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Technology Fees Versus GURTs in the Presence of Spillovers: World Welfare Impacts

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A two-country extension of an ex ante simulation model of research and development (R&D) in agriculture developed by Lence, Hayes, McCunn, Smith, and Niebur (2005) is used to analyze issues regarding intellectual property (IP) protection, spillovers, and genetic use restriction technologies (GURTs) in the context of the United States and South America soybean sectors. The model is used to examine how various IP protection levels in the United States and South America might have impacted on the level of innovation, market equilibrium and the welfare of market participants had they been in place prior to the introduction of Roundup Ready technologies. The results indicate that technology fees that are charged in the United States but not in South America are harmful to US producers. Neither producers in the United States nor US-based R&D firms have incentives to support or develop technologies such as Roundup Ready that can be easily adopted in countries with low IP protection. However, total world welfare is higher when this type of transferable R&D is conducted. Equalizing IP protection across countries gives R&D firms a strong incentive to conduct R&D of relevance to both countries. Surprisingly, the introduction of a low level of IP protection in South America does not necessarily improve expected welfare of US producers. To the extent that GURTs contribute toward IP protection harmonization, they can be world-welfare enhancing. However, the positive impact of GURTs could be greatly reduced if they increase IP protection beyond a certain level. The use of GURTs to impose IP protection in South America generally increases the expected welfare of US producers.

Key words: GURT, Roundup Ready soybeans, spillover, technology fee, welfare.

Introduction

Roundup Ready (RR) soybeans were developed by Monsanto to be resistant to glyphosate, a herbicide also developed by Monsanto and commercialized under the brand name Roundup. In order to access this technology, US soybean producers must pay a technology fee of about $7.50 per 50-pound bag of RR planting seed and must agree not to keep the harvested beans for future planting or for reselling to other farmers (Schnepf, 2003). The use of technology fees as a way to capture rents from intellectual property (IP) in US agriculture has become controversial, because US producers feel that they are paying for research that helps their foreign competitors. Despite the higher price of RR seeds, they have been widely adopted by US farmers because they reduce output costs and greatly facilitate crop management. Over 80% of the area planted with soybeans in the United States in 2003 corresponded to RR varieties (Monsanto Company, 2004).

Monsanto patented RR soybeans in the United States but was unable to obtain patent protection in either Brazil or Argentina, the two main competitors of the United States in the soybean market. Farmers in both Argentina and Brazil have thus been able to plant RR soybeans without paying the technology fee that US producers have had to pay and have been able to keep harvested soybeans for use as seed. The American Soybean Association has argued that "because Brazilian farmers receive all of the cost-saving and yield-enhancing benefits without paying for the right to use the technology, they have a distinct comparative advantage over US soybean farmers in competing in the global soybean market" (American Soybean Association, 2003, p. 2). This argument was supported by a recent report by the Congressional Research Service that concluded that "the cost saving to South American soybean growers on the technology fee alone nets out to about $8 to $9 per metric ton—a considerable cost advantage over US soybeans in the highly competitive international soybean market" (Schnepf, 2003, p. 1).

The United States, Brazil, and Argentina have all increased their output since the introduction of RR soybeans in 1996/97. However, the United States has lost market share to both Brazil and Argentina after RR soybeans became popular. FAOSTAT data show that the US market share of world soybean output declined from an average of 47.2% over 1993/94–1995/96 to an average of 39.6% between 2002/03 and 2004/05 (Food and Agriculture Organization of the United Nations, 2005). The combined market shares of Brazil and Argentina jumped from 28.6% to 41.7% over the same period, during which the two South American countries combined overtook the United States as the world's largest producer of soybeans. The noticeable increase in South American market share at the expense of the United States is consistent with the claims that the introduction of RR soybeans has put US producers at a relative disadvantage with respect to farmers in Brazil and Argentina.

It is clear that private-sector research firms such as Monsanto would not have developed this technology in the complete absence of IP protection; hence, any welfare analysis that assumes that the technology already exists will be biased in favor of low IP protection levels. Therefore, in the analysis that follows, we go back 20 years and conduct an ex ante welfare analysis of different IP protection levels in both the United States and South America (SA). We allow for research spillovers so that the production technology in one country can be enhanced when producers in that country adopt a technological improvement originally designed for producers in another country. In the case of the RR soybeans scenario discussed earlier, the level of spillover appears to be close to 100%.

Another controversial issue related to biotechnology is the adoption of *genetic use restriction technologies* (GURTs). GURTs can be classified into two major types: T-GURTs and V-GURTs. The former regulate the expression of a transgene that provides a particular agronomic trait in a seed that is fertile, whereas the latter render the subsequent generation sterile and are popularly known as the "terminator gene" (Working Group on Plant Genetic Resources for Food and Agriculture [WG-FAO], 2001). GURTs (and especially V-GURTs) may be used to prevent farmers from saving seeds for future planting and are controversial because some view this as a way to put poor farmers in developing countries at a distinctive disadvantage, as saving seeds is a common practice among such farmers. As a result, India has banned the technology, and the Consultative Group of International Agricultural Research (CGIAR) has recommended not using it in their programs (Wright, 2003).

GURTs are relevant to the controversy regarding the payment for technology fees on improved seeds, because GURTs may allow the firms involved in the research and development (R&D) of improved seeds to collect technology fees even where legal IP protection is weak. This is true because GURTs not only prevent farmers from producing improved crops without paying R&D firms for the seed, but also preclude R&D competitors from copying the improvement. For example, Cunningham and Cunningham (2004) state that "Melvin Oliver, the principal inventor of the terminator genes, admits that 'the technology primarily targets Second and Third World markets'—in effect, guaranteeing intellectual property rights even in countries where patent protection is weak or nonexistent."

An anonymous reviewer made the point that the IP protection offered by GURTs may not provide as strong a level of protection as suggested by Oliver. Farmers might not be able to take advantage of the new technology by replanting seeds, but other seed companies might be able to replicate the technology and insert it into their own lines. In short, it can be safely concluded that GURTs provide greater IP protection than more traditional means (WG-FAO, 2001), but the extent to which they do so is subject to debate. In other words, GURTs can be viewed as a way to have imposed some IP protection in South America, but we cannot ascertain how effective this protection might have been.

The purpose of the research presented here is to provide an ex ante evaluation and comparison of the welfare impacts from using legal mechanisms (e.g., patents) and technical methods (e.g., GURTs) to protect IP when the R&D improvements exhibit spillovers. Simulations are conducted using a calibrated two-country version of the single-country model of IP and R&D in the seed sector recently developed by Lence, Hayes, McCunn, Smith, and Niebur (2005). The two-country model allows for R&D conducted in one country to spillover into a second country. It is assumed that the first country provides legal IP protection and that R&D firms' incentive to introduce an improved seed is the collection of fees from producers in the first country.

The study begins with an overview of the two-country version of the Lence et al. (2005) model, followed by a description of the parameterization employed for the analysis. Next, simulation results are reported and discussed regarding the welfare impact of different levels of IP protection in both the US and SA with and without spillovers.

The Model by Lence et al.

