Returns from Private Sector Seed Research

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Executive Summary

This paper summarizes several academic papers that the authors have published or are in the process of publishing in peer reviewed academic journals. The conclusions of these papers may be summarized as follows. Stronger intellectual property rights in the seed sector are associated with higher yield growth. Society benefits from stronger IP up to a point; this optimal point is greater than exists for US corn. Other crops have even lower IP protections than US corn and so the case can be made for stronger IP across the spectrum of crops and countries. Consumers always benefit from stronger IP; this is true because IP leads to increased yields and lower commodity prices. Farmers always benefit so long as they differ in regard to the yield impact of new varieties or technologies. This is true because seed companies will optimally charge almost all of the farmers who adopt the new variety a premium that is substantially less than the farmer can expect to earn from adopting this variety. Our very preliminary estimate is that farmers get a $6 benefit for each $1 spent on private sector research.

I. Introduction

The increase in agricultural productivity observed over the two centuries has been a key contributor to the improved standard of living in developed and developing countries. Productivity growth has provided enough food to meet the needs of a growing worldwide population and it has allowed a significant portion of that population to add animal proteins to their diet. This improved productivity has become so consistent and predictable that it has sometimes been taken for granted.

An example of this complacency can be seen in the decisions of several European Union (EU) countries to restrict the use of biotech varieties despite evidence of their success. Another example is that governments throughout the world have implemented import tariffs to restrict the inflow of the inexpensive grains and livestock products that are the result of this improvement in agricultural productivity. This complacency becomes more obvious when one compares the way society treats energy with the way it treats food. Very few countries find it practical to impose tariffs on imported oil and even fewer would restrict access to cars with improved fuel efficiency.

Agricultural land is the textbook example of a fixed resource. Society has, and always will find ways to produce energy from sources other than oil but it has not found any way to produce more land. There are areas in South America and Africa that have the capacity to increase the number of arable acres but there is concern about the carbon that is released when this land comes in to production and the destruction of wildlife habitat that can sometimes accompany the conversion of pasture and forest into farmland.

Now that it has become technically feasible to use land for both food and fuel production the need for improved agricultural productivity has grown. In addition, the rapid increase in incomes in Asia has allowed millions of consumers to simultaneously increase their demand for livestock products. All of these demands can be met if the rate of increase in agricultural productivity can be improved.

This paper examines one important potential source of improvement in land productivity; the improved varieties that are the result of private sector seed research and the property rights that are necessary to incentivize this research. The authors of this paper have been working on this topic for the past decade.

We began this series of papers with the preconception that crop yields were so important that most of our colleagues would agree that more research is better than less research. We quickly realized that this is not the case. There are some in the public sector academic community who view private sector research as both a substitute for, and a hindrance to, public sector research. Our own view is that the needs are so great that public sector work will always have immense value. This is true for both the basic research that has allowed the private sector research to flourish and the applied research that is needed on crops that are grown in areas that are not conducive to private research.

We view the willingness of the private sector to take on some of the applied work in this area as a positive because it allows the public sector to focus on work that is too basic or too specialized for the private sector. We recognize that there are legitimate issues that occur when researchers in the public or private sector claim property rights for results of basic research that then limit the freedom to operate for other researchers. We avoid this issue by focusing our work on the property rights to improved varieties that flow from the applied research that is done in the private sector. We define applied research in this context as any work that the private sector is willing to perform that does not restrict the freedom of other researchers to operate. We view this work as an addition to, and not a substitute for public sector work. In this we are in full agreement with the following one-hundred year old sentiment.

> "I believe, in law, a seedling is regarded as the gift of God, and it would be hard to patent that; but could we not hope to have some law fashioned that would give a bonus to the man who does such skilled and valuable work as that which has come before us over and over again during the sessions of this conference."[1]

We have published five papers, have one paper that has been conditionally accepted and one that is about to be submitted for publication. These papers are provided in the reference section below. Some of the results in these papers are necessarily technical and most of the work was written for an audience of other professional agricultural economists. The purpose of the current report is to summarize the key results of these earlier papers in a way that makes them available to a wider audience. We present the work in a way that is chronologically out of order so that we can lay out the institutional detail as early as possible.

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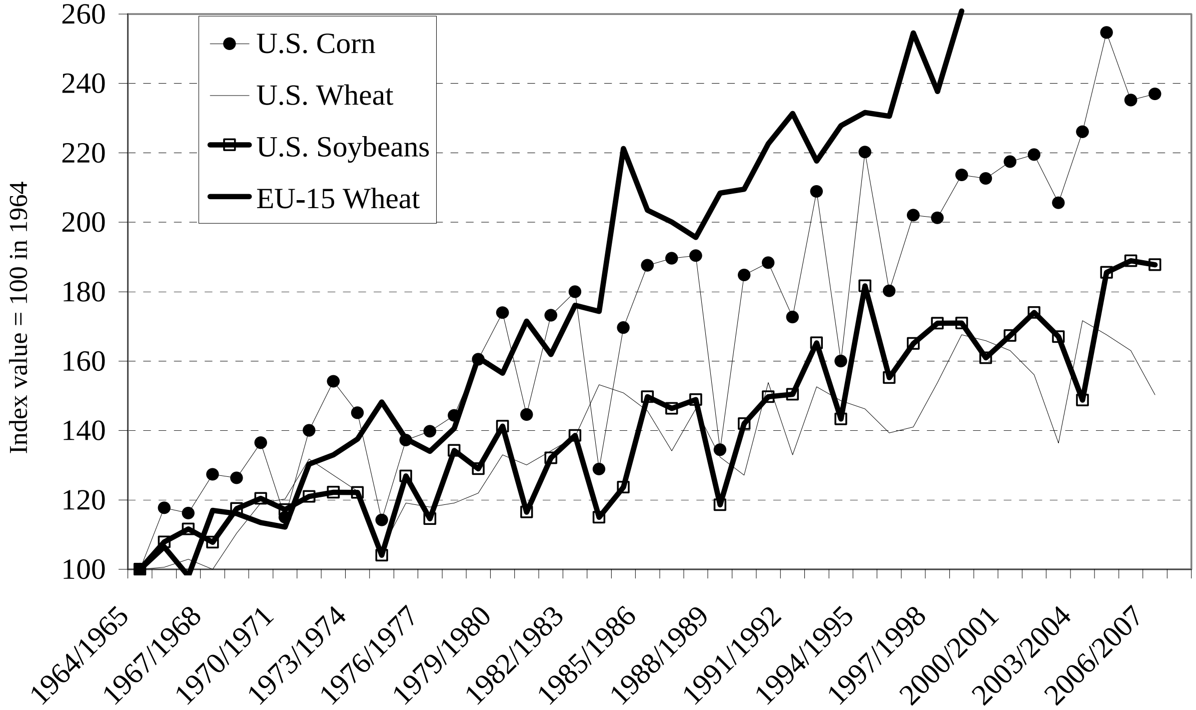
[1]Professor Hansen's comments at the Third International Conference on Genetics, organized by the Royal Horticultural Society, held in London in 1906, and most famous for the coining of the term 'genetics' by William Bateson as described in Dunwell.

