having been enacted in 1970 after only the briefest of debate."

and trade secret protection. Furthermore, the Supreme Court has reinforced the role of patents for plants, by allowing the use of utility patents for biotechnology in the key case of Diamond vs. Chakrabarty in 1980[8], and specifically for plants in the recent case of J.E.M. Ag Supply v. Pioneer Hi-Breed Int'l Inc. in 2001.[9] As a result, we have a system in which property rights are well-defined and enforced, and researchers can choose the level of protection they consider adequate to effectively protect their inventions in the market.

Seed Protection in Argentina: Changes in Legislation

The Argentine legal framework governing new seed varieties has evolved over time increasing the protection for researchers. The first law in this regard was enacted by Congress in 1935 (INASE). Although this legislation provided for the registration of new seeds and required government approval for new varieties to be introduced in the market,

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"[W]hen the Clinton Administration finally submitted the 1991 text of the UPOV treaty to the Senate for ratification, the Administration emphasized the benefits of PVPA as a reciprocity vehicle. The United States did eventually join the UPOV, perhaps guaranteeing the continued existence of the U.S. PVPA in some form."
Kesan and Janis, 2002, at 742, 745.
"The Plant Variety Protection Act (PVPA) grants breeders a Certificate of Protection that gives them exclusive rights to market a new plant variety for 18 years from the date of issuance. These exclusive rights are subject to a research exemption and a farmer's exemption."
"The *1994 amendment to the PVPA*, which went into effect in April 1995, brought the PVPA into conformity with international standards established by the International Union for the Protection of New Varieties of Plants and allowed the United States to ratify the 1991 International Convention for the Protection of New Varieties. Protection provided by Certificates of Protection extended from 18 to 20 years for most crops." Fernandez-Cornejo, 2004, at 19.

[7] "The *Patent Act of 1952 (PA)* extends patent rights to agricultural innovations under a much more general category that includes "any new and useful process, machine, manufacture, or composition of matter, or any new and useful improvements thereof." Patent protection under the PA covers agricultural machinery, equipment, chemicals, production processes, and similar inventions, and is termed "utility patent protection." More importantly, the PA's broad definition of what may be entitled to patent protection leaves an important opening for covering innovations in biotechnology and genetic engineering." Fernandez-Cornejo, 2004, at 19.

[8] Diamond v. Chakrabarty, 447 U.S. 303 (1980)
"In Chakrabarty, decided in 1980, the Court ushered in the age of biotechnology patenting, holding a 5-4 split that genetically-modified bacteria fell within the scope of patent-eligible subject matter." Kesan and Janis 2001, at 7.

[9] J.E.M. Ag Supply v. Pioneer Hi-Breed Int'l., Inc., 122 S. Ct. 1600 (2002)
"In a 6-2 decision handed down in December 2001, the US Supreme Court has confirmed that plants are eligible subject matter for protection under the utility patent regime, notwithstanding the existence of limited forms of intellectual property protection for plants under the Plant Patent Act (PPA) and the Plant Variety Protection Act (PVPA). The case J.E.M. Ag Supply v. Pioneer Hi-Bred, endorsed a longstanding practice of the US Patent and Trademark Office (PTO), under which the PTO has issued hundreds of utility patents on plants since 1985." (Janis and Kesan, 2002b, at 1161).

it did not provide any legal basis for intellectual property rights in new seeds (INASE). In the following decades, different governments created diverse agencies that were put in charge of managing the regulatory system (INASE). In 1973, the Military Government passed the Decree-Law 20,247 called the "Law of Seeds" (SAGyP). This was the first piece of legislation that gave commercialization rights to the inventors of new seed varieties.[10] Although this law was a step forward to protect intellectual property rights, it was not immediately enacted, and it has to wait until 1978 for implementation. It also provided for the creation of the National Seed Commission (Comision Nacional de Semillas, CONASE) in charge of advising and evaluating the government policies regarding the regulatory regime.[11] Second, it created a national registry for new varieties and a property registry for new varieties, providing exclusive commercialization rights to the owners for a term between 10 and 20 years, depending on the type of seed (INASE). This system of registration of varieties implied a two step procedure: the inventor of a new variety should register the variety in the National Variety Registry[12] and then apply for a property certificate to be included in the National Registry of Property of Varieties.[13] Third, it provided for recognition of foreign seeds, but it established that the country of origin should provide similar protection for Argentine researchers. Furthermore, the term of the IP rights was limited to the number of years left in the country of origin of the variety.[14] Fourth, the Executive Power could declare a new variety to be of "restricted public use" implying that the owner of the variety should be

[10] The article 22 of the law said: "The property right of a variety will be given for a period no less than 10 and no more than 20 years, according to the type of plant and the regulations." Law 20,247, INASE.
[11] Article 5: "The Commission will be formed by ten members designed by the Ministry of Agriculture and Livestock. …Five of the members will be State representatives, two from the National Agency of Agriculture Control and Commercialization (Direccion Nacional de Fiscalizacion y Comercializacion), two from the National Institute of Agriculture Technology (Instituto Nacional de Tecnologia Agropecuaria) and one from the National Grain Board (Junta Nacional de Granos). Five other members will represent the private sector, one from the seeders, two from the seed traders and production and two from the seed users. The Ministry of Agriculture and Livestock will name the president and vice-president from the members of the Commission." Law 20,247, INASE.
[12] Chapter IV of Law 20.247 provides the regulations for the registration of new varieties in the Registry. Law 20,247, INASE
[13] Chapter V of Law 20.247 provides the regulations for requesting the property rights in new varieties and its registration in the National Registry. Law 20,247, INASE.
[14] Article 26: "The property title requested for a foreign variety should be done by its inventor or legally authorized representative established in Argentina, and it will be granted only if the country of origin of the variety has similar property right protection for Argentine invented varieties. In such cases, the term of the property will be up to the term that is left in the country of origin for the same variety." Law 20,247, INASE.

compensated by the state and ownership of the variety should be transferred to the Ministry of Agriculture.[15] Finally, the law recognized the farmers' rights to use seeds saved from a previous crop, and researchers' right to use protected seed varieties to develop a new variety.[16] As a result, the first legal registration of new varieties in the country started in 1978, after the law was enacted by the Executive Power Decree 1995 of 1978 (Decree 1995/78, SAGyP). This decree was proposed by the CONASE, (CASEM, 1999) and slightly modified by Decree 50/89 (Decree 50/89, SAGyP). Nonetheless, this legislation did not provide enough protection and enforcement of intellectual property rights for new seed varieties since its regulations are similar to the PVP certificates in the United States.

A modification to the 1978 Decree was enacted in 1991, introducing important changes to the regulatory regime and updating the legislation according to international standards. The Executive Power issued Decree 2183/1991 on October 21st 1991 (Decree 2183/91, SAGyP). This modification to Law 20,247 had its origin not just on the need for modernization of property rights legislation, but also on the political pressure exerted by some associations of seed producers and other interest groups inside CONASE like the Argentine Seed Association (ASA) and Association for the Protection of Plant Breeders (ARPOV).[17] Among the main changes, we find the following: First, CONASE

[15] Id., Article 28, but Article 29 limited the use of such right to two years, but the Executive Power could extend it for other two years.