The Lence et al. (2005) model used as the foundation for the present study is in turn based on Dixit (1988); Loury (1979); Lee and Wilde (1980); and Srinivasan and Thirtle (2002). Related studies concerned with R&D include Alston and Venner (2002) and Tongeren and Eaton (2002). They incorporated a similar incentive structure for the R&D firms, but they did not include spillovers, the market for the crop, or the welfare of those who produce the crop. Žigic (1998, 2000) examined spillovers in the context of IP protection and North-South trade, but he equated the intensity of spillovers to the strength of IP protection and focused on economy-wide spillovers. Dinopoulos, Oehmke, and Segerstrom (1993), Dinopoulos and Segerstrom (1999), and Segerstrom, Anant, and Dinopoulos (1990) developed dynamic general-equilibrium models of R&D and trade, but they did not analyze spillovers. Similarly, Dinopoulos (1996) used a dynamic general-equilibrium model of R&D to analyze the mix of agricultural and industrial R&D investments but did not address spillovers. The literature on GURTs includes Swanson and Goeschl (2000) and Goeschl and Swanson (2002), who acknowledged that GURTs are a way for R&D firms to protect their intellectual property. They quantified the potential impact of GURTs on crop yields in developing countries by extrapolating the experience with hybrid seeds. Harhoff, Régibeau, and Rockett (2001) discussed GURTs as a means by which innovators can exert market power and concluded that GURTs may be beneficial because they improve market performance.

Unlike the aforementioned R&D studies, the Lence et al. (2005) model is specialized to reflect the seed industry. In particular, its structure requires simultaneous equilibrium in three markets in each country. First, the seed R&D industry must in equilibrium conduct an amount of research that can be justified by the expected earnings from that research, and each seed R&D firm must respond to incentives and to competition from other R&D companies in an optimal way. Second, the market for seeds and breeding stock must also be in equilibrium, and the farmers who purchase the improved seed should do so only if the premium charged for them is less than the additional profits they can expect. Finally, the domestic and international markets for the final product (e.g., grain) must also be in equilibrium, and market prices must reflect the changes in costs and farm productivity brought about by the improved seedstock.

The strength of IP protection in country q is summarized in an appropriability parameter $\mu_{q,IPP} \equiv \mu_{q,right} + \mu_{cost} \geq 0$, which measures the degree (measured in terms of the proportional markup over marginal production costs) to which the developer of an improved seedstock can appropriate the benefits associated with the innovation in that country. The level of $\mu_{q,IPP}$ determines the degree of market power that the developer of the improved seed can exercise when selling it to farmers in country q. Parameter $\mu_{q,right} \geq 0$ is assumed to be increasing with the extent up to which the developer is granted IP rights on the innovation in country q and with the level of enforcement of such IP rights in q. Appropriability $\mu_{q,IPP}$ also increases with parameter $\mu_{cost} \geq 0$, which reflects the costs of transferring or copying the output-enhancing innovation by competing R&D firms or would-be copiers.

Figure 1 depicts the relevant timeline involved in the R&D process and the subsequent commercialization of a new technology. Three main periods may be identified: (a) pre-innovation, (b) post-innovation with innovator enjoying legal IP protection, and (c) post-innovation after expiration of legal IP protection. The pre-innovation period starts at time 0, with R&D firms investing resources to compete in a race to develop x_1, a more productive version of an existing farm input (e.g., seed or breed) x_0. A successful outcome (x_1) of the development process is random, and the R&D competition ends at time t, when x_1 is first obtained. Thus, the length of the pre-innovation period ($t - 0$) is random.

The second period begins at time t, when the first developer of x_1 is granted IP rights for T periods. Hence, the successful innovator enjoys appropriability level $\mu_{q,right} + \mu_{cost}$ over the interval $[t, t + T]$. During this period, the improved farm input x_1 is sold at the monopoly price if the innovator's appropriability level is high enough. Otherwise, the innovator will charge a markup of $\mu_{q,right} + \mu_{cost}$ over its marginal cost of producing x_1 (c_1). Note that the model always allows producers to save seeds and that the extent of any IP protection is limited to the advantage that the new seed has over potentially saved seed.

The third and final period starts when the IP rights expire at time $t + T$. Expiration of IP rights means that $\mu_{q,right}$ is reduced to zero, so that the innovator's appropriability level decreases to μ_{cost}. This further restricts the innovator's ability to charge the monopoly price. The Lence et al. (2005) model then in turn addresses the various components affecting the R&D investment decision at time 0. Such components include the derived demand for the improved farm input x_1—which in turn

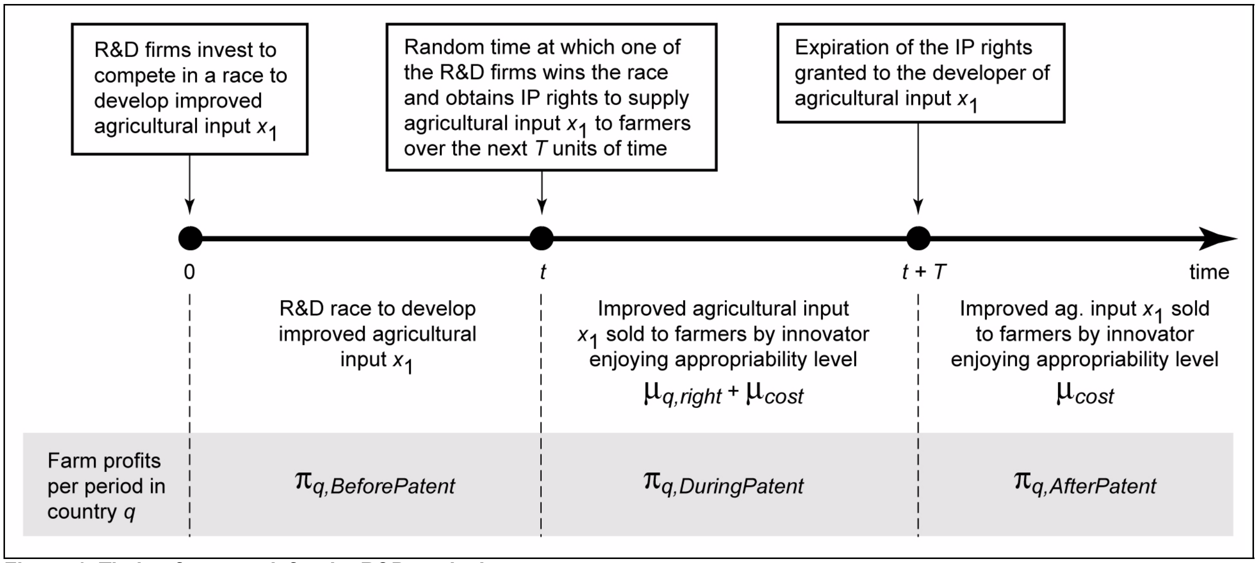

Figure 1. Timing framework for the R&D analysis.

involves the end demand for farm output, the R&D firm's optimal pricing decision regarding x_1, the nature of the R&D process, and the determination of equilibrium in the R&D market at time 0. The two-country version of the model is available from the authors upon request.