II. Institutional Background

The following is based on the paper Lence, Hayes and Goggi that has been conditionally accepted. This paper involved three case studies of which one is discussed in detail below. We quote at length from one of these cases because it helps describe the institutional structure within which seed companies operate in the U.S. and the EU. We use these case studies here because they help explain and document a relationship between the private sector incentive to become involved in seed research and the resulting improvement in yields. In our earlier work we had simply assumed that this link existed, but given the peer reviews we obtained for this earlier work we found it useful to document this link.

The case studies involved corn, wheat, and tomatoes. In these case studies we described the strength of intellectual property protections within which the companies operated and then we related the resulting yield improvement (as measured by genetic gain) to the strength of these property right protections. These case studies indicated (a) that the stronger the property right protection, the more likely it was the private sector would become involved, and (b) the more private sector research that was done, the higher the rate of genetic gain.
Figure 1 is taken from that paper and helps motivate our research and the cases that we chose and it helps motivate our general interest in this topic.

Figure 1. Yield index for U.S. corn, U.S. soybeans, U.S. wheat, and wheat in the EU-15



Wheat yields in the EU have grown at a much faster rate than in the U.S., as have corn yields in the U.S. relative to soybean yields in the U.S. These very large differences in the rate of yield growth have welfare implications. To appreciate these welfare impacts, consider what would have happened had all four yields grown at the rate of U.S. wheat yields. Alternatively, consider what U.S. agriculture would look like if U.S. soybean and wheat yields had grown at the same rate as for corn.

Conceptually, gains in crop yields can be partitioned into (a) gains due to husbandry, fertilizer, pesticides, fungicides, etc., and (b) genetic gains due to breeding. Thus, there are several possible explanations for the yield growth data shown in Figure 1. For example, it may be true that EU wheat yields have grown because wheat is grown on the best soils and because EU policy has encouraged fertilizer use. U.S. wheat yields may have disappointed because wheat production has been moving to marginal land. There may be something fundamental about the soybean biology which makes the production of hybrid seed difficult, thus restricting its yield growth compared to corn. However, it is also possible that differences in intellectual property protection and in the degree of private sector research are partially responsible for the differences we observe. In order to untangle these differences, we need to get much closer to the data.

II.1. The Situation in the U.S.

The intellectual property rules under which the private sector operated in the U.S. wheat sector are described in Fernandez-Cornejo. Prior to 1970, it was almost impossible for the innovator to realize any benefit from non-hybrid seeds such as wheat.[2] The 1970 Plant Variety Protection Act gave breeders an exclusive right to market a new variety for 18 years. This Act resulted from work done by the Breeders Rights Study Committee of the American Seed Trade Association (ASTA). The Act contained two exemptions that limited its applicability, namely, the research exemption and the farmer's exemption. The former allowed other companies to use protected seeds to develop new varieties, whereas the latter allowed farmers to save and, under certain rules, sell seed grown from a protected variety. The Act is enforceable only through the actions of the owners of the protected varieties. In 1994 the Act was strengthened to require farmers to obtain permission from the owner of the protected variety before selling the progeny of the protected seed. This permission requirement was extended slightly in 1995 to require a license.

A 1980 interpretation of the Patent Act extended protection to genetically modified plants in the form of utility patents awarded under the Patent Act. These utility patents have been a source of protection for companies introducing genetically modified corn and soybeans, but to date genetically modified wheat has not been commercially introduced. In 1990, U.S. based Pioneer Hi-Bred International, Inc. (Pioneer Hi-Bred) discontinued the development, production and sale of hard red winter wheat and donated its wheat germplasm collection to Kansas State University. The justification for this decision was reported as follows (Omaha World-Herald): "Pioneer officials cite what they call a weakness in the Plant Variety Protection Act that allows farmers to save seed for their own use in planting their next crop, which they say fails to adequately discourage farmers from also selling seed wheat they have grown to others." Although the

[2]Protections were introduced for asexually propagated plants by the Plant Patent Act of 1930 and to patentable improvements in general by the Patent Act of 1952, but neither of these acts contained language that extended intellectual property to seeds.

company had not been spending very significant resources on wheat research before the announcement, at least in relation to expenditures on corn research, the donated varieties were well received by Kansas State and they formed the basis of two very successful seed lines from that institution, varieties 2145 and 2137 (Paulsen, Fritz *et al*.).

In our discussions with Pioneer Hi-Bred executives, conducted as part of the present study, it was clear that the lack of interest in investing in new U.S. wheat varieties was related to the lack of premiums available from the marketplace. In addition to the farmer's exemption described above, the executives also indicated that the transactions costs involved in enforcing the existing intellectual property rules were relatively high, particularly given the tradition of saving and selling seed among wheat growers. In addition to the actual legal costs associated with enforcement, the brand name of the company is eroded when the company brings lawsuits against producers who are simply following tradition. One interesting aspect of this discussion is that soybean producers are viewed as being less opposed to paying royalties, in part because they are used to making these payments for corn and used to purchasing new seed each year.

Other wheat seed companies in the U.S. also appear to have arrived at a similar conclusion, and as a result almost all of the research and variety releases for wheat are from the public sector (Fernandez-Cornejo). The report by Fernandez-Cornejo also shows that soybean breeding research by the private sector was almost non-existent prior to 1975, but gradually picked up so that it exceeded public sector research on soybeans in 1994. The interviews we conducted, as well as the data in Fernandez-Cornejo, indicate that the availability of utility patents on genetically modified soybeans has greatly increased the amount of private sector research since the commercially successful introduction of glyphosate-resistant soybeans in 1996.

In summary, wheat breeders in the U.S. have not had access to effective intellectual property protection, especially in areas of the country where farmers traditionally save seeds. Wheat breeders are also obligated to take action to implement any intellectual property protections that are afforded to them, and the anticipated cost of this action appears to have deterred them from enforcing some of the existing rules. Even though the legal situation regarding soybeans is similar to wheat, lower transactions costs associated with enforcement prior to 1996 and the successful use of utility patents after that date have stimulated significant amounts of private sector research on soybean breeding.