[16] Article 25: "The property of a variety does not prevent that other persons could use the variety for the creation of a new variety, which could be claimed by its creator without the consent of the owner of the original variety used in the process of creation…" *Id*.
Article 27: "The property right of a variety is not affected if the seed is given by authorization of the owner, or somebody saves and sow seeds for his/her own use, or use or sell as primary product or feeding the seed obtained from the crop of the variety." *Id*.

[17] "ASA, which has been in operation for 54 years and groups together the 67 main seed companies, and ARPOV, set up more recently, are the bodies which deal with sectoral union activity and work for the technological development and protection of phytogenetic creations. ASA, which is member of CONABIA, since it was set up 11 years ago, has played a major role in the discussion of the regulations which Argentina now possesses for the commercial release of a transgenic event.
Three years ago, the Association of Agricultural Technology Chambers (ACTA) was set up and groups together the sectors providing technological material for agricultural production, seeds (ASA), agrochemicals and fertilizers (Chamber of Plant Health and Fertilizers –CASAFE), veterinary products (Chamber of Veterinary Producers – CAPROVE) and agricultural machinery (Association of Tractor Manufacturers – AFAT), which has been acquiring major importance in agro-industrial production activities, and is the most important in Argentina.
As a result of the work of those institutions, Argentina acceded to the 1978 Act of the UPOV Convention and discussions regarding accession to the 1991 Act of the UPOV Convention are very advanced." Domingo, 2003, at 11.

continued to be an advisory committee to the Secretary of Agriculture[18] and other specific agencies created by this Decree.[19] Second, a new agency, the National Seed Service (Servicio Nacional de Semillas, SENASE) was created to be in charge of managing and enforcing the regulatory regime for new varieties.[20] As a result, all the activities concerned with the management of the system were concentrated in a specific government agency instead of being dispersed among different secretaries inside the Secretary of Agriculture. Accordingly, this change would allow the government to focus on enforcement and definition of rules and norms for the market of new varieties. Third, the Decree defines the specific steps and requirements for registration of a new variety and the granting of property rights.[21] Fourth, the Decree also defined the different types of plants that could be registered, including seeds or germ and phytogenetic breeding varieties (Decree 2183/91, SAGyP). Fifth, the special "restricted public use" right of the Executive Power was preserved (Decree 2183/91, SAGyP). Finally, the use of saved seed is restricted only for research purposes and for the farmer's privilege.[22] Nonetheless, the Decree 2817 of December 30th 1991 created the National Seed Institute (Instituto Nacional de Semillas INASE) which replaced the SENASE in the management of Law 20,247 (Decree 2817/91, SAGyP). This agency is in charge of the national registry for varieties and property of seeds and the enactment of rules regarding the management of the system and the enforcement of the regulations of the law (Decree 2817/91, SAGyP). By creating this new agency, the government sought to improve enforcement and control of property rights in new varieties.

"One of the main achievements of the process, initiated in 1990 and completed and consolidated with the creation of INASE, was to make more transparent the commerce of self-pollinating seed species, particularly soybean and wheat, where the legal market for these species reached just 25% of the total demand of seeds.

This meant that most of the market for seeds had no guarantee of identity and quality, there was a high degree of tax evasion and there was no recognition of the

[18] In this text "Secretary of Agriculture" and "Ministry of Agriculture" are the same, since the Ministry of Agriculture was renamed to Secretary of Agriculture in the early 1990s. Nonetheless its role in the government continue to be the same.
[19] Chapter II of the Decree 2183/91 established the role of the CONASE, *supra* note 49
[20] Chapter III of the Decree 2183/91 established the main activities for the Servicio Nacional de Semillas, *Id.*
[21] Chapters V to VII of the Decree 2183/91 describe the procedures for registration of new varieties, *Id.*
[22] The Article 41 of the Decree 2183/91 establishes the different cases in which authorization from the owner of the variety is needed, (Decree 2183/91, SAGyP).

property rights of the inventors of varieties registered in property giving as a result a disincentive to invest in new varieties …" (INASE, at 15)

However, as we show in this article, this kind of property right protection has not been useful to protect the soybean seed market from brown-bagging and even stealing.[23]

In contrast to CONASE, INASE's only role is the management and enforcement of the different issues concerning commercial rights on seeds, although the same constituencies that formed CONASE were represented in this agency (Decree 2817/91, SAGyP).

With respect to the farmer's privilege, the INASE issued the Norm 35/96 INASE on February 1996 defining the limits and scope of this privilege that was broadly established in Law 20,247 (Norm 35/96 INASE, SAGyP). This Norm tried to limit the application of farmer's privilege to specific cases where the farmer actually saves some seed for the next crop, thus limiting the scope of saved seed established by Article 27 of Law 20,247, which allowed other uses for saved seed (Article 1 Norm 35/96 and Article 27 Law 20,247, INASE). It established specific rules for saved seeds to be considered under this privilege. For example, the main condition for being considered under this rule are: The solicitor should be a farmer, who should prove that the original seed was legally bought, that the saved seed was obtained from the originally legally bought seed, that the saved seed should be specifically set aside and identified from other varieties and the purpose of use is for it to be sown by the farmer, prohibiting any transfer or sale of the saved seeds (Article 1 Norm 35/96, INASE). As a result, the norm increased the difficulty for farmers to save seed for other purposes thereby trying to control the trade of non-legal varieties.

In 1994, the Law 24,376, enacted on September 21, 1994 modified the Law 20,247 and its Decrees (Law 24,376, SAGyP), bringing the legislation in conformity with the guidelines set by the International Agreement for the Protection of the Vegetal Obtentions (UPOV/78), approved in Paris (France) in 1961 and modified in Geneva

[23] "A group of Argentine seed companies and breeders, called the Argentine Association for the Protection of Plant Varieties, in cooperation with the government, have had an effort under way since 1990 to enforce the law and limit the sale of uncertified seed on the black market. The effort helped reduce black market sales from about three-quarters of all soybean seed sales in 1992 to about half in 1994. However, according to Argentine industry officials, black market sales subsequently increased in response to higher prices for

(Switzerland) in 1972 and 1978 (UPOV). This Law approved the UPOV agreement and established that the clauses of this agreement should prevail over the regulations of the Law 20,247 and its regulatory Decrees (Law 24,376, SAGyP). The changes with respect to the previous legislation are not too relevant, except for the political decision of being part of the UPOV international agreement (Law 24,376, SAGyP). Nonetheless, the approval of the UPOV 1978 guidelines is not as complete as the more recent UPOV 1991 agreement, which has not been approved in Argentina.[24]

Recently, due to the economic crisis in the country, the Secretary of Agriculture closed the INASE, leaving the regulatory regime for new varieties without any management.[25] The Institute was opened again in 2004 (Pirovano, 2004).