Model Parameterization

In order to use the model to perform simulations, it is necessary to specify the functional forms for each country's crop production and demand and for the technology of individual R&D firms. Crop production functions under the traditional input are postulated to exhibit constant elasticity of substitution between inputs and decreasing returns to scale, crop demand is assumed to be isoelastic, and the R&D technology is represented by a Cobb-Douglas hazard function with decreasing returns to scale. The innovation is assumed to be a Hicks-neutral improvement of an all-or-nothing type. In addition, the model assumes zero transportation costs and no barriers to trade the crop or other domestic policies and distortions (which would raise second-best possibilities for alternative results). In the interest of space, the extent to which relaxation of these specific assumptions modifies the general conclusions is left for future research.

For the purpose of reporting simulation results, unless specifically stated otherwise, the parameterization of the seed and crop markets chosen for the benchmark scenario consisted of a crop-supply elasticity of $\eta = 0.5$, an own-price crop demand elasticity of $\varepsilon = -0.5$, an elasticity of substitution between seed x and other inputs used for crop production of $\sigma = 0.3$, and a 10% cost share of unimproved seed x_0 in crop production. Parameters relevant to the R&D sector involved $N = 5$ R&D firms, no costs of copying the enhancing seed ($\mu_{cost} = 0$), a legal IP protection period of $T = 20$ years, an interest rate $i = 10\%$ per year, and 40% shares of capital and labor in the R&D process ($\kappa_K = \kappa_L = 0.4$). Other parameters of the model are normalized to unity; these are the price of other inputs used in crop production (r) and the cost of producing unimproved and improved seeds (c_0 and c_1, respectively).

Letting q = "US" denote the country for which the new input is developed and q = "SA" represent the country receiving the technological spillover, simulations were conducted by fixing the US seed improvement factor at $\alpha_{US} = 10\%$ and allowing for two alternative spillover levels from the US to SA ($s_{SA} \equiv \alpha_{SA}/\alpha_{US}$): no spillover ($s_{SA} = 0$) and full spillover ($s_{SA} = 1$).[1] To explore the effects of legal IP, simulations were performed for a large range of feasible values of US appropriability ($\mu_{US,right}$), whereas SA appropriability ($\mu_{SA,right}$) was allowed to vary between 0% and 100% of the appropriability levels in the United States.

1. *The seed improvement factor represents the increase in crop yields attained by switching from the unimproved seed and can also be interpreted as the cost savings in crop production that would be attained if the enhanced seed were sold to farmers at the same price as the unimproved seed.*

In the reported simulations, the US and SA were assumed to have similar market shares in crop production and consumption before the introduction of the enhanced seed. These simulations correspond loosely to the US/SA RR soybean dispute. The United States grows approximately as many soybeans as do Brazil and Argentina, and 10% is a reasonable approximate estimate of the cost advantage of RR soybeans before the technology fee (e.g., Bullock & Nitsi, 2001). The RR technology was originally developed in the US and it spilled over into SA. United States producers pay a technology fee when they use this technology, and until very recently SA producers did not.

An Important Caveat

As with all ex ante counterfactual simulation models of this type, the results are best used to understand relative welfare impacts and the motivation and behavior of market participants. The results are not accurate enough to provide precise impact measures, nor can we say with precision how the world soybean market might have evolved over the past 20 years under different IP protection levels.

Results and Discussion

The main results from the simulations are summarized graphically in Figures 2 through 8. Importantly, the shapes of the relationships depicted in these graphs are robust under a wide range of parameters.[2] The graphs show expected welfare changes for a range of IP appropriability levels in the US ($\mu_{US,right}$) and SA appropriability varying between 0% and 100% of US appropriability (i.e., $0 \leq \mu_{SA,right} \leq \mu_{US,right}$). Simulations with varying SA appropriability levels are performed to explore the potential impact of introducing GURTs because, as mentioned earlier, GURTs have been advocated by some as a solution to the free-rider problem faced by R&D firms. By resorting to GURTs, R&D companies may be able to capture IP rents beyond those allowed by the legal IP protection in a particular country. However, because there is no consensus as to the extent to which the latter may occur, the simulations cover the potential range of SA appropriability after introduction of GURTs. In Figures 2, 3, 6, 7, and 8, panel A depicts no spillovers ($s_{SA} = 0$), whereas panel B illustrates the case of full spillovers ($s_{SA} = 1$).

Expected Change in US Producer Surplus

Figure 2A shows the expected change in US producer surplus in the absence of spillovers. United States farmers gain when there are no spillovers, because the improved technology allows them to gain market share from SA farmers. Expected US producer surplus increases with US IP appropriability up to a certain point, because in such a range higher appropriability provides stronger incentives for R&D firms to speed up the R&D process. Beyond a certain US appropriability level, however, US farmers' gains from speedier R&D are outweighed by the higher cost of technology fees charged by R&D firms. Note that SA IP appropriability does not affect the expected change in US farm surplus, because the technology is aimed at the United States and there are no spillovers to SA.

In the presence of full spillovers (as appears to have been the case with RR soybeans), US producers are always expected to lose when SA appropriability is zero (see Figure 2B). This occurs because full spillovers allow SA farmers to use the improved seed to compete against their US counterparts, and no SA appropriability means that SA farmers do not have to pay technology fees. Losses to US farmers increase monotonically with respect to US appropriability, as the latter spurs R&D, which puts US farmers at a clear disadvantage vis-à-vis SA producers.

According to Figure 2B, when there are full spillovers, US farmers are expected to lose even if SA farmers have to pay the same technology fees. Such an expected loss is a consequence of the inelastic demand assumed for the simulations, as the percentage increase in world crop output due to the innovation is smaller than the percentage decrease in crop price. As shown in Figure 3, had demand been assumed to be elastic, the expected welfare change of US producers under spillovers would have been positive but always smaller than their welfare change without spillovers.

A surprising result from Figures 2 and 3 is that holding US appropriability constant, US farmers' maximum expected loss in surplus occurs where SA appropriability is strictly positive rather than zero. In other words, US producers lose more if SA introducers a small license fee (as has recently occurred with the license fee that Brazilian producer have agreed to pay; see http://www.mindfully.org/GE/2005/Monsanto-Royalty-Brazil29mar05.htm).