II.2. The Situation in the EU

At first glance, the intellectual property protection for wheat breeders in the EU is very similar to that which exists in the U.S. This is true because the U.S. Plant Variety Protection Act was amended in 1994 to bring it into conformity with the same rules that govern variety protection in the EU. The rules that govern variety protection in both geographic areas are now based on the International Union for the Protection of New Varieties (UPOV). However, the implementation of the UPOV rules is very different. This is true because regulations and institutions in the EU have been created to ensure that the companies actually collect royalties that are due. Under European regulation (European Council, Article 14), farmers have a right to grow protected seed but they are subject to payment of royalties. Payment rates are determined by national authorities.

In the United Kingdom (UK), the agency developed to organize and encourage these payments is an organization known as Fair Play. This group was developed as a joint initiative between the British Society of Plant Breeders (BSPB) and the major farming unions in the UK in order to "combat farm-saved seed evasion."[3] Farmers can pay these fees in two ways. If they purchase seed, the payment is included in the invoice sent by the seed dealer and these payments are then forwarded to the seed company. If the farmer saves seed, then the farmer must pay the fee directly to the BSPB. The system is not perfect and some farmers avoid paying fees by claiming that they are planting non-protected varieties. However, the vast majority of fees are recovered, in part because 80% of the seed comes from registered dealers.

As an example of how the provisions that are included for royalty collection impact the industry, compare the reasons given above by Pioneer Hi-Bred for exiting the hard red winter wheat breeding business with the following quote from the Fair Play site:

[3]See http://www.fairplay.org.uk/site/faq.html.

> "Until the early 1960s, plant breeding in Britain was largely confined to publicly funded research. This situation changed dramatically in the mid-1960s when Plant Breeders' Rights were introduced in the UK through the 1964 Plant Varieties and Seeds Act. This triggered a rapid expansion of plant breeding as a commercial enterprise in its own right, and paved the way for major advances in the performance, quality and diversity of crop production in Britain."

The availability of a mechanism for collecting seed royalties allowed the main breeding agency to become privatized in 1987, when Unilever acquired the breeding and applied science resources of the Plant Breeding Institute. This group was later sold to Monsanto. Thirtle *et al.* provide a detailed history of public and private sector research efforts in the UK.

The situation in France and the rest of the EU is similar to that in the UK. In response to a question posed as part of the present report, Bernard LeBuanec, the French Secretary General of the International Seed Federation, said that:[4]

> "I think that there are two main reasons why wheat breeders are better protected in Europe and in France: seed certification is compulsory and breeders get royalties on all the certified seed and, as you say, there has been a royalty system in place for farm saved seed since the ratification by Europe of the 1991 Act of the UPOV Convention."

Despite the similarities in the intent of the intellectual property regulations, the systems in the U.S. and EU generate very different incentive structures. Breeders in the EU will typically be paid a premium if their variety is used and this gives them an incentive to innovate. Breeders in the U.S. can in theory collect this premium when a farmer grower sells protected varieties but not when the farmer uses the protected variety himself. In the U.S. the responsibility for collection lies with the owner of the intellectual property right and there is a perception among seed company executives that the costs associated with collection, both legal and reputational, are likely greater than the benefits.

[4] E-mail communication dated August 23, 2007.

II.3. Impact of Wheat Breeding Programs in the U.S. and EU

It is clear from Figure 1 that wheat yields in the EU have increased much faster than in the U.S., both in absolute and proportional terms. However, as we mentioned earlier, the reason for this gain may be due to changes in land quality, fertilizer use or even agricultural policy. We were fortunate to find four studies that controlled for all of these extraneous factors and which measured the increase in yields due to breeding between the 1970s and the 1990s. The term that is used for measuring the impact of breeding is genetic gain and it is defined as “the increase in productivity achieved following a change in gene frequency affected by selection” (Zaid *et al*., p. 124).

Two of these studies, by Donmez *et al.* and Fufa *et al.*, evaluated the rate of genetic gain in winter wheat cultivars that are typically grown in the U.S. Great Plains. Donmez *et al.* conducted the field experiments in Kansas, whereas Fufa *et al.* did so in Nebraska. Another study, by Shearman *et al.*, evaluated the rate of genetic gains among wheat cultivars grown in the UK, and a fourth study by Brancourt-Hulmel *et al.* focused on genetic gains for wheat in France. The results show that wheat yields are substantially higher for the UK and France than for the U.S. over the period analyzed. Further, annual genetic gains are also higher for the European countries than for the U.S. While it is impossible to prove causation from the data described here, it is possible to conclude that the stronger intellectual property incentives in the EU are associated with higher genetic gains. Given the very small resources devoted by the public sector in the U.S. to wheat breeding, the rate of genetic gain is impressive. But as the data in Fernandez-Cornejo show, when properly motivated the private sector can bring vastly more resources to breeding programs than the public sector has been able to provide to date.

III. Winners and Losers from Private Sector Research

Our first paper on this general topic simply assumed that there was a link between the incentive for the private sector to conduct research and the resulting yield improvement. This is the link that we subsequently attempted to document with the case studies described above. At the time we wrote the first paper, the prevailing academic work on the subject, Moschini, Lapan, and

Sobolevsky had taken the research that led to the introduction of Round Up Ready soybeans as a given and had focused on the allocation of the benefits of this research among the company, the consumer, and the producer. This work was highly cited because it showed that Monsanto, the company that developed this technology, was also capturing a significant share of the benefits. This result was viewed in a negative light because it appeared to show that Monsanto was capturing benefits that should have gone to producers and consumers. This later argument ignored the incentives that were created by the success of this technology. In particular, we expected the success of the technology to provide incentives for additional seed company research.

We constructed a model of the seed sector in the U.S. that assumed that seed companies maximized profits and that they competed with each other in a race to develop the next breakthrough technology. The incentive to participate in this race was that that grower would be willing to pay a premium for this technology. These premiums would then be used by the company to generate profits and to fund the next cycle of research.

We modeled the relationship between research spending and the resulting yield improvements at the firm level and we acknowledged that in the absence of strong intellectual property protection, some companies would simply steal the successful technology. If this was the case, then the incentive to conduct research was weakened because the firm that did the research would not be able to charge a premium for the seed in the presence of competition from the firm that simply copied the seed. This provided a link between intellectual property protection and yield research that was the focus of the paper.

We modeled the grower as an agent who bought the most valuable seed after comparing the value of the expected yield increase against the seed premium, and we acknowledged that when many growers adopted a yield improving variety the price of the resulting crop would fall. This created a link between intellectual property protection and the consumer benefit because intellectual property protection lead to increased yields which in turn led to lower prices for the commodity that was produced with the improved seed.

At the time we wrote this first paper we were interested in the tradeoff between the interests of the seed company and the rest of society, and we did not spend a lot of time breaking out the separate interests of the producer and consumer. We assumed a single representative consumer and a single representative producer.