The evolution of the legislation in Argentina has focused on the development and improvement of Plant Variety Protection type of intellectual property rights without any advance in the field of utility patent protection for new varieties. As a result, the level of protection established by PVP regimes is weak in the case of plants like soybean, where a utility patent provides better property rights protection. Nonetheless, PVP protection can be adequate for the commercialization of hybrid varieties such as corn. As we mentioned before, this difference in actual market protection will be a key to test the main hypothesis of our model. In the next section, we provide empirical evidence on the functioning of the seed market in Argentina and compare these results to the empirical implications derived from our model.

Research Effort

According to our model, an increase in property rights protection should increase the incentives for research and development of new varieties. In the Argentine case,

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commercial seeds following the initial marketing of Roundup Ready soybean seeds in 1996." GAO, 2000, at 14-15

[24] *See*, http://www.sagpya.mecon.gov.ar/ (for the evolution of legislation and the adoption of the UPOV 78 treaty).
See also, http://www.proyectonacion.entupc.com/proyectosart/proteccion_legas_obtecion_vegetales.htm (describing a bill presented this year in Congress by Congressmen Eduardo Di Cola proposing the adoption of UPOV 91).

[25] "The National Seed Institute (INASE) was reinstated after three years of inactivity. In 2000 the GOA dissolved the INASE due to a lack of budget. On January 6 2004 the INASE was reactivated. Its main goals are: to assure quality and proper identification of the seed to be marketed, to promote the supply of improved varieties through the protection of their property rights, to foster production and marketing of planting seeds as a way to improve crop production in Argentina." Pirovano, 2004, at 4.

since the enactment of new legislation in the 1990s could induce a better environment for research in the case of corn as opposed to soybeans, we should observe that the registration of new varieties in corn in Argentina should surpass the number of new soybean varieties (see Graph 2). As we can see, after 1991, there is a sharp increase in the number of new corn varieties, while new soybeans varieties registration stood at low levels. The increase in the registration of soybean varieties in 1996 is mainly due to the government allowing the registration and commercialization of genetically modified varieties (Domingo, 2003). From 1995 to 2003, 21.2% of the new corn varieties registered were transgenic, while for soybean, the percentage reached 61.5% during the same period (Domingo, 2003). The decrease observed after 1998 is mainly due to the economic recession and crisis, and the fact that the government closed the INASE because of lack of budget resources from 2000 to 2004.

If we compare this situation to the United States, where property rights are better defined and enforced for both corn and soybean, the registration of new varieties is similar for both corn and soybean (see Graph 3). As predicted by our model, this is an indication that differences in appropriation in the market generate disparate incentives for research and development.

Consumption of Seeds, Production and Yields

More secure property rights have some effect on market transactions. First, there is an increase in the price of the variety whose property right is enforced as compared with the other variety. In the case of Argentina, we should observe a higher price for new corn seeds compared to soybeans since the producers of corn seeds can exploit monopoly rights in the market. We compare Argentina's seed prices with respect to prices in the U.S., where property rights are similar in both markets (see Table 4). As we can see, prices for corn varieties were at a high price in the 1990s close to prices in the United States, while at the same time, we observe an increase in the number of new corn varieties. This is an indication of the monopoly power of seed producers, since they could charge international prices while the number of competing seeds increased. The case of soybean is different, where we observe much lower prices in Argentina compared to the U.S. In this market, seed producers could not reap monopoly benefits because of

the lack of adequate property rights protection. Therefore, the price for soybean varieties declined, despite the fact that the number of new varieties is much lower for soybean compared to corn and, as we will explain next, there was a boom in the production of soybean.

Graph 2: New Seeds Registered: Corn and Soybean

Graph 3: New Varieties, United States

This evidence is in accordance with the conclusions of our theoretical model, since seed prices tend to be higher in the market where property rights are better protected and the supply of new varieties will also be higher in this market. The lack of protection in the market for seeds has generated an important "black market" for soybean seeds, which has reduced the prices of soybean seeds (see Table 5). For example, around 80% of the acreage planted with soybean in Argentina is Roundup-Ready soybean that is produced by Monsanto, while the percentage of legally sold soybean reaches between 28 and 50% (see Table 5). Legal sellers of Roundup-Ready soybeans had to adjust their prices to this black market. In 1997, when Roundup-Ready soybean was introduced, the price of a 50 lb bag was $25 as compared to the price in the black market of $15. By 1999, the legal price had dropped to $9 very close to the price in the black market, which was a little lower (GAO, 2000). As a result of the lack of adequate intellectual property rights protection, in late 2003 and early 2004, Monsanto stopped selling Roundup-Ready technology in Argentina and also stopped developing new varieties in the country.

What we should explore now is whether the higher price that farmers had to pay for new corn seeds has paid off in terms of improvement in crop yields for corn (see Graph 4). As we can see in 1990, corn yields in Argentina were 54% of the yield in the United States, while in 2002 that ratio increased to 79.2%. This important increase in yield is an indication that the higher investment in research and development in corn varieties in Argentina had a positive impact on productivity. However, we do not have data on quantities sold in the market for seed in order to calculate if there was a higher or lower demand for seeds.

As for the case of soybean, there is not much difference in yield between Argentina and the U.S. In 1990, yields in Argentina were the same as in the U.S., and they are still the same in 2002.[26] The fact that yields are the same in both countries despite the low investment in the development of new varieties in Argentina is a result of the advances in research for soybean which has not led to an increase in yield but has instead focused on other characteristics of the seed, like herbicide resistance.

Table 4: Agricultural Seed Prices in Argentina

Table 5: Sources of Soybean Seeds

Graph 4: Yields in Argentina and United States

Crossed Research Effort

One of the most important implications of our model is that differences in property rights protection for one variety should have an impact on the research effort in the other variety. In this case, because property rights are better protected in the market for corn seeds, we should observe that firms in Argentina would specialize in the production of corn seeds as opposed to soybean. This specialization would lead to an overproduction of new corn varieties compared with a situation when intellectual property rights are equally well-defined and enforced in both markets.

