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Elite Germplasm for GMO's in Brazil: Modeling Government-Agribusiness Negotiations

ABSTRACT: Advances in agricultural biotechnology have led to interest by agribusiness to license elite germplasm from national programs in developing countries, now in need of funds. Uncertainties about the value of the material have delayed negotiations. This article proposes a method of setting upper (monopoly; no seed saving) and lower (competitive) negotiating bounds on values. The model accounts for (1) annual productivity enhancements, (2) effects on world prices, and (3) obsolescence effects of greater R&D. A demonstration application for soybeans in Brazil, which has completed the preconditions (IPR, biosafety, internal policy), suggests limited private value for public germplasm. The optimal solution is cooperation (licensing).

INTRODUCTION

Agricultural biotechnology is largely a U.S. creation. The original Cohen–Boyer transformation techniques were developed there, the private sector made its major initial investments there, and the U.S. government adopted the first comprehensive regulatory system (in 1986 and 1990). It was no surprise the first transgenic

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crop, the FlavrSavr® tomato, was introduced in the U.S. (in 1992), and U.S. acreage of genetically modified crops leads the world (James, 1999).

With this level of U.S. market dominance, the current focus of agri-biotechnology firms has been on expanding sales to overseas markets. Sharp opposition to genetically engineered foods has limited the potential in the EU so that, instead, attention has focused on developing countries. The target countries are those with large commercial agricultural sectors relatively free of governmental control. The larger Latin American nations fit this scenario, with Argentina already a major participant. An obvious second target nation is Brazil, the largest nation in Latin America geographically and second worldwide in soybean exports. This article uses as an example efforts, particularly by Pharmacia (formerly Monsanto), to sell bioengineered soybean products in Brazil using Brazilian soybean germplasm. We consider one aspect of the technology marketing process—a means for governments to identify the value of elite germplasm as the delivery vehicle for GMO's technologies.

In a broader context, the issues considered here are not limited to a single country or firm—the identification of Brazil and Pharmacia is done solely to provide a context and motivation for the model building. Moreover, the pricing of developing country genetic resources, too, is broadly applicable to pharmaceuticals and cosmetics, among other products. However, the structure of the model as presented here to include periodic improvements (successive new varieties) limits its application to agricultural products.

Soybean Production in Brazil

Following 50 years of an inward-focused economy, sweeping economic reforms were implemented in Brazil in 1994. Over the next several years, the economy grew strongly, but in January 1999 the *real* plunged by 40%. The direct consequence for agriculture has been to make Brazil highly competitive on world markets. However, budget cutting extended to the Brazilian Agricultural Research Corporation (Embrapa), the research arm of the Ministry of Agriculture, which recently was mandated to raise some 30% of its own revenues (Hudson, 1998; World Bank, 2000) compared with 10% previously.

Brazil produces about 30 million tons and exports an equivalent of 19 million tons of beans. Brazil holds 23% of the world market for (soy) beans (second to the U.S.), 29% for meal (first), and 19% for oil (second to Argentina) (USDA-Foreign Agricultural Service and ABIOVE).

For the past 20 years, Embrapa has released on average two soybean varieties a year, equivalent to one for each major (central and southern) region (Warnken, 1999). A sizeable private seed sector also exists; Pharmacia bought some local soy breeding programs, forming its own breeding and seed company called Monsoy.

However, Monsoy varieties are presently not as productive as Embrapa's current offerings.

Only one Embrapa research center, CENARGEN (National Research Center for Genetic Resources and Biotechnology), with an annual budget of about $1.8 million, has responsibility for biotechnology research. Embrapa employed 61 professional personnel at the National Soybean Research Center in 1995, compared with 156 in the U.S. in 1994 (101 private, 55 public) (Warnken, 1999; Frey, 1996).

Given this relatively small budget, the decision was made to access externally developed technologies when available. Thus, technologies applicable to soybeans are to be accessed rather than redeveloped, and Pharmacia is an obvious source for those technologies. This article addresses the issue of the terms of any agreement with Pharmacia, but first it must be determined if the property rights and regulatory arrangements are in place to satisfy the needs of the private sector.