2. *The exception to this assertion is the impact of demand elasticity on producer surplus. The effect of demand elasticity on producer surplus is addressed below in connection with Figures 2, 3, and 6.*

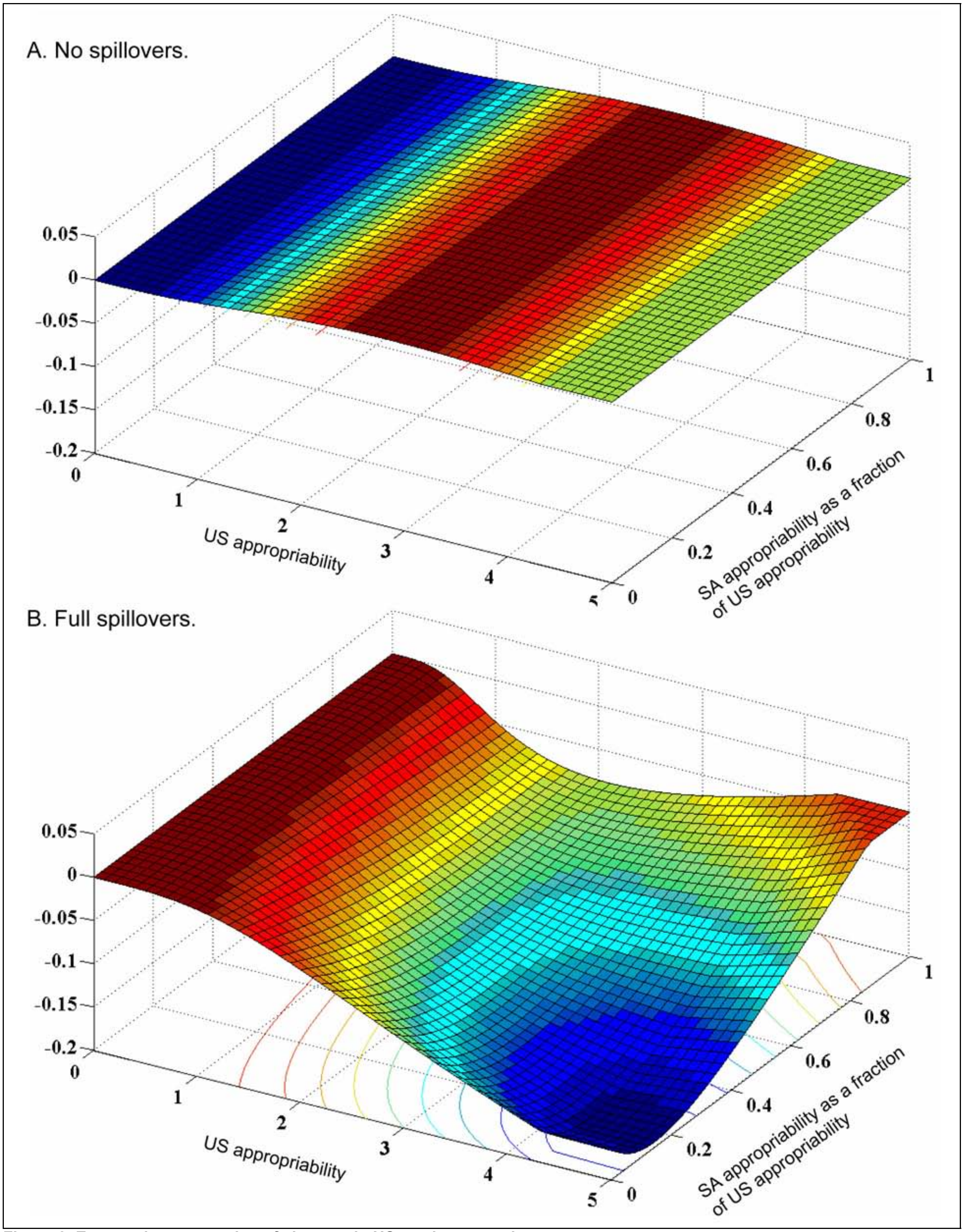

Figure 2. Expected present value of changes in US producer surplus.

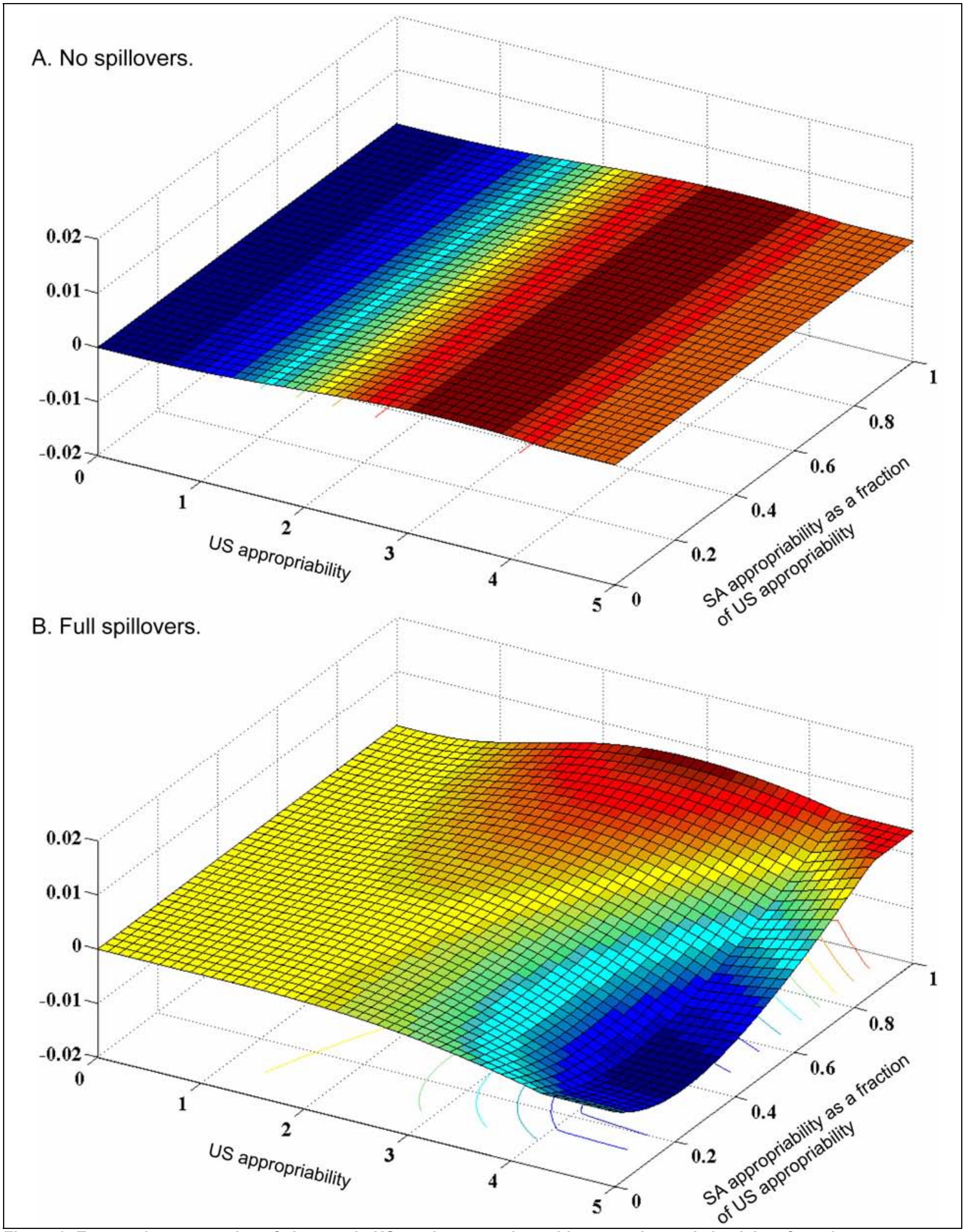

Figure 3. Expected present value of changes in US producer surplus, with a crop demand elasticity of ε = -1.5.