Again, we will consider the United States as a yardstick for comparison with Argentina. If we compare the number of new soybean varieties registered in Argentina vs. the United States, we see that during the 1990s, the number of new varieties in the United States increased, while in Argentina, they stayed at low levels (see Graph 5). From 1979 to 2002, there were 339 new varieties of soybean registered in Argentina, compared with 879 in the United States, implying that Argentina had only 38% of the varieties registered in the United States. From 1991 to 2002, the new varieties registered

[26] "Soybean yields in Argentina are quite the comparable to yields in the U.S. We asked nine experts about soybean yields and the lack of seed production investment in Argentina. Eight of the nine respondents stated that while at the present time the effects of lack of soybean testing and quality control are not obvious, in the future problems would become evident." Goldsmith, 2001, at xii.

in Argentina were 254, while in the United States this number reached 573. In this case the number of varieties registered in the 1990s in Argentina represented 41% of those registered in the United States. The increase in the number of varieties registered after 1996 in Argentina appears to track the improved IP protection for genetically modified varieties for soybeans, which gave a boost to the research in this kind of varieties in the country. As a result, we can conclude that the higher level of corn varieties registered in Argentina, compared to the United States, and the lower level of soybean varieties registered in Argentina provides evidence concerning the research processes inside each firm. Accordingly, seed producers devote most of their resources to research and development in markets that are better protected by property rights, transferring resources from other varieties with low levels of protection.

In the case of new corn varieties, the situation is totally different (see Graph 5). From 1979 to 2002, there were 930 new varieties of corn registered in Argentina, compared with 670 in the United States, implying 38% more registrations in Argentina. From 1991 to 2002, the new varieties registered in Argentina were 713, while in the United States, this number reached just 505. This implies that there were 41% more varieties registered in Argentina.

Graph 5: New Seeds Registered: Soybean

Graph 6: New Seeds Registered: Corn

It is interesting to notice the boom in the registration of new varieties in the 1990s compared with the United States, which was in part a result of the incentives for private firms to invest in corn as compared to soybean. This evidence is in accordance with the implications of the theoretical model. As we have shown, differences in intellectual property rights protection in Argentina have led to an excess in investment in new varieties of corn as compared with soybean. Accordingly, private companies, both local and foreign in Argentina, will bias the allocation of their research resources to the production of corn varieties.

Finally, we would like to compare the behavior of foreign and local seed companies. According to many authors, local seed producers in developing countries are not responding to the same incentives when compared to foreign producers. In this case, according to our model, both local and foreign seed producers should face the same incentives for production. As a result, we should observe that both types of producers should specialize in corn instead of soybeans. The evidence shows that both foreign and local producers have followed a similar pattern in the production of new seed varieties (see Graphs 7 and 8). As both graphs show, the registration of new varieties by foreign and local producers followed similar patterns throughout this period. The main difference we observe is that there is a higher number of corn varieties registered by foreign companies and a higher number of soybean varieties registered by domestic producers. This difference could be explained by the lack of adequate intellectual property protection in the market for soybean. As a result, foreign companies may choose not to offer their varieties of soybean in the local market (Goldsmith *et. al.,* 2002). And, as our model predicts, they will switch to corn varieties instead. Nonetheless, it could be the case that for local producers their base market for soybeans is the local market, and they have to then supply these varieties despite the lack of adequate property protection. This would result in a slightly higher number of varieties for local producers when compared to foreign producers. That said, we also observe that local producers prefer to allocate their resources to the production of corn varieties instead of soybean.

Graph 7: New Corn Seeds Registered: Foreign and Domestic Companies

Graph 8: New Soybean Seeds Registered: Foreign and Domestic Companies

Using Taxes to Overcome Property Rights Failure

In early 2004, because of the lack of adequate property rights protection and enforcement, Monsanto decided to stop the commercialization of soybeans in Argentina. This decision caused concern to the authorities since Monsanto's Roundup-Ready soybean represents around 95% of the soybean planted in the country. As a result of Monsanto's protests, the government is proposing a tax on farmers' crops. This tax would be distributed among seed producers as a mechanism to compensate for the lack of

property rights enforcement. If we consider the effect of a tax on the price of the seed in our model, we can show that theoretically, the implementation of a tax can be a substitute for the effective protection of property rights. However, the assumptions needed to reach this result are very restrictive creating serious problems for producers' incentives. In order to analyze the effect of a tax in our model, let us assume that the government can successfully implement a tax on variety A, and that this tax represents a percentage of the total amount of seeds sold by the seed producer. As a result, the demand for variety A would be:

$$q_A = Q(A_A, p_A) = \frac{A_A}{B} - \frac{(1+t)p_A}{B} \tag{12}$$

where t is the tax rate as a percentage of the price charged by the seed producer. We assume that the government will distribute the tax directly to the seed producer in the same proportion as the sales in the market. Accordingly, there is no redistribution from one seed producers to others, or to the government. In the second period, the seed producer will maximize the profit function,

$$\pi = \delta p_A\left[\frac{A_A}{B} - \frac{(1+t)p_A}{B}\right] + tp_A\left[\frac{A_A}{B} - \frac{(1+t)p_A}{B}\right] - e\left[\frac{A_A}{B} - \frac{(1+t)p_A}{B}\right] \tag{13}$$

In this case, the seed producer is taking into account the extra revenue the company is receiving from the tax charged to consumers of the seed. From this maximization problem, we obtain the optimal price and quantities, which are replaced in the first period maximization problem in order to obtain the optimal investment in quality.

$$A_A = \frac{2B(s_A + \delta + t)b}{2D(s_B + \gamma) + 2B(s_A + \delta + t) - e^{-pt}}$$

$$A_B = \frac{2D(s_B + \gamma)b}{2D(s_B + \gamma) + 2B(s_A + \delta + t) - e^{-pt}} \tag{14}$$

As we can see, an increase in the tax rate will increase the investment in the quality of variety A and will decrease the investment in variety B. In particular, the optimal tax is when $t=1-\delta$, that is the tax revenue must exactly compensate seed producers for the loss generated by weak property rights. In case the government can find the optimal tax, investment will reach the optimal level as secure property rights. However, compared to the case of secure property rights, consumers' welfare, measured by consumer surplus on the demand function, will always be lower in the case of a tax. This negative result is due to the deadweight loss generated by the presence of the tax. As a result, the implementation of the tax can induce levels of investment closer to the optimal ones under secure property rights, but at the cost of reducing consumers' welfare.

Even though theoretically, the imposition of a tax can increase the level of investment close to the optimal level, there are some caveats to this result. First, nothing ensures that seed producers are going to receive the full revenue from this tax. There is always a chance that part of the revenues is going to be used by the government. This is very different from the secure property rights scenario, where inventors are certain to receive the full "royalty" revenue from the market. Second, even though the government distributes all the revenue to producers, there could be transfers to other producers, and it is not clear how the government is going to determine the exact market share of each producer. Third, a general tax does not discriminate among different users and uses of the invention. Since it seems that there is no particular exemption to this tax, we are in the presence of a compulsory license, which can have important effects on the allocation of R&D resources. Finally, we are assuming that the cost of implementing and enforcing a tax are equal to the costs of enforcing property rights. If that is not the case, then society may be paying higher transaction costs in order to protect property rights.

Conclusions

The effect of property rights' definition and enforcement on biotechnology in agricultural markets is one of the main issues under debate today. Scholars and policymakers debate the pros and cons of different IP regimes. According to the literature, the effective protection of property rights offers adequate incentives for

research and development in a biotechnology market controlled by private firms. This kind of protection was not needed decades ago, when most of the research was in hands of governmental or non-profit institutions. However, in the last few decades, the growth of private research and the consolidation of the private sector in multinational corporations have brought the issue of property rights to the international arena. This article addresses the issue of property rights protection, and the incentives it generates with respect to research and development.