Brazilian IPR, Regulations, and Technology Transfer Agreements

As part of the 1994 economic reforms directed to attracting foreign investment, and to comply with Brazil's commitments under the TRIPs (Trade-Related Aspects of Intellectual Property Rights) appendix to the WTO (World Trade Organization), a number of sweeping changes have been made in property rights legislation and biotechnology in recent years. Here, only those applicable to accessing seed-based technologies will be highlighted.

Patents

The Brazilian patent law was revised in 1996 (Law No. 9.279). Following the minimum requirements of TRIPs, patents are not permitted for plants or animals. However, the law is silent on whether gene constructs can be patented (a silence found in most countries). At the same time, a "pipeline" clause (Article 229) applies "to all applications pending" which had received patent protection in other countries. Pharmacia and other firms were thus able to patent soybean technologies in Brazil.

Plant Breeders' Rights (PBR)

A Brazilian PBR law (No. 9,456) was passed in 1997 following the 1978 Act of UPOV (International Convention for the Protection of New Varieties of Plants). Although the Brazilian law follows the 1978 Act in most respects, it does incorporate the "essentially derived" component of the 1991 Act (Article 14.5). Essential derivation establishes a hierarchical dependency situation whereby a variety identified as "essentially derived" cannot be commercialized without the permission of the owner of the initial variety. Among the ways that a variety may be judged as "essentially derived" is transformation by genetic engineering. That is, for purposes here, if Pharmacia were to transform a protected Embrapa soybean variety using its technologies, the resultant material could not legally be commercialized without permission from Embrapa. Embrapa used a 'pipeline-like' clause to protect previously released varieties on adoption of the PBR legislation. PBR clarifies the ownership of these improved materials. For purposes here, it is assumed that Embrapa has the necessary legal rights to sell the products of its breeding programs.

Biosafety

Most countries require an assessment for environmental safety before the full commercial release of genetically modified crops. Brazil adopted a national biosafety law in 1995. An early application was for bioengineered glyphosate resistant soybeans.

Food safety is an additional important consideration, but as humans and animals worldwide react uniformly to the same food toxins, it is an accepted practice to allow a granting of food safety based on an approved application elsewhere in the world.

Embrapa Intellectual Property Rights Policy

In the totally public sector environment that prevailed until recently in Brazilian agriculture, there was no need for policies on ownership and relationships with the private sector. Recent internal and external factors have, however, changed that, indicating the need for specific policies covering public/private sector relationships (Sampaio and Brito da Cunha, 1999). Embrapa in 1995 adopted a general policy including, among others, the objective of maximizing the returns from assets produced by the research program, when not conflicting with Embrapa's social mission. A recent (September 1998) implementation step has been the establishment of an "Intellectual Property Secretariat" with responsibility to negotiate access rights with Pharmacia and other private sector firms for the use of Embrapa varieties (see Maredia, Erbisch, and Sampaio, 2000).

Objectives

All the components are in place: (1) Pharmacia is motivated to license Embrapa soybean varieties as the best delivery vehicle for its herbicide resistant technologies; (2) Embrapa is looking to such agreements as a source of self-funding for research; and (3) intellectual property and food and bio-safety regulations are in place to protect investors, the public, and the environment.

Although much of this has been true for several years, no agreement has yet been reached. One complicating factor, according to those familiar with Embrapa, has been a fundamental uncertainty within Embrapa of the value of its varieties and possible effects on public welfare, leading to reluctance to complete an agreement. Here we develop those aspects specifically for the licensing of soybean varieties in Brazil.

The specific objectives are twofold: (1) develop a general conceptual model for the valuation of licensed germplasm, and (2) provide preliminary estimates of the upper and lower bounds for the value of soybean germplasm in Brazil. The model is intended to be general, while the preliminary figures can subsequently be modified as needed for negotiation purposes. The model is sufficient to establish minimum and maximum values only with any final agreed value expected to fall between those limits.

The figures developed herein, while approximate, are for demonstrative purposes only and should not be taken to represent current market values. An actual application would also likely include sensitivity analysis that is excluded here because of the demonstration role of our application. Furthermore, the numbers are all deterministic so that any risk premium sought by either party would be an aspect of the negotiation. The rapid and monotonically rising adoption of herbicide resistant soybeans in the U.S. through 2000 does suggest there are no unexpected issues with growing (as contrasted with market acceptance of) these products (see McBride and Brooks, 1999 for an overview of survey evidence on the U.S. experience).