To explain this counterintuitive finding, let $\pi_{q,BeforePatent}$, $\pi_{q,DuringPatent}$, and $\pi_{q,AfterPatent}$ denote the equilibrium annual farm profits before the innovation, during the patent's life, and after patent's expiration, respectively (see Figure 1). In the presence of full spillovers, the innovation may provide a competitive advantage to SA farmers only during the life of the patent. That is, $\pi_{US,BeforePatent} = \pi_{SA,BeforePatent}$, $\pi_{US,DuringPatent} \leq \pi_{SA,DuringPatent}$, and $\pi_{US,AfterPatent} = \pi_{SA,AfterPatent}$. This is true because farmers in both the US and SA pay the same price for the "traditional" input before the innovation, and the innovative input's price is the same across the two regions after its patent expires. In contrast, US farmers must pay a higher price for the innovative input than their SA counterparts during the patent's life (except when appropriability in SA is the same as in the US). The different level of appropriability in the US and SA is the only reason why farmers' annual profits differ across countries. Thus, as shown in Figure 4, for a given level of US appropriability, annual profits for US farmers increase as SA appropriability increases, and the opposite is true for SA farmers' annual profits.

Unlike Figure 4, the graphs illustrated in Figures 2 and 3 are not monotonic in the level of SA appropriability when US appropriability is held constant. This fundamental difference stems from the fact that Figure 4 illustrates annual farm profits, whereas Figures 2 and 3 depict expected present values of changes in farm surplus. That is, Figures 2 and 3 take into account (a) changes in annual profits, (b) "capitalization," and (c) uncertainty.

Regarding (a) changes in annual profits, Figures 2 and 3 involve $[\pi_{US,DuringPatent} - \pi_{US,BeforePatent}]$ and $[\pi_{US,AfterPatent} - \pi_{US,BeforePatent}]$, rather than $\pi_{US,DuringPatent}$ only, as in Figure 4. As per (b) capitalization, $[\pi_{US,DuringPatent} - \pi_{US,BeforePatent}]$ and $[\pi_{US,AfterPatent} - \pi_{US,BeforePatent}]$ are annual flows occurring in the future, so they must be converted to a present value stock. If the innovative input were to be obtained immediately, the respective present value of such flows would be given by Equations 1 and 2:

$$\frac{[1-\exp(-iT)]}{i}[\pi_{US,DuringPatent} - \pi_{US,BeforePatent}], \quad (1)$$

$$\frac{\exp(-iT)}{i}[\pi_{US,AfterPatent} - \pi_{US,BeforePatent}]. \quad (2)$$

Equation 1 is the present value of changes in farm profits between now and the end of the legal IP protection period T, and Equation 2 is the present value of changes in farm profits that accrue after expiration of the legal protection.

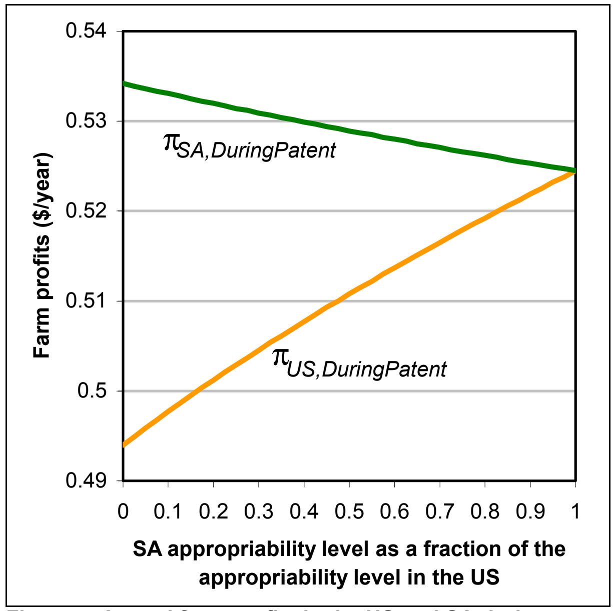

Figure 4. Annual farm profits in the US and SA during patent's life, assuming a US appropriability level of $\mu_{US,right}$ = 2.

Finally, regarding (c) uncertainty, the time when the innovation will be discovered is unknown ex ante. If the innovation does not occur immediately, the present value Equations 1 and 2 must be corrected to account for the fact that the flows involved will occur later in the future; that is, they must be discounted. Clearly, the less likely it is for the innovation to occur in the near future, the higher the discounting of Equations 1 and 2 should be (because the innovation is expected to take longer until it is obtained). The formulas corresponding to Equations 1 and 2 corrected for uncertainty are Equations 3 and 4, respectively (see, e.g., Lence et al., 2005):

$$\frac{1}{(1+i/H)}\frac{[1-\exp(-iT)]}{i}[\pi_{US,DuringPatent} - \pi_{US,BeforePatent}], \quad (3)$$

$$\frac{1}{(1+i/H)}\frac{\exp(-iT)}{i}[\pi_{US,AfterPatent} - \pi_{US,BeforePatent}], \quad (4)$$

where H denotes the equilibrium probability of the R&D sector obtaining the innovative input during the next unit of time.[3] The term $1/(1 + i/H) \in [0, 1]$ is a discount factor due to the uncertainty about the innovation's time of discovery. The uncertainty discount factor

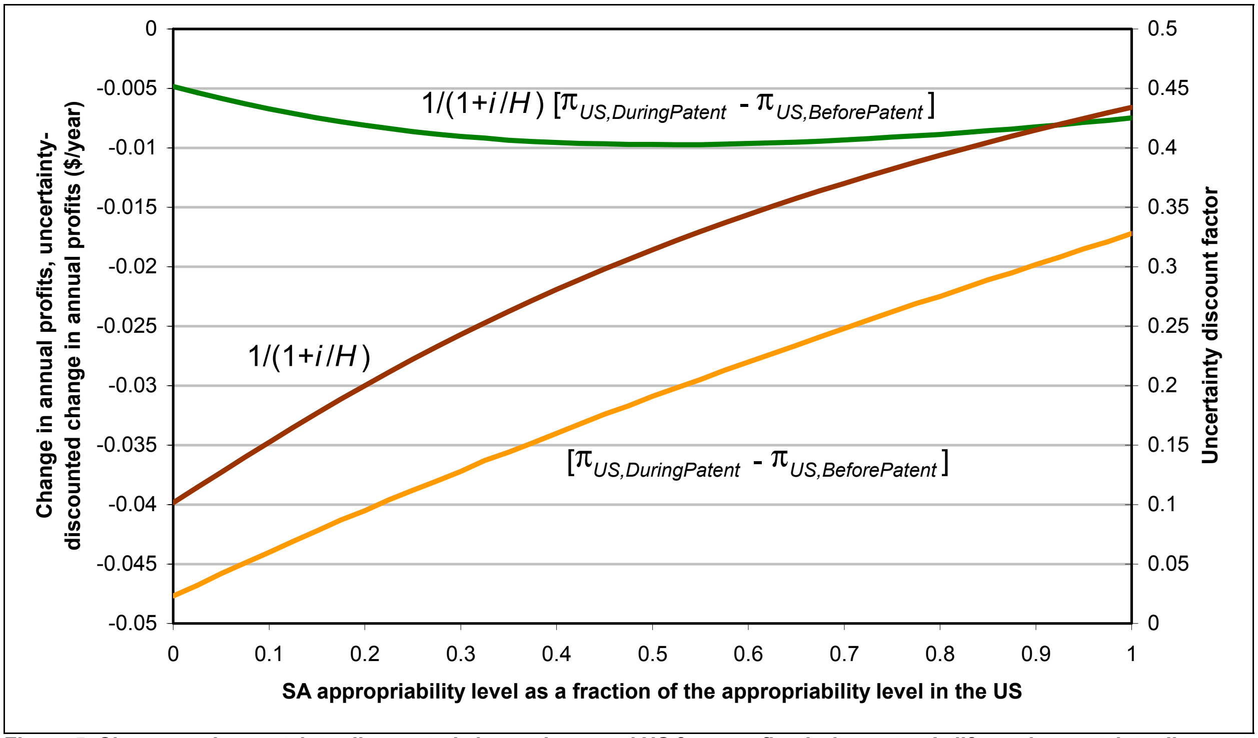

Figure 5. Change and uncertainty-discounted change in annual US farm profits during patent's life, and uncertainty discount factor, assuming a US appropriability level of $\mu_{US,right}$ = 2.