With three markets (research, seed, and commodity), many companies and a producer and consumer all optimizing over a long time period, the model became mathematically complex. With this type of model one would normally expect that the results were sensitive to parameters that were not known with accuracy. We were pleasantly surprised to discover that this was not the case. Some key results were robust with respect to the choice of parameter. The robustness of these results helped us get the paper accepted in the top journal in this area, the *American Journal of Agricultural Economics*.

The two figures reproduced below are from that paper, and they summarize the key results. These figures both use an economic concept called "surplus" as a way to measure benefits to producers and consumers. The term "producer surplus" is very closely linked to the concept of producer gross margin, and as such, it measures the profits earned by growers over their variable costs. The term "consumer surplus" is based on the difference between what consumers pay for the product and the maximum that would have been paid had prices been higher. For example, if a meal costs $4 and the consumer would have been willing to pay $6 for that meal, then the consumer surplus is $2.

The vertical axis on Figure 2 below shows the sum of producer and consumer surplus. The higher this value, the better off society is. The line across the bottom of this figure measures the strength of intellectual property protection. The original paper presents many versions of this figure with each one showing how the results adjust to a change in a key parameter. All of the results show changes in welfare increasing up to a maximum point, and then declining before flattening out. In all instances, the expected change in welfare is positive regardless of the level of appropriability, but there is clearly an "optimum" level of appropriability that maximizes the welfare change. This optimum level is typically in the range between 0.5 and 0.7, and is surprisingly robust to changes in model parameters. The actual level of appropriately for the US corn sector is marked in red and is 0.39.

The change in surplus rises with the appropriability level up to a maximum point as more research increases the rate of yield growth, and it declines after this point as deadweight losses associated with the exercise of market power are introduced.

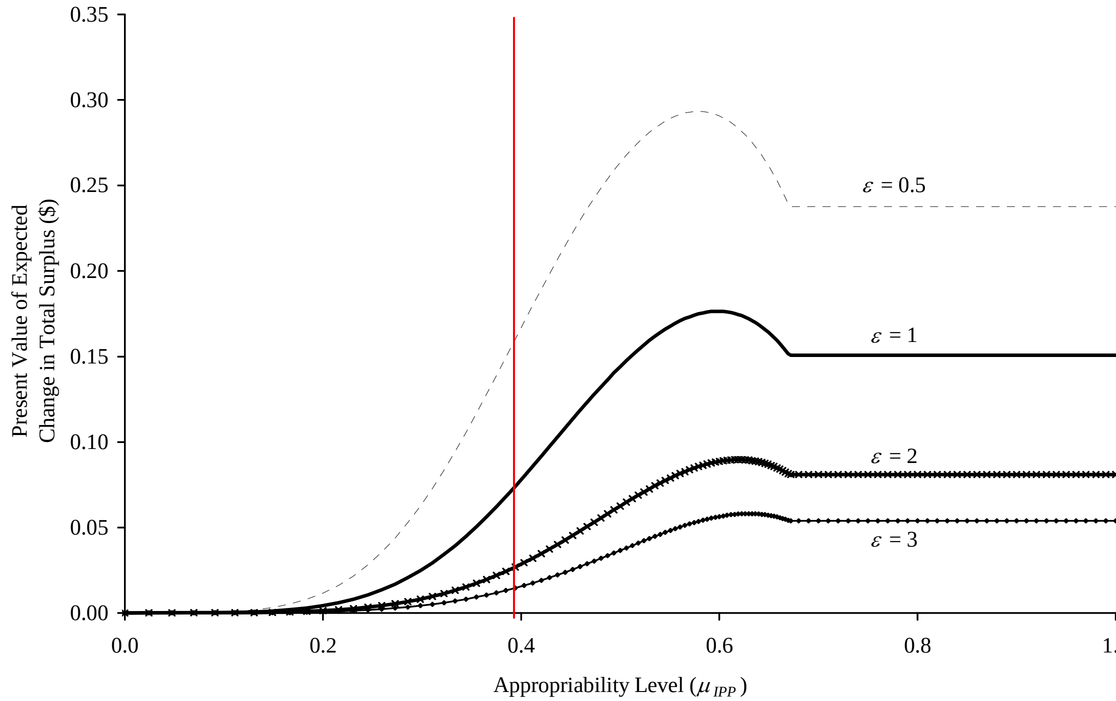


Figure 2. Present value of expected change in total surplus as a function of appropriability level (μ_{IPP}), for different demand elasticities (ε).

The decline in welfare halts when the price on the improved seed rises to a level where farmers become indifferent between adopting it and using unimproved hybrids/varieties. Rather than lose these customers, seed companies optimally charge a lower price for seed than their market power situation would dictate if there were no substitutes. The ability of producers to switch to the unimproved hybrids/varieties limits the ability of the seed company to charges too much for the improvement.

Figure 3 shows some results that compares the welfare of consumers and producers on the vertical axis and the profitability of the seed sector on the horizontal axis. The graph shows how different levels of intellectual property appropriability impact on these two welfare measures for a 20-year patent protection period (the one that is currently in use in the U.S.) and an infinite protection period. The most interesting result in the 20-year line of Figure 3is that there is a wide range of appropriability levels over which the interests of both groups are complementary. Increased appropriability in this region increases the surplus of the R&D firms *and* increases the welfare of the rest of society. The results also suggest that over a different range of appropriability increases in the welfare of R&D firms come at the expense of the rest of society.