MODEL

An agricultural biotechnology product combining genetically engineered genes with elite cultivars creates a classic joint product valuation problem—how to determine the value contributed by each component? Here we develop a model designed to do just that, while considering relevant seed market characteristics, particularly that (1) variety price is associated with the net productivity enhancement of the new variety, and (2) the availability of improved (next generation) varieties reduces the market for older varieties. The model functions by establishing high and low price points, with an exchange price expected to be negotiated between those extremes. It is, in general, not possible to determine the exchange price as it depends on the market power balance between the component suppliers, as well as calculations of market shares should the varieties compete in the market.

Specifically, the model must allow for the following:

1. Productivity enhancement of new varieties, referred to here as k, a standard increment for every new variety i. The k is as assessed by farmers compared with previously available materials. That is, k may be the result of a new attribute or, more commonly, the restoration (maintenance breeding) of productivity that ebbed over time as pests and diseases evolved with a variety. From a farmer's perspective, any source of k is equivalent as a contribution

to profitability. It is assumed here that the variety and genetically engineered trait (herbicide resistance in our soybean example) combined to create a GMO are additive with no interactive effect on variety obsolescence. If there were such an effect on obsolescence, then research costs would increase but the basic model structure would be unchanged as the model operates as if new seed were purchased annually. In a competitive market, a variety's value is associated with the net productivity enhancement, where productivity refers to higher yields and/or lower production costs, and/or improved product quality (such as higher oil content).

2. Calculation of the effects of productivity improvements on world supply and prices.
3. Monopoly sales of a variety with no seed savings (as is possible to require with patented plants or plant parts).
4. Recognition by firms of the effects of their own R&D efforts on the output of new varieties and, through competition, on sales of existing (now relatively less productive) varieties. Moreover, in concentrated markets, firms will also be conscious of the R&D investments of competing firms.

Perfect Competition

Consider first varietal value and pricing under perfect competition. A profit-maximizing firm solves:

$$\max_{Q} pf(Q) - rQ - C(Q,Z), \tag{1}$$

where: p is output price, Q is quantity of input (seed), r is input (seed) price, and C is all other input costs defined as a function of seed quantity and other variables Z. Assuming $f()$ is concave in Q and $C()$ is convex, the necessary and sufficient first-order condition for a maximum is:

$$pf'(Q) = r + \frac{\partial C}{\partial Q} \text{ or } r = pf'(Q) - \frac{\partial C}{\partial Q} \tag{2}$$

This is just the standard notion of marginal value product equaling marginal cost and ultimately provides the input price the firm (farmer) is willing to pay for the seed. For simplicity, we can assume that at least over the relevant range of Q, that output is proportional to input seed quantity (i.e., $f'(Q) = \phi$, a constant).

Now consider a perfectly competitive output market scheme, but as a result of breeding or other technological change, productivity of the seed is enhanced by a factor of k. The first-order condition for the profit-maximizing firm for the new seed variety i with productivity enhancement k_i is:

$$pf'(Q_i) \cdot (1 + k_i) = r_i + \frac{\partial C}{\partial Q_i} \text{ or } r_i = pf'(Q_i) \cdot (1 + k_i) - \frac{\partial C}{\partial Q_i} \tag{3}$$

where i corresponds to the improved variety. Thus, we have $r_i > r$ and the difference is proportional to $(1+k_i)-\partial C/\partial Q_i$. Intuitively this makes sense since the firm (farmer) is now willing to pay more for the productivity-enhanced seed. For simplicity, we shall assume that a "new variety" always corresponds to a productivity increase of approximately k.

Monopoly Sales

Now, imagine the technological advancement produced as above, but with a monopolist supplier of technology. This case would apply, for example, for varieties that were protected by patents or (at national discretion) Plant Breeders' Rights, and recognizing varietal improvement as a sequential process, r can be thought of as a vector of sequential improvements. The monopolist firm will recognize that the value of r_i would decline in part as a consequence of the supply of additional (i.e., subsequent) improved varieties, r_j, $j > i$. That is, the farmer would be willing to pay less for a variety today if sequential improved varieties are forthcoming.