attains its smallest value of zero when the innovation is expected to never take place (i.e., $H = 0$), in which case Equations 3 and 4 equal zero. The factor approaches its highest value of one when the innovation is expected to occur immediately (i.e., $H \to \infty$), in which case Equations 3 and 4 yield Equations 1 and 2, respectively.

In Figures 2 and 3, the nonmonotonic curvature in the SA appropriability dimension is due to the interaction between the annual profit change $[\pi_{US,DuringPatent} - \pi_{US,BeforePatent}]$ and the uncertainty discount factor $1/(1 + i/H)$. Holding US appropriability constant, enhancing SA appropriability improves $[\pi_{US,DuringPatent} - \pi_{US,BeforePatent}]$ and encourages R&D activity, which increases the uncertainty discount factor $1/(1 + i/H)$ (see Figure 5). Importantly, the uncertainty discount factor increases at a much greater decreasing rate than the annual profit change does. Hence, because the annual profit change is negative when SA appropriability is low, a small increase in the latter makes the annual profit change slightly less negative but increases its present value more than proportionately because of the much higher uncertainty discount factor. In other words, increasing SA appropriability affects both the annual profit difference and the expected time to reach it. At low SA appropriability values, the annual profit difference for US farmers becomes less negative, but it is expected to be obtained much sooner. Because the latter effect outweighs the former, the uncertainty-discounted change in US farm profits ends up becoming more negative as SA appropriability increases (see Figure 5).

Expected Change in SA Producer Surplus

In contrast to US farmers, SA producers are always better off with full spillovers than without spillovers. Figure 6 shows that even though SA producers do not pay technology fees, they may lose under full spillovers when US appropriability levels are low. This somewhat counterintuitive outcome follows from the inelastic demand assumed to construct Figure 6, which implies that the percentage increase in total crop output induced by the technological innovation is smaller than the associated percentage reduction in price.

Under full spillovers and relatively low US appropriability, SA farmers cannot gain much market share from US farmers, because the latter pay small technology fees. Under such circumstances, SA farmers can

3. *More precisely, H dt is the probability that the innovation will occur over the next infinitesimal period of time dt. (Note that H can be greater than 1.)*

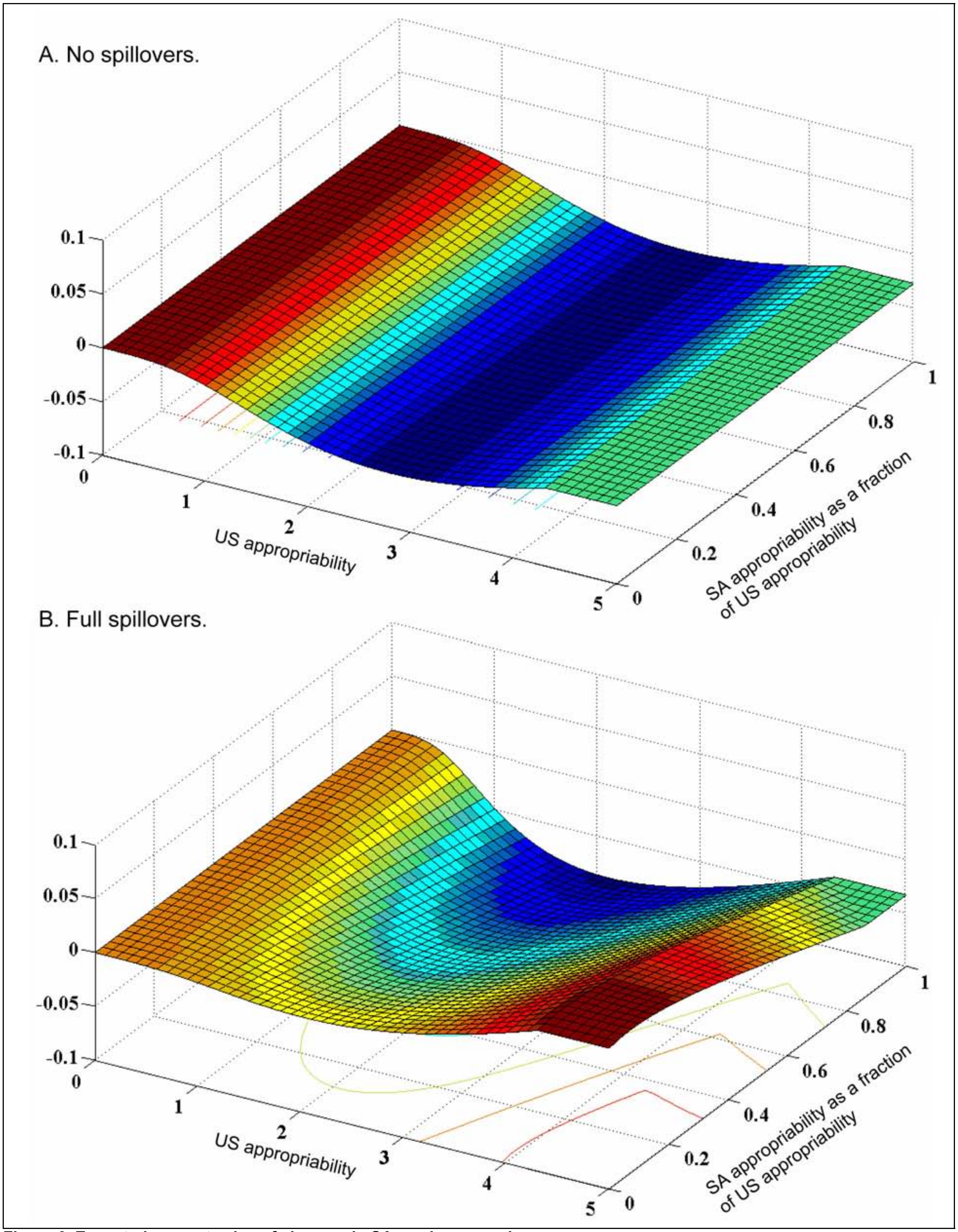

Figure 6. Expected present value of changes in SA producer surplus.

expect to lose even though they do not pay for the technology, because their additional output is not large enough to compensate for the reduction in crop prices. At sufficiently high US appropriability levels, however, technology fees charged to US farmers put them at such a disadvantage relative to SA farmers that the latter's gains in market share outweigh the lower crop prices induced by the innovation. Hence, under full spillovers and high US appropriability levels, SA farmers gain even if crop demand is inelastic.