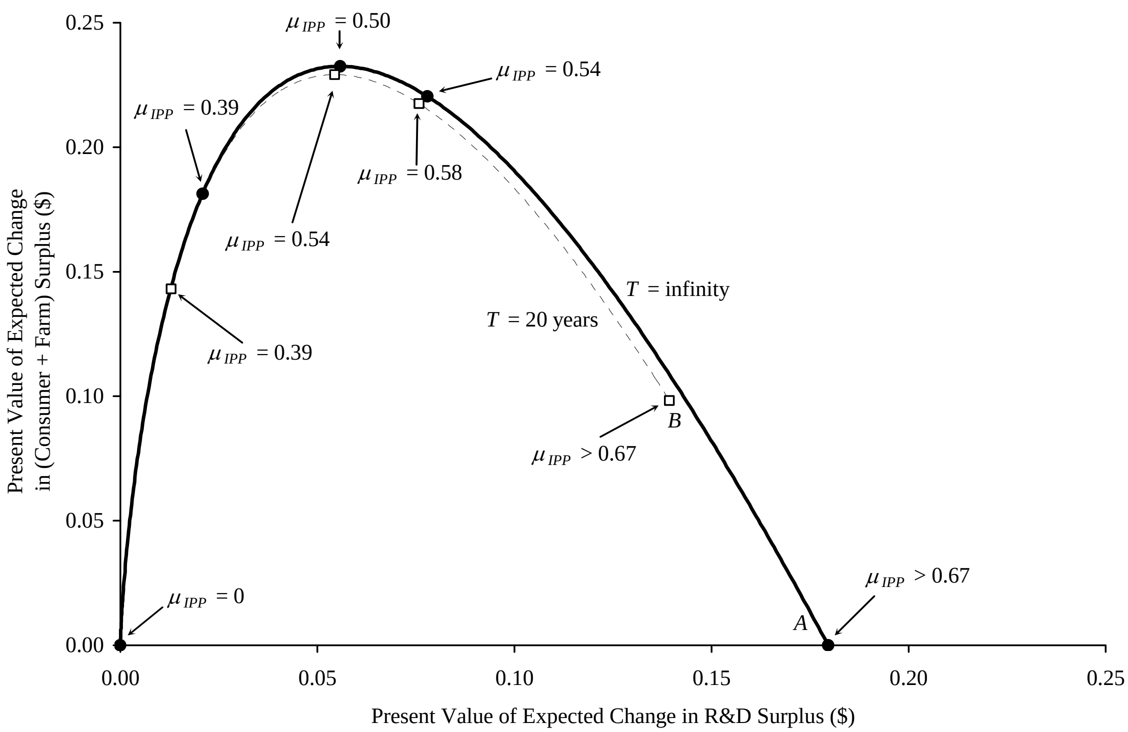


Figure 3. Tradeoff between present value of expected changes in (consumer + farm) surplus and present value of R&D surplus.

III.1. What is the Appropriability Level in the U.S. Seed Industry?

To assess the simulated results vis-à-vis real-world appropriability levels, it is worth noting that the magnitude of intellectual property protection in a particular market can be estimated from the marginal production costs for seed (excluding R&D expenditures) and the sales price for that seed. We were able to measure the strength of intellectual property protection in the U.S. corn market at about 0.64 on this scale.

The above results suggest the appropriability level that exists in this sector is probably lower than the social optimum. Yet the hybrid seed corn market in the U.S. represents an extreme in terms of appropriability. This is true because hybrid seed lines are difficult to copy and because U.S. intellectual property rights are strong. This comparison suggests that appropriability levels for other seed markets where appropriability levels are weak (e.g., open pollinated crops such as wheat and soybeans in the U.S., and all crops in countries with poor intellectual property rights) are far lower than the social optimum. So long as this situation is in place, public research, research subsidies or prizes, and related policies will be essential to offset the lack of sufficient private incentives.

IV. Do Farmers Benefit from Seed Research?

The results presented in the previous section did not attempt to separate the interests of farmers from the interests of consumers. We combined these two groups because we were interested in the overall benefits of stronger intellectual property protection. There is also an apparent tradeoff between the interests of consumers who prefer low prices and farmers who prefer higher crop prices. When yield increasing research is adopted by farmers, crop prices will typically fall; and, therefore consumers will almost always gain. Whether farmers gain or lose will typically depend on how fast prices fall relative to the rate of increase in average yields.

At the time we wrote this first paper it was conventional knowledge among the agricultural economics community that when demand is inelastic (i.e., consumption levels are not very sensitive to price) then farmers lose when yields increase. Under this convention, each farmer adopts the higher yielding varieties because they realize that their additional production will not cause market prices to fall. But as more and more farmers make the same decision, the market becomes swamped with the additional food, and market prices will fall faster than yields are increasing. The results of our earlier work were in line with this conventional wisdom. When demand was inelastic farmers as a group lost, and when demand was elastic farmers as a group gained.

One might expect inelastic demand for a broad consumption category such as “food” because there is a limit on caloric consumption. One would typically expect an elastic demand for a narrowly defined consumption category such as a brand of bacon because consumers can easily switch to other products.

After we had published the original papers on this topic, we were contacted by ASTA and were asked to tease out and validate the earlier results with respect to producer welfare. This group gave us access to seed company executives that we had not had the chance to interview, and these meetings convinced us that in some respects our earlier work was over-simplified. We used the information we collected to rebuild our model and are in the process of finishing an academic paper that shows the new results.

The new model has several features that improve upon our earlier work. Whereas the old model had seed companies compete in a race for the next big breakthrough, the new model acknowledges that progress on improving yields comes as a result of a gradual improvement in the yield potential of the varieties that are on the market. Each year seed companies release new improved varieties and these varieties compete with varieties from other companies that were released that year and with varieties that were released in previous years.

In the new model, seed companies decide on the optimal price premiums for new varieties after allowing for the level of competition from other companies and other older varieties both from that company and from other companies. Companies realize that older varieties will eventually become obsolete as new varieties come on line and they build this obsolescence into their research and pricing decisions.

In order to accurately model these pricing and research decisions, we constructed a dynamic model where key parameters are measured in terms of rates of gain. In this world, stronger intellectual property protection does stimulate additional research by all companies and research speeds the rate at which old varieties become obsolescent and the rate at which average yields grow. The new model is extremely rich in detail and we believe that it accurately reflects the competitive realities that we encountered when we conducted the interviews with industry executives.

One set of results that we obtained is consistent with what we were told by industry executives and is contrary to our original expectations. This result suggests that there are circumstances where farmers on average can gain from new yield increasing varieties, even after allowing for the price suppressing impacts of the additional production from higher yielding varieties. The rest of this paper focuses on this result.

The difference with our earlier work was that we assumed that there was a single representative farmer. Equivalently, we had assumed that all farmers received identical benefit from each new variety. Under these (unrealistic) circumstances, the seed company will be able to calculate the value of the improved variety to the farmer relative to other available varieties and charge the farmer a premium that is close to this value. For example suppose that the new variety increased corn yield by two bushels per acre relative to all other varieties and that the corn was worth $4 per bushel. Then the value of the new variety will be $8 per acre and the seed company will optimally charge a premium that is just lower than this amount.

Whether the farmer wins or loses from this development will then depend on what happened to farm revenues when the additional two bushels per acre from all farmers hits the market. If price falls by more than the proportional increase in yields then farmers will lose, and vice versa. This explains why our earlier producer welfare results were so sensitive to the elasticity of demand.

Our interviews with seed company executives convinced us that the example provided above is too simplistic. Executives were aware that producers differed widely in their willingness to pay a premium for the trait. This difference across producers is due to differences in perception among wary, risk-averse producers who must make purchase decisions before they know the insect pressure, expected per-bushel price of the crop, or actual weather patterns and the weather-related value of insect resistance. If they were to find the farmer who was willing to pay the highest premium for the new variety and then charge this premium on every bag of seed, they would end up with a single customer! This customer obviously could never buy enough seed to allow the see company to spread the overhead costs associate with developing the improved seed[5].

Instead traits are priced so that a ***target producer*** will find it easy to justify the purchase of the trait, and this target producer is an individual who will only benefit by a relatively modest amount from the improved trait.