Strictly speaking, the last statement holds only if the crop can be used as a seed source for subsequent seasons, something allowed under most national PBR laws, but generally prohibited for patented materials. This suggests, in turn, different models must be used for patented and PBR-protected varieties, a major complication. However, Hansen and Knudson (1996) have shown that seed companies can appropriate most of the value for varieties used for multiple seasons, since farmers are willing to pay a higher price initially for a multiseason variety than for one used only once. Thus, if the marginal costs of producing and distributing seed along with cash flow considerations are ignored, for purposes here we can treat all seeds as if they were purchased annually.

Now consider the marginal revenue of the monopolist technology firm, where the monopolist can influence price (r_j) by limiting release quantities of sequential varieties (Q_j). From total revenue, $TR = r_j Q_j$, we can write marginal revenue as:

$$MR = r_j + \frac{\mathrm{d}r_j}{\mathrm{d}Q_j} \cdot Q_j = r_j\left(1 + \frac{\mathrm{d}r_j}{\mathrm{d}Q_j}\frac{Q_j}{r_j}\right) = r_j\left(1 + \frac{1}{\eta}\right) = r_j\left(1 - \frac{1}{|\eta|}\right) \tag{4}$$

where η is the market demand elasticity for varietal improvement Q_j $[(\mathrm{d}Q_j / \mathrm{d}r_j)(r_j / Q_j)]$. Intuitively, this compares with the traditional-sense monopolist quantity restriction, but here is interpreted as the restriction of the sale of forthcoming varieties. Since we do not have market estimates of the demand elasticity for innovation, it is decomposed into component parts, as follows.

First define ϵ as the supply elasticity of innovation, where:

$$\epsilon = \frac{\%\Delta\ Q_j}{\%\Delta\ I} = \frac{dQ_j}{dI}\frac{I}{Q_j}. \tag{5}$$

The elasticity of innovation can be interpreted as the relative percentage change in sales of new varieties to a change in innovation effort (I), $\epsilon > 0$. This can be thought of as a firm productivity characteristic, for example, the change in new varieties relative to your research staff, or hours worked, *ceterus paribus.* This elasticity is expected to vary across firms given the productivity of their scientists.

Next, we need to relate the price change in varieties to supply response and, as will be shown, incorporate a varietal supply restriction in terms of the frequency of release of subsequent varieties. To do this, define δ as the own-price effort elasticity, then:

$$\delta = \frac{\%\Delta I}{\%\Delta\ r_j} = \frac{dI}{dr_j}\frac{r_j}{I}. \tag{6}$$

In contrast to ϵ, the effort elasticity (δ) can be thought of as a cost efficiency characteristic of the monopolist firm which describes the change in effort level (to develop more or fewer varieties per unit time) from a change in varietal prices. In other words, holding all else constant, and given an expected change in price, a relatively more cost-efficient breeder of varieties would be willing to expend more effort to develop subsequent varieties, thus implying more varieties produced per unit of time. New varieties, however, reduce the commercial life of existing ones so that, if firm *i* receives more for its product today, it would be willing to contribute less effort for production of new varieties; hence $\delta < 0$. Because we do not know levels of δ for individual breeding firms, we assume a proxy variable for this where $|\delta|$ is measured as the number of new varieties per unit of time; that is, as δ increases, *ceterus paribus,* the time increment between varieties should decrease. Note that δ applies to the breeder (Embrapa in our example), not to the biotech firm supplying the specialized genes.

Returning to our monopolist technology supplying firm's marginal revenue function, by substitution we have:

$$MR = r_j\left(1 + \frac{1}{\epsilon\delta}\right) = r_j\left(1 - \frac{1}{\epsilon|\delta|}\right). \tag{7}$$

Substituting these results into our first-order conditions for the firm purchasing the (seed) input Q_j we have:

$$pf'(Q_j) \cdot (1 + k_j) = r_j\left(1 - \frac{1}{\epsilon|\delta|}\right) + \frac{\partial C_j}{\partial Qj} \text{ or } r_j = \frac{pf'(Q_j) \cdot (1 + k_j) - \dfrac{\partial C_j}{\partial Q_j}}{1 - \dfrac{1}{\epsilon|\delta|}} \quad (8)$$