With full spillovers and the same IP appropriability in both countries, the expected changes in producer surpluses are the same in SA as in the US (see Figures 2B and 6B). This is not surprising, because in such instances SA farmers are essentially identical to their US counterparts.

Interestingly, the expected change in SA producer surplus is not monotonically decreasing with the level of SA appropriability. The reason for this is analogous to the nonmonotonic relationship between the expected change in US producer surplus and SA appropriability discussed in the previous subsection. That is, there are two offsetting forces at work within the expected change in SA farm surplus: (a) the change in profitability for SA producers and (b) the expected time to discovery of the new technology. As SA appropriability increases, the change in SA farmers' profits is reduced, but the expected time to discovery is also reduced, because the higher SA appropriability translates into additional rents paid to R&D firms by SA farmers, which induces an expansion in R&D. At low SA appropriability levels, the latter effect dominates the first one, resulting in an increase in the expected present value of SA producer surplus as SA appropriability is raised.

Expected Change in R&D Surplus

Figure 7 shows that for a given level of spillovers, the expected surplus of the R&D industry increases monotonically with respect to IP appropriability in the United States. This is not surprising, as higher US appropriability enhances the prospects for R&D. However, the welfare of the R&D sector stays constant if US appropriability is raised beyond a certain level. The reason for this is that past such a point, higher appropriability would not allow R&D firms to charge higher technology fees, as doing so would induce farmers to switch back to the old technology.

Figure 7B also demonstrates that for any given level of US appropriability, the welfare of R&D firms rises monotonically with SA appropriability when there are full spillovers. This result is due to the same forces that enhance R&D welfare as US appropriability increases. However, the level of SA appropriability has important implications for R&D firms. If SA appropriability is zero, R&D firms are best off when there are no spillovers. This occurs because with full spillovers and no SA appropriability, R&D firms can only capture rents from the US farm sector, and the absolute size of the latter falls as it is out-competed by SA farmers. In contrast, if SA appropriability is the same as in the US, expected R&D firms' welfare is maximized with full spillovers. Equalizing appropriability across countries gives R&D firms a strong incentive to conduct research of relevance to both countries.

Expected Change in Total World Surplus

In the present model, expected total world welfare is defined as the sum of expected producer and consumer surpluses across regions plus the expected R&D industry surplus. As illustrated in Figure 8, the expected change in total world welfare tends to rise as US appropriability grows up to a certain point and tends to decrease slightly as US appropriability increases past such a point. Rising appropriability induces both higher technology fees and greater R&D. R&D ultimately increases consumption, but higher fees lead to lower consumption, and the former effect is more than offset by the latter over the decreasing region.

Interestingly, if SA appropriability is zero, expected world welfare is substantially higher with full spillovers, even though US producers and R&D firms are better off with no spillovers (see Figures 2, 3, and 7). This may be explained by the fact that full spillovers make consumers substantially better off and, to a lesser extent, also make SA producers better off (see Figure 6). Figure 8 implies that with no SA appropriability, the full spillover gains to all consumers and SA farmers far outweigh the spillover losses to US farmers and R&D firms.

With full spillovers, expected total world welfare rises as SA appropriability increases, but after a certain level of SA appropriability is reached it falls as SA appropriability grows. This occurs because under very high IP protection in SA, R&D firms capture almost all of the rents associated with improved technology, thereby introducing the welfare losses that characterize less than perfectly competitive markets.

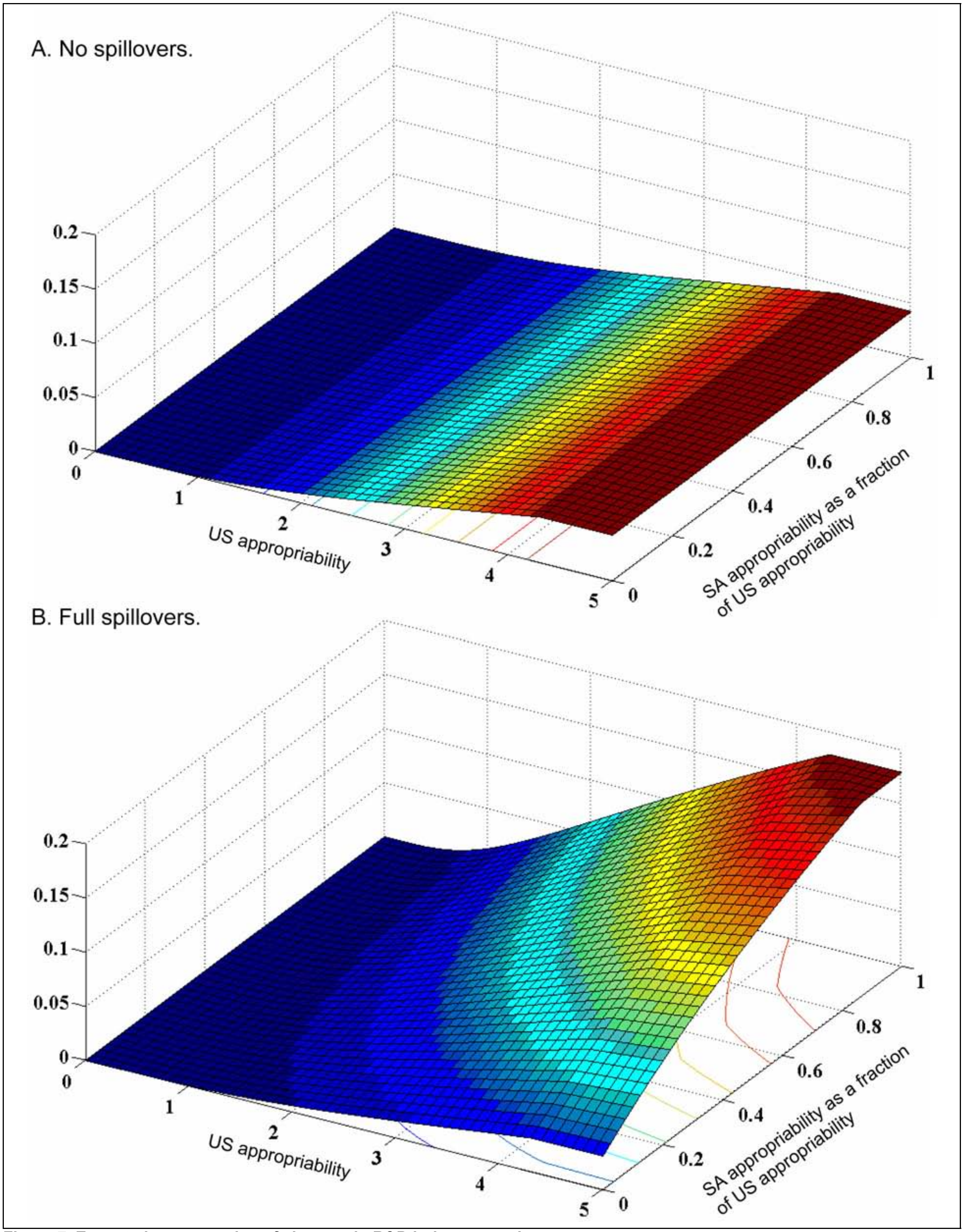

Figure 7. Expected present value of changes in R&D industry surplus.