We develop a theoretical model in order to study the effect of property rights on agricultural research effort. Taking off from our model, we then undertake a case study of Argentina and compare its property right regulation and enforcement with the United States. In order to understand the effects of different regulatory regimes from PVP protection to utility patent protection, we analyze the case of corn and soybean. We use the case of Argentina because this is one of the main world producers and exporters of both soybean and corn. It is also a developing country, and we can evaluate whether the behavior of private firms is the same here as compared to developed countries.

From our empirical case study, we obtain the following conclusions. First, increases on market appropriation will increase investment in all varieties only if the increase in appropriation is similar for all market varieties. As we show, change on legislation and increase in enforcement effort in the early 1990s produced an increase in the number of new corn varieties, given that the legal system in Argentina provided for PVPCs for plant innovation in corn. Accordingly, soybean varieties, which need more strict property protection like utility patents, did not experience such an increase in the number of new varieties. Second, if the changes in appropriation affect just the market for one variety, then investment for this variety should increase, while investment for other varieties should decrease. In our case study, we observe that the research and development activities of the private sector in Argentina follow our theoretical model. Because property rights could be protected much better in the case of hybrid crops like corn, there is a higher allocation of resources to the production of new corn varieties, which reached a higher number than in the United States, while the investment in self-pollinated crop like new soybean varieties stagnated, reaching much lower levels than in the United States. This result corroborates the implication of our theoretical model, that

there is a strong relationship in the research process between varieties. That is, an increase in property rights protection in the market for one variety will increase the research and quality of this variety, but it will decrease the quality level of the other one. Third, more secure intellectual property rights will lead to higher market prices for new seeds and a higher quantity of supplied seed. As we show, in the case of Argentina, corn seed prices were closer to prices in the United States because of the higher level of appropriation in the corn market, while prices for soybean are very low, close to the level of the black market, and much lower than United States' prices. This evidence is also in accordance with the results of our theoretical model. Fourth, we should observe productivity gains for the higher investment in the varieties with more secure property rights. In the Argentine case, we observe that the increase in investment in research and development in corn is positively correlated with an increase in yield, producing a convergence to the levels of yields observed in the United States. This allowed the country to increase production and exports, even when there was a substitution from corn to soybean crops because of higher international prices for soybean. Farmers also benefited from this situation since they could buy cheap soybean seeds in the black market and sell their crops in the international market. Fifth, even though foreign companies have the highest share of the market for seeds, we observe a very dynamic domestic seed production sector, which has evolved similarly to their foreign counterparts. This is an indication that foreign and domestic firms face similar restrictions and opportunities offered by the prevailing property rights regime. Finally, resorting to alternative means to protect property rights, for example, the use of a consumption tax on seeds, can increase the level of investment in the market for seeds, but at the cost of reducing social welfare. As a consequence, the implementation of a secure property rights system is a better instrument to foster investment and market development when compared to taxes and government regulations.

From the results of our model, we can conclude that the type and strength of property rights regimes are important for research and development. As has been showed, PVP type of protection may be sufficient for crops like corn, but they are ineffective in the case of self-pollinating crops, like soybean, which need utility patent protection. We found a strong relationship between property rights definition and

enforcement and research effort. More importantly, property rights definition in one market will have an effect on the research effort in other varieties. This result is the key to understanding the complex relationship between property rights and research investment in agricultural markets. Furthermore, our evidence provides important insights for the design of property rights regimes in other countries, both developing and developed ones.

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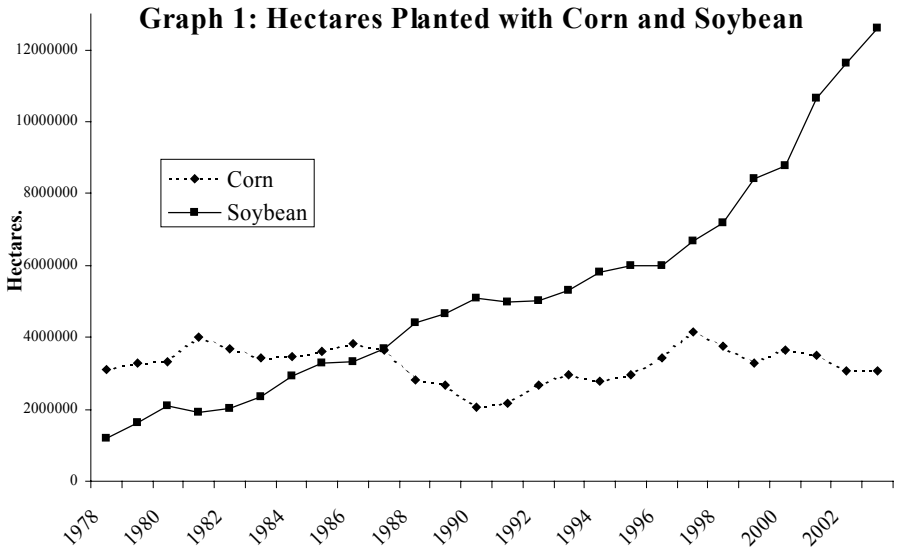
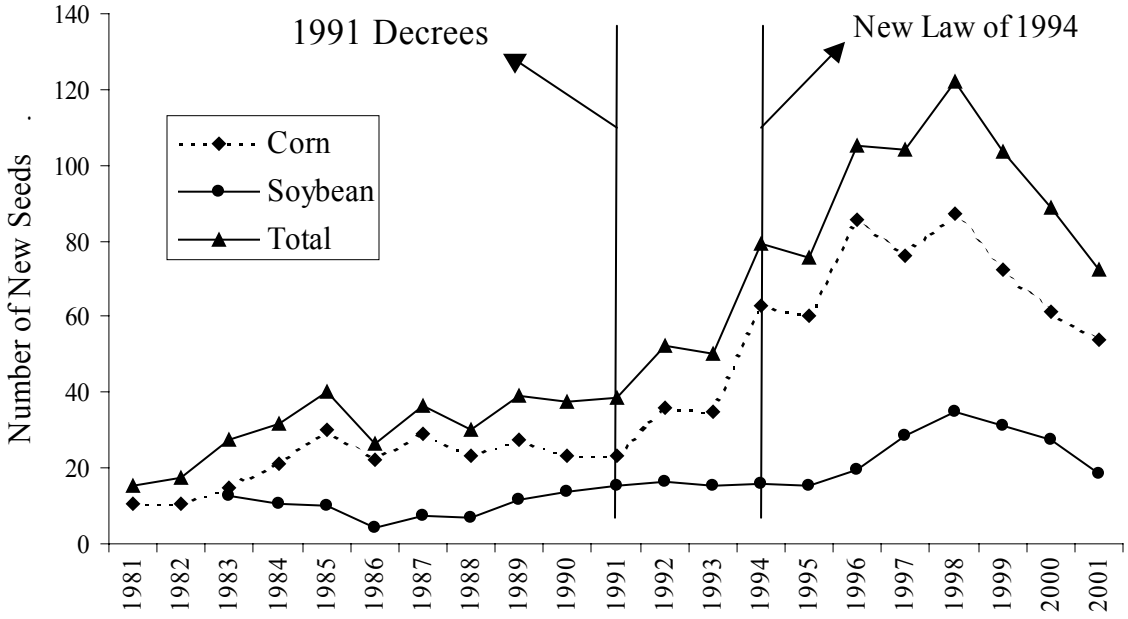