The two pricing models described above lead to very different price premiums. Under the first model, the premium would be the full expected value to a representative producer. Under the second one, the trait would be priced well below the full value so as to attract marginal producers.

This new pricing model has important implications because it means that the seed companies will rationally share the benefits of the new varieties with their farmer customers. We decided to determine if we could find evidence of this revenue sharing using the recent introduction of the corn rootworm (CRW) trait. We were able to collect data on the actual premiums for the CRW-resistant trait to determine which of these pricing models were followed in practice. We had access to the *ex ante* expected value that appears similar to the kind of information that the company would have had when it decided on the premium level, and we also had access to the actual premiums that were charged. We also followed this up with an *ex post* evaluation to ensure that the *ex ante* analyses of producer value was accurate.

IV.1. *Ex Ante* Benefits

In a paper written before the commercialization of the CRW-resistant trait, Alston *et al.* present some very detailed farm-level calculators on the likely benefits of the Monsanto's YieldGard Rootworm trait. Alston *et al.* assumed that Monsanto would charge a seed premium that was

[5] James Tobin, Director of Biotech Business Development at Monsanto was the first executive to make this point

equal to the cost of controlling CRW with insecticides, averaging $12.43 per acre nationwide and $13.52 per acre in the "heartland." They also assumed that any additional yield benefits over and above those that were available under existing treatment alternatives would be allowed to accrue to the producer. They calculated the value of these additional benefits at $16.49 per acre (assuming corn was worth $1.85 per bushel). Their survey results also suggested that producers would pay an additional $6.61 per acre for convenience and safety. Alston *et al.*'s estimate of the total corn area that would have been treated for CRW was 13.8 million acres, and their estimate of the total benefits to producers from usage of the CRW-resistant trait on all of such area was $289 million.

IV.2. *Ex Post* Benefits

We were able to find publicly available data on the actual prices for a unit of seed containing the YieldGard Rootworm trait sold by Midwestern seed dealers for several versions of Monsanto's seed lines DKC60 for recent years. To measure the premium charged for the CRW-resistant trait, we subtracted the per-unit charge for DKC60-15 with no CRW-resistant trait from the premium charged for DKC60-12 with the trait. To express this premium on a per-acre basis, we divided the per-unit premium by 2.7 acres per unit.

Once the seed became widely available, the premium for DKC60-12 fell into a range of $15 to $16 per acre. This corresponds very well to Alston *et al.*'s projection of the average cost per acre of the next-best alternative to control CRW, especially when one factors in the inflation in pesticides and application costs between 2000 and 2006. This premium does not reflect the additional yield that farmers could earn with the improved variety. This suggests that the company sold the seed trait at well-below the anticipated benefit to the producer.

There is some anecdotal evidence to suggest that the expected yield impacts have been greater than those anticipated by Alston *et al*. An evaluation of CRW control products in Iowa indicated that YieldGard Rootworm hybrids averaged yields between 21 and 33 bushels per acre or 18% higher compared to the insecticide treatments (Rice and Oleson). Similar trends were also noted in Indiana (Krupke, as cited in Sankula). Steffey and Gray.

V. Results from the New Model

Figures 4 through 6 shown below summarize the results of the new model in the case where demand is inelastic. (This is the case in our previous work where farmers as a group lost as yields improved.)

In Figure 4, the vertical axis measures the present values of the gains in farm surplus. This is the best measure of the producer benefit over several years. The other two axes show how this measure of producer benefit responds to stronger intellectual property protection on one axis and to the degree of differentiation across producers on the other. If producers are identical as we had assumed in our previous work then this measure would be very large, and the relevant welfare comparison would be with the values shown on the extreme right of the graphs. As producers become more and more differentiated this measure becomes smaller and the relevant comparison is to the left of the graph.

From Figure 4, it is clear that producers benefit from stronger intellectual property protection so long as they are differentiated with respect to the benefits they obtain from the trait. As we had discovered earlier, if producers are very similar with respect to the benefits they obtain from new varieties, then they lose from stronger intellectual property protection.