Market Rivalry

Finally, consider the case where the technology supply industry is an oligopsony, where firms are conscious of the actions and reactions of their competitors. Innovation and effort elasticities can be defined for a firm's competitors analogously to the above, except now the resulting impact on the market demand elasticity varietal improvements is manifested in the resulting relative relations between the competing firm's innovation and effort elasticities. To make this clearer, we introduce a little more notation. First define Ψ_i to be the total elasticity of varietal improvement, where, from above, $\Psi_i = \epsilon_i|\delta_i|$, and in the case of the monopoly $\Psi_i \equiv |\eta|$. Next let Ω_i be the total elasticity of varietal improvement for firm i's competitors; that is, what firm i conjectures to be his or her competitor's (say firm h) $\Psi_{h.}$ Thus, $\Omega_i = \Psi_h = \epsilon_h|\delta_h|$. Finally, since the resulting impact on the market is the relative contribution of both components, we can infer: $|\eta| \equiv \Psi_i/\Omega_{i.}$ Substituting this relationship into (8) we have:

$$r_{ij} = \frac{pf'(Q_{ij}) \cdot (1 + k_{ij}) - \dfrac{\partial C_{ij}}{\partial Q_{ij}}}{1 - \dfrac{\Omega_i}{\Psi_i},} \quad (9)$$

where *i* represents technology supplying firm *i* of variety *j*.

This relation makes intuitive sense. For instance, if firm *i*'s total varietal elasticity is higher than a competitor's, *i*'s varietal improvements are more frequent on the market place and, *ceterus paribus,* should be worth relatively less today to the profit maximizing firms (farms) purchasing input Q_{ij} at $r_{ij.}$ This total elasticity concept then is derived from firm innovation and effort elasticities.

World Price Effects

To account for world price effects from productivity-enhanced supply shifts, we adopt the methodology developed in Alston, Norton, and Pardey (1995) for an open-economy, exporter (large country) innovation, with no technology spill-overs. We consider two markets, Brazil and rest of the world (ROW), with horizontal shifts in supply from productivity enhancements. World price reductions are solved for based on linear supply and demand relationships, where domestic supply is a function of price and the technology supply shifter, *k*. Other supply and demand equations are functions of equilibrium world price only.

Because we cannot empirically estimate these equations (with a forthcoming productivity shifter), we use reasonable elasticity and productivity estimates. The linear supply and demand trade model (see below) can then be used to derive world price effects based on elasticities and export shares. Assuming the pre-adoption prices, quantities, and relevant elasticities are known, and using the trade equilibrium assumption, the absolute value of the relative change in price (Z) can be expressed as:

$$Z = \epsilon_A K / [\epsilon_A + s_A \eta_A + (1 - s_A)\eta_{EB}], \tag{10}$$

where ϵ_A is the domestic (Brazil) supply elasticity, η_A is the absolute value of the domestic demand elasticity, η_{EB} is the absolute value of the elasticity of ROW excess demand (calculated based on ROW supply and demand, domestic exports, and ROW demand and supply elasticities), s_A is the share of domestic production consumed domestically, and K is the vertical shift of the supply function expressed as a proportion of the initial price. Assuming the use of variable or quasi-fixed inputs does not change to bring forth the projected yield increase, the net cost change in time t, $k_t^{*,}$ can be estimated by using the productivity enhancement (k_t) as:

$$k_t^* = (k_t / \epsilon_A) WP_{t-1}, \tag{11}$$

where WP is world price. Finally, the relative shifts (K) in supply can be derived as:

$$K_t = k_t^* / WP_t. \tag{12}$$

Producer and Consumer Surpluses

In addition to production, consumption, and world price effects, welfare effects of the productivity enhancements (via changing world prices) are also calculated. As derived in Alston, Norton, and Pardey (1995), the changes in producer and consumer surpluses can be calculated as:

$$\Delta CS_{A,t} = WP_{t-1} C_{A,t-1} Z(1 + 0.5Z\eta_A), \tag{13}$$

$$\Delta PS_{A,t} = WP_{t-1} Q_{A,t-1} (K - Z)(1 + 0.5Z\epsilon_A), \tag{14}$$

$$\Delta CS_{B,t} = WP_{t-1} C_{B,t-1} Z(1 + 0.5Z\eta_B), \text{ and} \tag{15}$$

$$\Delta PS_{B,t} = WP_{t-1} Q_{B,t-1} Z(1 + 0.5Z\epsilon_B), \tag{16}$$

where ΔCS and ΔPS are changes in consumer and producer surpluses in time t, respectively (A = Brazil, B = ROW), C is consumption in time t, and Q is