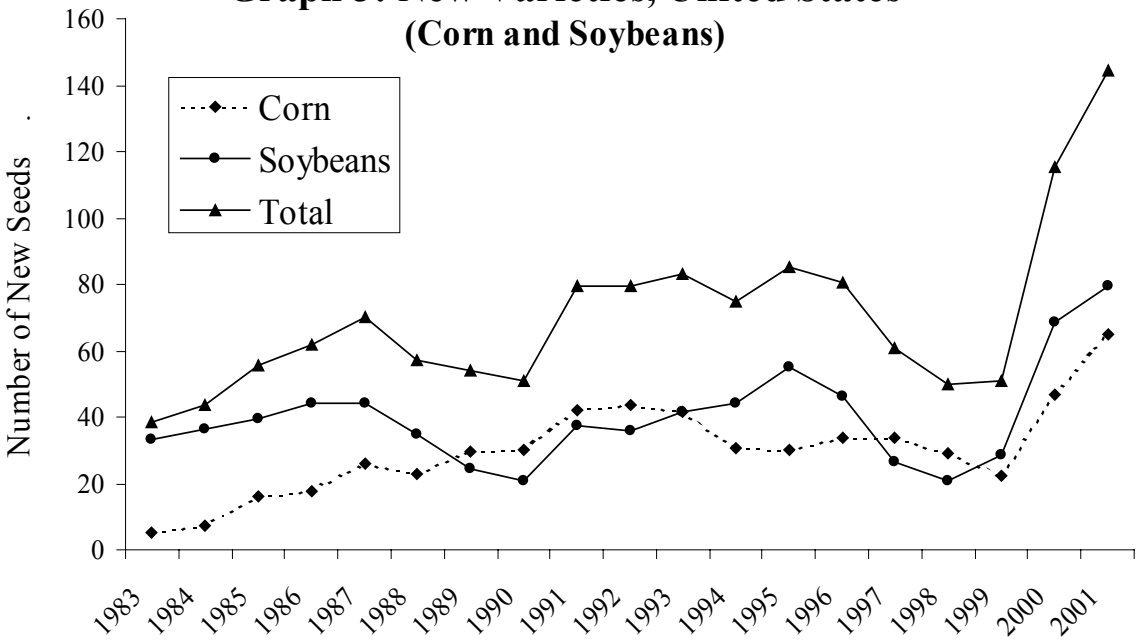
Source: SAGyP, at www.sagpya.mecon.gov.ar