Figure 4. Present Value of Gains in Farm Surplus

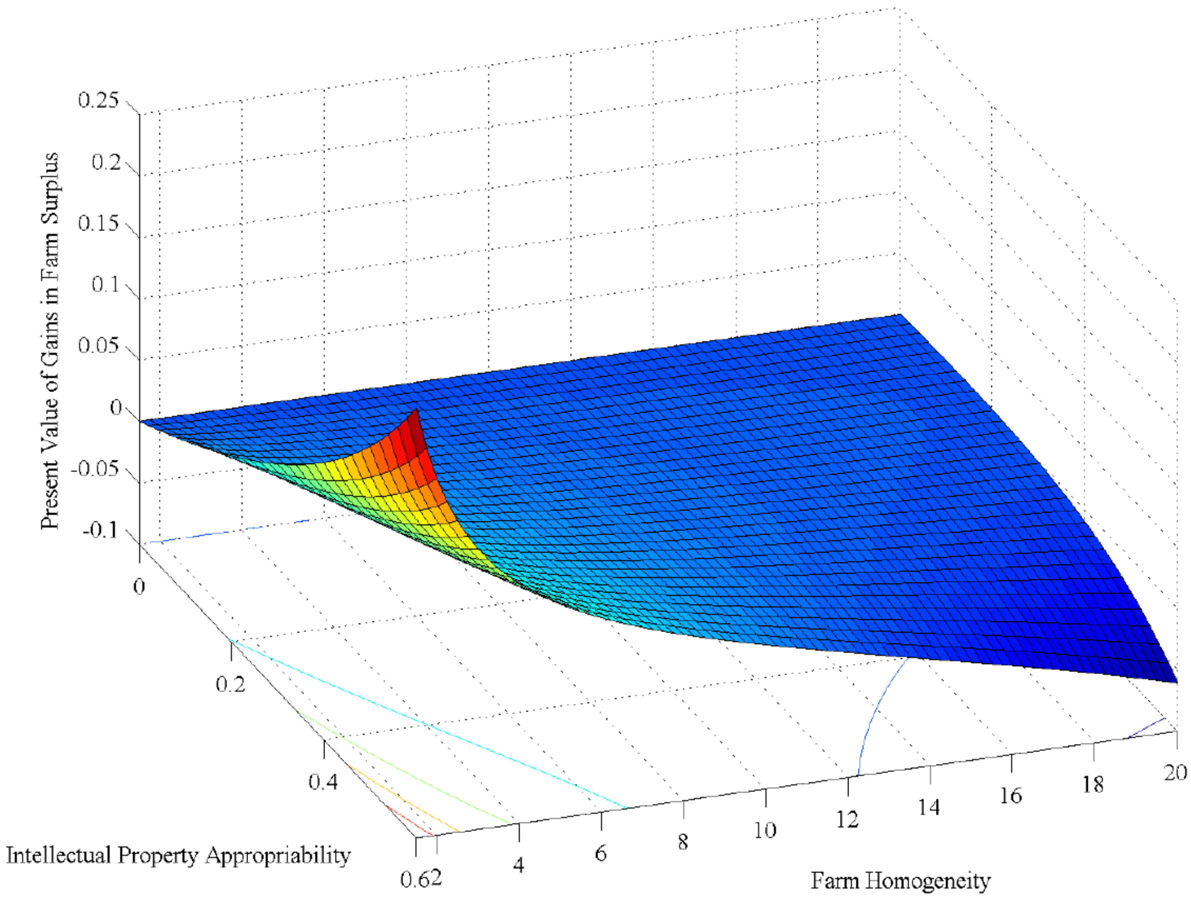


Figure 5 below shows the relationship between consumer surplus and both intellectual property protection and the degree of producer differentiation. Consumers benefit uniformly from stronger intellectual property protection because it results in increased yields and lower prices. The amount of consumer benefit is highest when farmers are identical. As farmers become differentiated, the seed company is forced to share the benefits of the yield improvement with them, and as a result, the level of yield growth falls. This is shown in Figure 6 below, where the level of yield growth is lower as producers become more differentiated and as the level of intellectual property protection falls.

Figure 5. Present value of Gains in Consumer Surplus

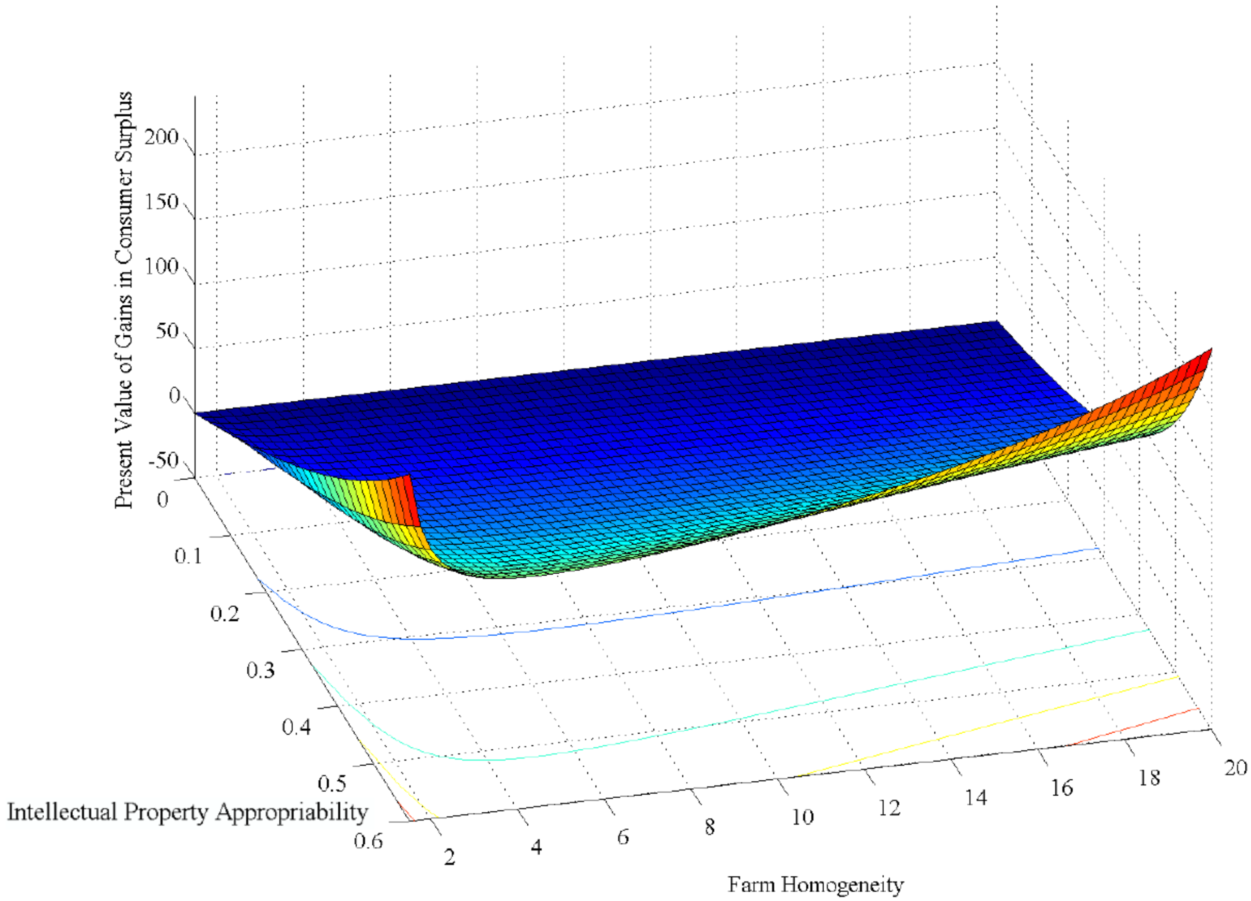
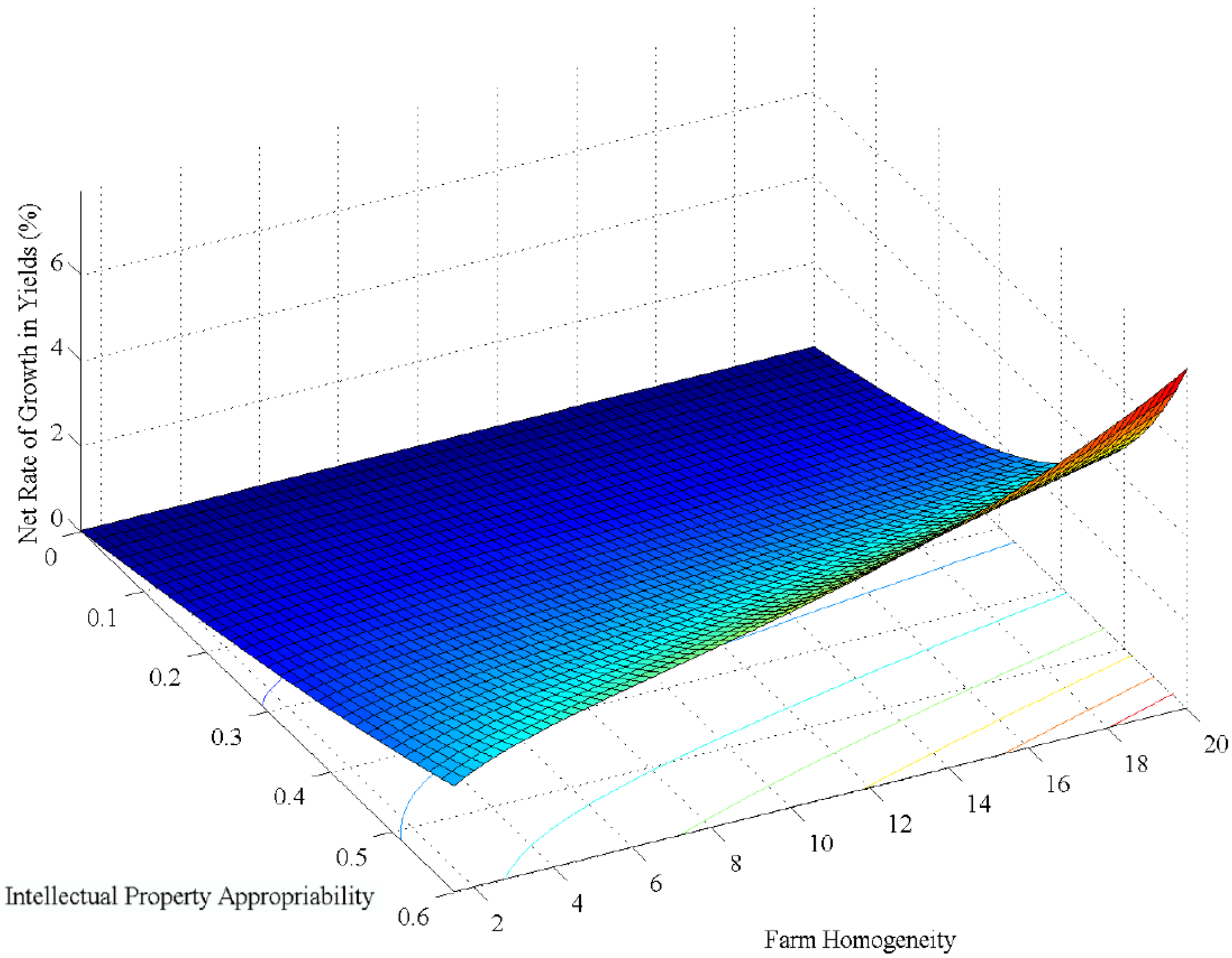