Table 1. Starting Values and Parameter Assumptions

Factor	*Value*	*Source(s)*
ε_A	0.85	Sadoulet and de Janvry (1995)
η_A	0.03	Sadoulet and de Janvry (1995)
η_{EB}	2.704	Heien and Pick (1991)
s_A	.35	Computed from USDA
ε_{ES}	1.37	Computed
ε	3	Assumed for Embrapa alone
	4	Assumed for Pharmacia alone
	4	Cooperative (max. of two)
δ	1	Embrapa (1/varietal release time$^{1/2}$)
	.447	Pharmacia (1/varietal release time$^{1/2}$)
r_j	$36.32/ha	USDA-Attache Reports
Q_j	.80 mt	Computed from initial plantings of 11.9m ha. and seeding rate
Yield	2.3 mt/ha	USDA-FAS
Seeding rate	.067 mt/ha	Greaser, 1991
dC/dQ	$7677/mt	Calculated costs from USDA and FECOTRIGO ($514/ha)
P	$235/mt	Initial World Price

production in time t. Total changes in welfare in each region can be determined by summing the producer and consumer surpluses.

ESTIMATES

We estimate the previous model, applied to soybean germplasm in Brazil. The section first presents the parameter values used, then the results using three scenarios for the supply of transgenic soybean seeds: (a) Embrapa alone, (b) Pharmacia alone, and (c) combined. Scenarios (a) and (b) represent the base bargaining positions of Embrapa and Pharmacia respectively, while (c) represents the benefits to cooperation, thereby establishing the high and low values for the two participants, and the bargaining range. We attempt to identify and fit scenario values that are reflective of field conditions, but recognize that many other figures could be used as well. Thus, we propose this section as more reflective of how the model can be used than it is of establishing any value of direct use in negotiations.

Parameters and Starting Values

To assess the seed market and the values involved in the innovations, a trade model was used to calculate the impact of a new seed variety on production and therefore on world price (Eq. 10). The word price and quantities produced determine farm revenues, and the value of the seed is related to its marginal benefits (Eq. 8). The seed price and quantities determine the revenues for the seed industry. Calculations are based on aggregated and average data for the soybean market. Elasticities, world price, imputed domestic share, and other parameters are listed in Table 1. Production and consumption values for Brazil and ROW are five-year average levels.

The calculation of production effects requires information on productivity of the soybean varieties with and without herbicide resistance (discussed below), as well as baseline prices and production costs. The initial seed demand in Brazil was computed based on initial production, yields, and an assumed seeding rate of 0.067 mt/ha. The initial seed price was converted to $U.S. per metric ton for ease of calculation in the simulation model, and can be converted readily to the more familiar hectare basis. The average costs of production ($514/ha. excluding seed costs) are used as an estimate for dC/dQ and were calibrated from the initial seed price in the model to the actual assumed seed price in Table 1.

Table 1 contains no *ex ante* estimates of the supply elasticity of innovation (ϵ) and the own-price effort elasticity (δ). This is because we lack data for computing them, and instead resort to using fitted values which give 'reasonable' starting values for soybean seed prices and other results. It was assumed that innovation elasticities are highly elastic while the own-price effort elasticity estimates were calculated via the proxy measure explained above. Note also the assumption that Embrapa releases new varieties each year, with a 1% productivity enhancement, while Pharmacia's technology provides a 4.7% productivity increase (James, 1998), but is released in new varieties only every five years because of costs and regulatory requirements. If Pharmacia cannot license Embrapa's newest releases, then it must use those from Monsoy which are assumed to be five years behind Embrapa's in productivity. These assumptions are key in determining the results.

World price, consumption, and demand quantities were estimated annually over a 20-year period. In addition, since the productivity-related supply shifts affect the inherent elasticity estimates these were recalculated and adjusted over the period as well.

Results

We estimate three scenarios as follows: (1) Embrapa alone, 100% current market share, and 1% annual productivity increase. (This is the baseline scenario reflecting the maximum Embrapa revenue under a profit maximizing pricing plan.); (2) Pharmacia alone, 100% Embrapa's current market share, 4.7% initial productivity increase starting 5 generations back, then 5% in five-year increments. (This is Pharmacia's maximum revenue with no cooperation.); (3) cooperative scenario combining productivity increases with current generation. (This represents the maximum combined revenue that can be divided between Embrapa and Pharmacia.)