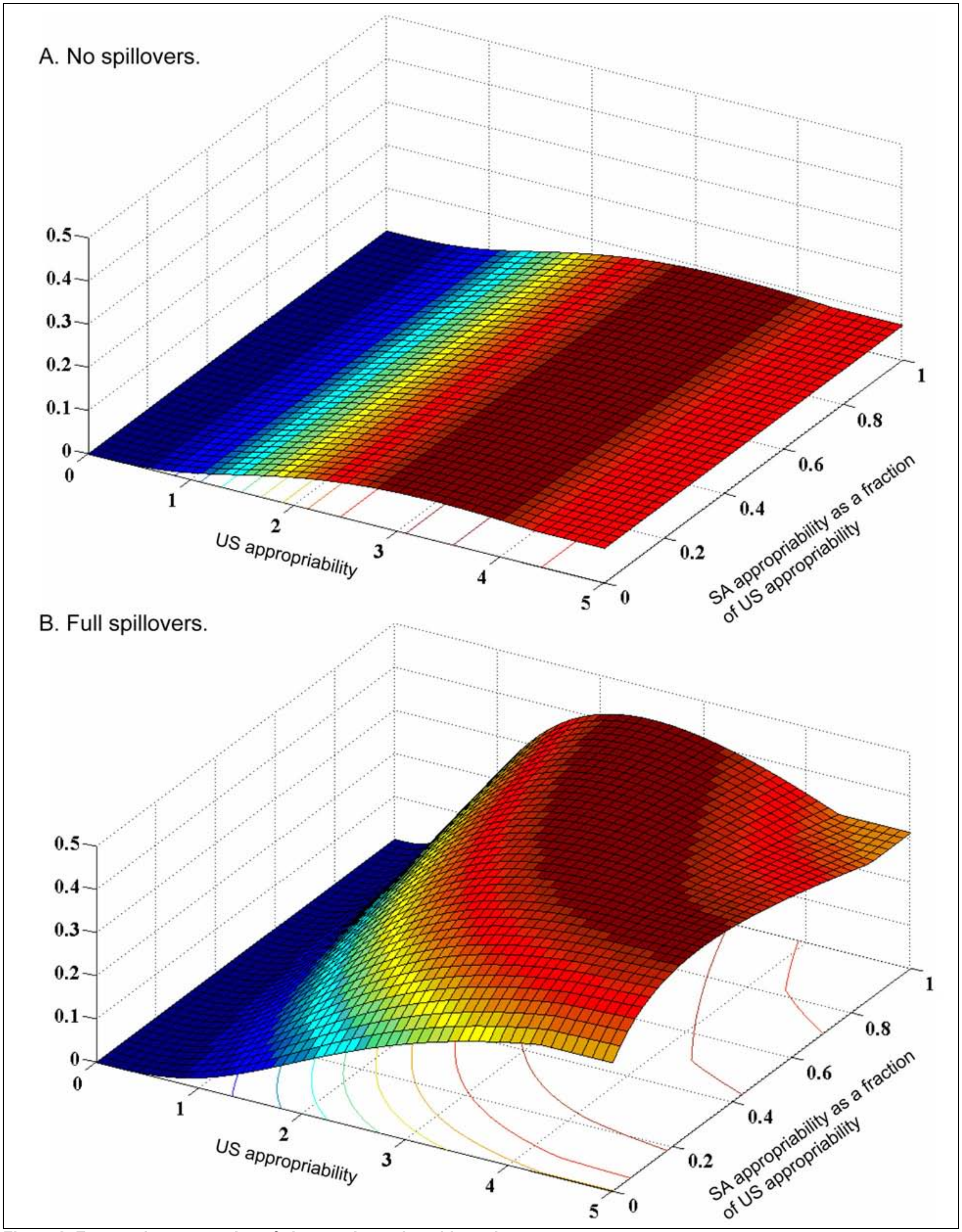

Figure 8. Expected present value of changes in total world surplus.

Concluding Remarks

The possibility of technology spillovers across countries raises important incentive and distributional issues, in particular when the level of IP protection is substantially different across countries. These issues are currently relevant, as demonstrated by the gains in market share experienced by South American soybean producers and the reduction in market share by US producers after the introduction of Roundup Ready soybeans. RR soybeans were likely developed for US farmers, who were expected to pay a fee for the technology. However, RR soybeans proved to be very successful in South American conditions, and farmers in Argentina and Brazil were able to use them at little, if any, extra cost.

The present study evaluates and compares the welfare impacts of using legal mechanisms (e.g., patents) and technical methods (e.g., GURTs) to protect IP, in the presence of R&D improvements that exhibit spillovers. Importantly, the analysis is performed from an ex ante perspective (i.e., before the innovation is obtained) so as to specifically account for the research firms' incentives to engage in R&D.

The present results indicate that technology fees that are charged in one country and not in the other are harmful to producers in the first country when spillover is high. They also suggest that neither producers in the first country nor R&D firms have incentives to promote, finance, or develop technologies that can be easily adopted in countries with low IP protection. The results also suggest that this outcome is unfortunate, because total world welfare is expected to be higher when transferable R&D is conducted. This is a classic free-rider problem.

It is also found that the welfare of R&D firms rises monotically with appropriability in the country for which they target the improved technology, regardless of whether the other country protects IP or not. However, R&D firms' welfare is greater under no spillovers than with full spillovers if the second country does not protect IP, whereas the opposite is true if the levels of IP protection are identical across countries. Thus, equalizing appropriability across countries gives R&D firms a strong incentive to conduct R&D of relevance to both countries.

Counterintuitively, the present value of the expected change in surplus for the producers' targeted for the new technology does not increase monotonically with the appropriability level in the competing country. This occurs because there are two major forces driving such surplus, namely, the change in producers' profitability, and the expected time to discovery of the new technology. As appropriability in the competing country increases, the change in the targeted farmers' profits becomes less negative, but the expected time to discovery is reduced because the competing farmers pay additional R&D fees, which induce greater R&D. For low appropriability levels in the competing country, the latter effect dominates the first one, resulting in an increase in the expected present value of producer surplus as IP appropriability in the competing country is raised.

Genetic use restriction technologies may allow the firms involved in the research and development of improved seeds to collect technology fees even where legal IP protection is weak. Simulation results suggest that to the extent that GURTs contribute toward harmonization of international IP protection, they can be world-welfare enhancing. However, increasing appropriability above a certain level may be undesirable, as there is a point beyond which stronger appropriability reduces world welfare under harmonization. If GURTs were to extend IP protection beyond this optimal level, they would provide excessive IP protection as well. This suggests that a possible strategy to maximize world welfare may be to rely upon usage of GURTs together with restrictions on the degree to which R&D firms are allowed to capture IP rents.

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