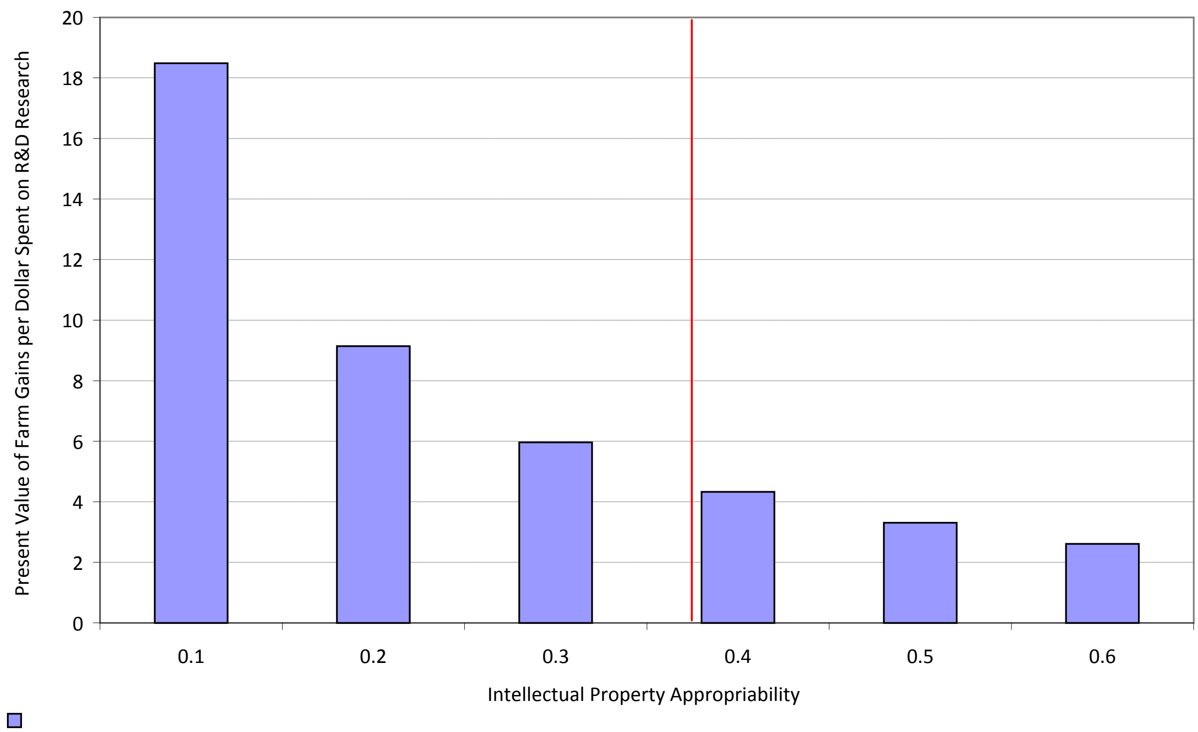
Figure 6. Net Rate of Growth in Yields



V.1. How Much Value do Farmers Capture per Dollar Spent on Research?

The new model allows us to calculate producer surplus under a range of assumptions about seed pricing and intellectual property protection. We designed a set of thought experiments to measure how much farmers benefit from each dollar spent on research. To do this, we ran the model for a specific set of parameters and calculated the producer welfare. Next, we ran the model under the same set of parameters but increased the incentive for seed companies to conduct research. We then calculated producer welfare in the second case and compare it to the first. These results are summarized in Figure 7.

Figure 7. Net Return to Farmers for Each Dollar Spent of Seed Research by Private Sector Seed Companies
(Farm Homogeneity = 3)



The results suggest that for this particular parameterization farmers obtain at least two dollars of value for each dollar that is spent on research by seed companies. This value is highest when intellectual property protection is weak, and it is lowest when intellectual property protection is strong. These results make sense. When intellectual property protection is strong, firms are already doing a lot of research, and as a result, it becomes more and more expensive to develop yield improving varieties. This is a classic example of the law of diminishing returns. As research becomes more and more expensive, the amount of surplus (per dollar spent on research) that is available to share with the producer is reduced.

If we use a level of intellectual property protection of 0.3, then the producer receives approximately $6 per dollar spent on private sector research. This number includes the gains made by producers for all the years that the improved variety is in commercial use. The USDA has calculated that in 1996, the U.S. private sector spent $554 million dollars on private sector plant breeding activities. It seems highly likely that this amount is now much greater. If we use a value of one billion dollars then the total value to producers using the parameters described above is approximately $6 billion.

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