Graph 2: New Seeds Registered: Corn and Soybean

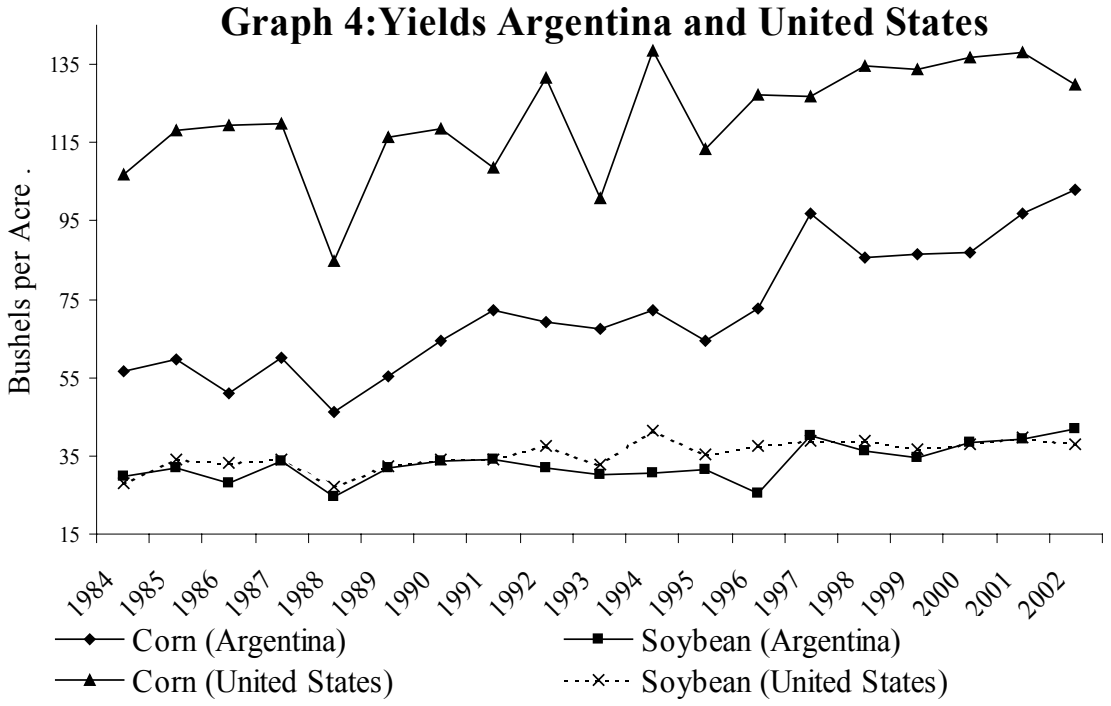


Source: Own elaboration based on data from INASE, at www.sagpya.mecon.gov.ar

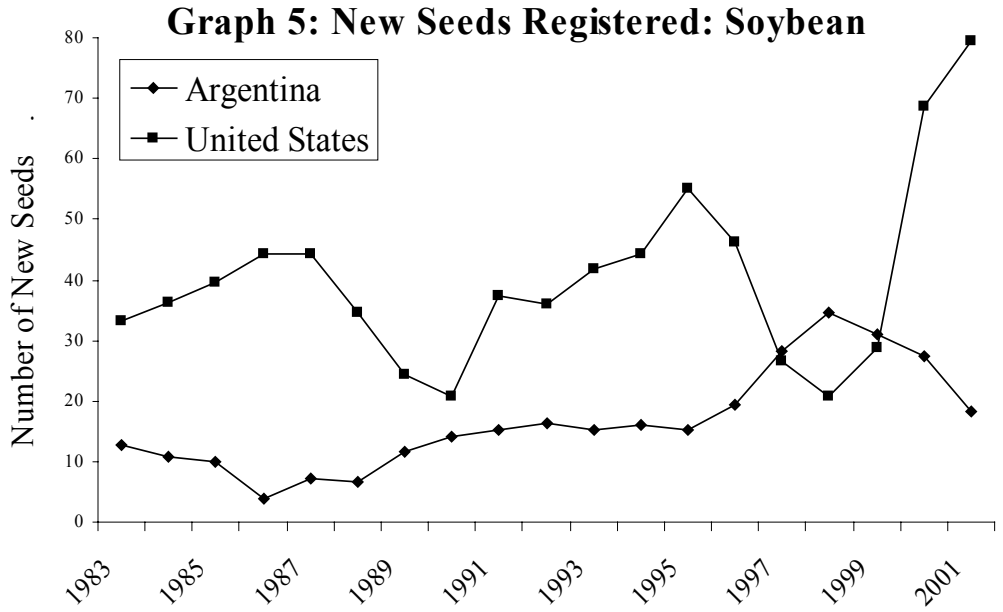
Graph 3: New Varieties, United States
(Corn and Soybeans)



Graph 4:Yields Argentina and United States



Source: Own elaboration based on data from INASE, at www.sagpya.mecon.gov.ar, USDA, at www.usda.gov



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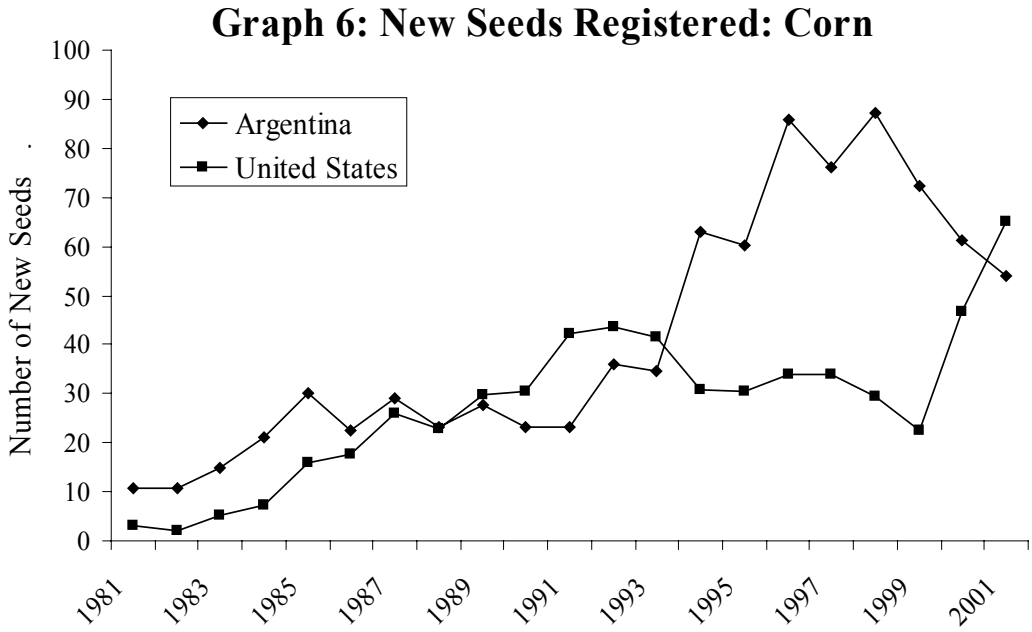
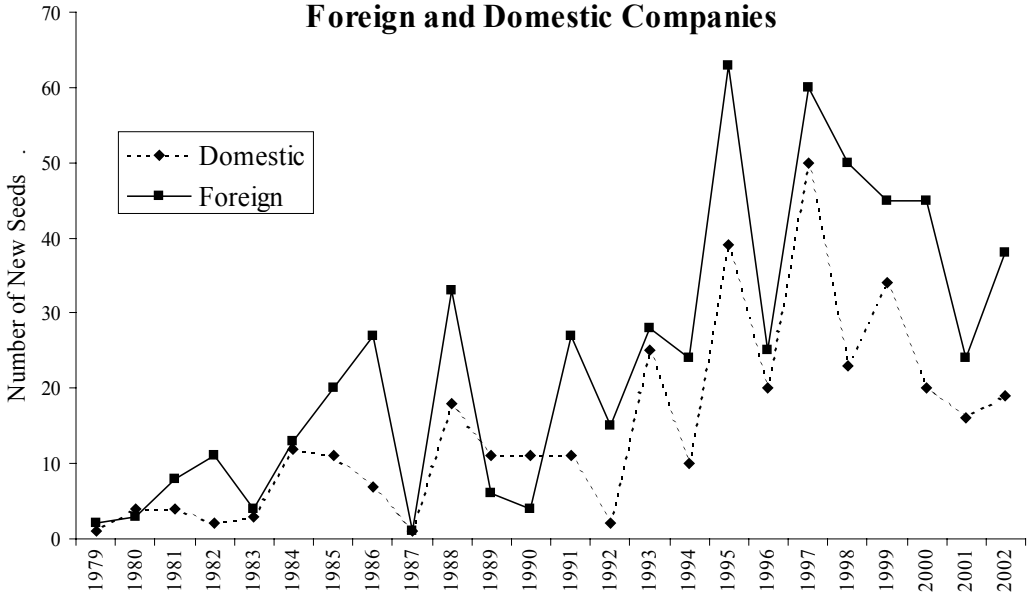


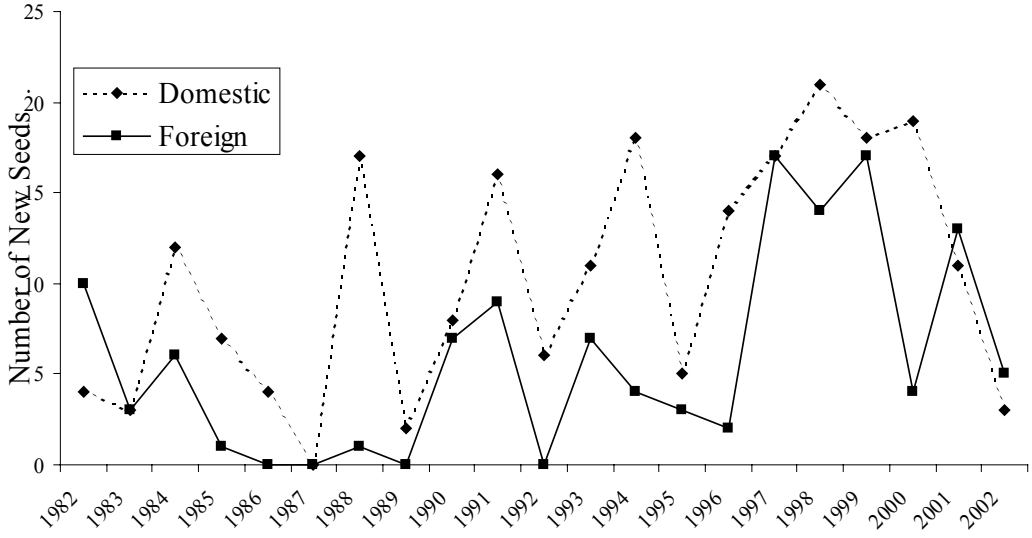
Source: Own elaboration based on data from INASE, at www.sagpya.mecon.gov.ar, USDA, at www.usda.gov

Graph 7: New Corn Seeds Registered
Foreign and Domestic Companies



Source: Own elaboration based on data from INASE, at www.sagpya.mecon.gov.ar, USDA, at www.usda.gov

Graph 8: New Soybean Seeds Registered
Foreign and Domestic Companies



Source: Own elaboration based on data from INASE, at www.sagpya.mecon.gov.ar, USDA, at www.usda.gov

Table 1: International Trade, Corn Exports

Country	1999/2000	2000/2001	2001/2002	Average	% World Exports
		1,000 metric tons			
United States	49,378	48,192	46,917	48,162	64.5%
Argentina	8,859	12,229	8,581	9,890	13.3%
China	9,935	7,276	8,611	8,607	11.5%
Brazil	50	3,741	3,857	2,549	3.4%
Hungary	1,786	730	2,751	1,756	2.4%
South Africa	836	1,415	1,182	1,144	1.5%
Ukraine	55	397	349	267	0.4%
Canada	449	127	211	262	0.4%
Romania	400	50	200	217	0.3%
Thailand	75	407	184	222	0.3%
EU	210	266	70	182	0.2%
Others	1,291	1,590	1,221	1,367	1.8%
Total	**73,324**	**76,420**	**74,134**	**74,626**	**100.0%**

Source: Agricultural Statistics 2003, USDA, at www.usda.gov

Table 2: International Trade, Soybean Exports

Country	1999/2000	2000/2001	2001/2002	Average	% World Exports
		1,000 metric tons			
United States	26,537	27,103	28,918	27,519	52.7%
Brazil	11,161	15,470	15,000	13,877	26.6%
Argentina	4,131	7,415	6,005	5,850	11.2%
Paraguay	2,120	2,550	2,110	2,260	4.3%
Canada	949	747	450	715	1.4%
Netherlands	841	1,090	1,650	1,193	2.3%
Others	944	701	868	837	1.6%
World total	**46,683**	**55,076**	**55,001**	**52,253**	**100.0%**

Source: Agricultural Statistics 2003, USDA, at www.usda.gov

Table 3: Estimated Values of Commercial Markets for Seed

Country	Internal Commercial Market (Million of Dollars)	
United States	5700	23.2%
China	3000	12.2%
Japan	2500	10.2%
Commonwealth of Independent States	2000	8.1%
France	1370	5.6%
Brazil	1200	4.9%
Germany	1000	4.1%
Argentina	930	3.8%
India	900	3.7%

Italy	650	2.6%
United Kingdom	570	2.3%
Canada	550	2.2%
Poland	400	1.6%
Mexico	350	1.4%
Spain	300	1.2%
Netherlands	300	1.2%
Australia	280	1.1%
Hungary	200	0.8%
Denmark	200	0.8%
Sweden	200	0.8%
Other	1967	8.0%
Total	**24567**	

Source: Fernandez Cornejo, 2004, at 8

Table 4: Agricultural Seed Prices in Argentina

Year	Corn ($/80 lbs.)		Soybean ($/50 lbs.)	
1996	78	n/a	15	n/a
1997	84	n/a	16	n/a
1998	87	87	17	11
1999	88	87	17	8
2000	88	65	17	7
2001	92	n/a	21	n/a
Average	86	80	17	9
% U.S. Price		***93%***		***51%***
		GAO Estimate		
Average	95	87	18	11
% U.S. Price		***92%***		***61%***

Source: Goldsmith *et. al.* (2002), at xxii

Table 5: Sources of Soybean Seeds

	Estimated percentage of total soybeans planted	
Source of seeds	United States	Argentina
Commercial sales	80-85	28-50
Farmer-saved	15-20	25-35
Black market sales	0-2	25-50

Source: GAO 2000, at 4

Figure 1: Reaction Functions of Research and Development in New Varieties

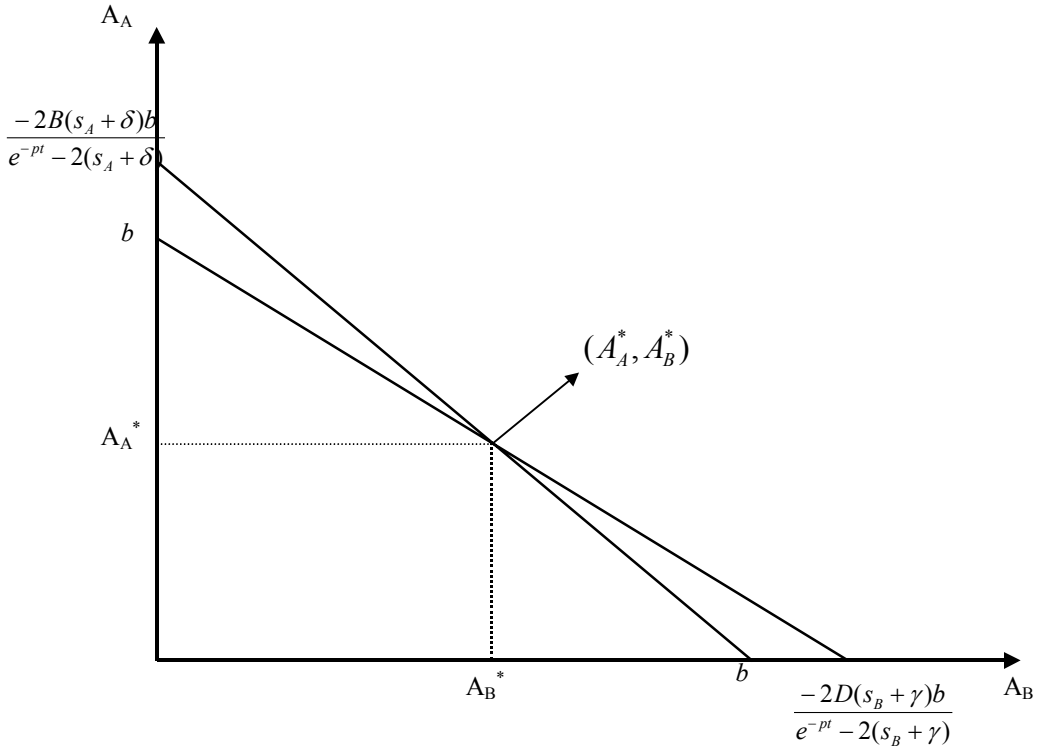


Figure 2: Effect of a Change in Property Rights on Research and Development