Although the assumed parameter estimates and averaged supply and demand levels are somewhat arbitrary, for purposes here, the important figures are the differences among the estimates rather than the absolute levels. Each scenario is estimated for a 20-year period, which allows for the different periodicity of the

Table 2. Computed Sales and Prices for Cooperative and Non-Cooperative Agreements Over Soybean Seed Sales in Brazil

Scenario	*Av. Annual Sales ($ million)*	*Av. Annual Seed Price*	
		$/ha	*% 1999*[a]
1. Embrapa alone	591.4	49.6	137
2. Pharmacia alone	1,007.0	84.5	233
3. Combined E&P	1,070.2	89.8	247

[a] Starting seed price was $540/mt or $36.3/ha.

introduction of the Embrapa (annual) and the Pharmacia (5-year increments) improvements. Values are then deflated to the present at a 5% rate. Table 2 reports the scenario results for seed sales and prices.

Some explanatory notes will be helpful in interpreting these results. First, note that Scenario 1 treats Embrapa as a monopolist, something that is now technically possible under PBR. Actual implications would, of course, have to take into account political considerations. In past years when little or no royalties were collected, the value of Embrapa seed sales were essentially passed along to cooperatives and foundations, or to farmers (and through them to consumers, both Brazilian and international).

Second, the discounted value of sales differences between Embrapa and Pharmacia is attributable to the different rates at which the improvements are introduced onto the market. For the traditionally bred Embrapa varieties as noted, an annualized 1% improvement is used, meaning the most productive (and highest priced) variety is available only the 20th year. Biotech improvements on the other hand are assumed to be introduced less frequently, but in larger increments. Note that a greater productivity enhancement attributable to biotech, and/or more frequent transformations and releases of new GMO varieties would create an even greater discrepancy between the value of Embrapa and Pharmacia sales acting alone (scenarios 1 and 2 in Table 2).

The same time path of effects of improvements can be seen in the combined strategy (Scenario 3, Table 2) where there is only a relatively small difference between the Pharmacia only and combined seed sales values. According to these results, Embrapa sales could be enhanced between 0 and $479 million annually ($1,070 million - 591 million), depending on the deal struck with Pharmacia. That, however, does not necessarily imply the maximum benefit to Pharmacia could be only $ 63 million ($1,070 million - 1,007 million) annually. The values in Table 2, scenarios 1 and 2, are based on a 100% market share. Should Pharmacia, operating in competition with Embrapa, achieve only a 50% share, its average annual sales would be around $500 million ($1,007 m/2). Hence, the value to Pharmacia of cooperating could be as much as $500 million annually, less

Table 3. Annualized Discounted Changes In Welfare Under Alternative Scenarios ($ m)

	Brazil			ROW		
Scenario	Δ *CS*	Δ*PS*	Δ*Total*	Δ *CS*	Δ *PS*	Δ*Total*
1. Embrapa alone	6.13	35.23	41.37	79.54	−68.26	11.28
2. Pharmacia alone	3.84	21.55	25.39	49.76	−43.11	6.65
3. Combined E&P	7.63	43.86	51.49	99.00	−85.36	13.64

if a higher than 50% market share were projected for Pharmacia in competition with Embrapa, and more if Embrapa priced at less than profit maximizing rates, capturing a greater market share under duopoly. The benefits of cooperation would be far smaller if the productivity benefits of the Pharmacia technology were nearer 15% than the 5% level used in the calculations. The results do, nonetheless, indicate that Pharmacia (and presumably other private sector firms) do have viable alternatives to collaborating with Embrapa. That is, the likely Embrapa value could well fall short of expectations, which would be difficult to accept and hence delay negotiations.

Welfare effects of the productivity enhancements were calculated for both Brazil and ROW. Productivity enhancements are modeled only for Brazil, and ROW supply is assumed unchanged, as are other potential exogenous demand shifters. Changes in the consumer surplus (ΔCS) and producer surplus (ΔPS) are shown in Table 3. It should be noted that under the current no- or limited-royalty policy for Embrapa, the total surplus, assuming the total Embrapa contribution is passed on to consumers, is $591.4 million higher (the estimated average annual monopoly seed sales value to Embrapa from Table 2) for a total of $632.8 million (591.4 + 41.4). (Note that these calculations do not net out R&D costs or other associated expenditures.) The actual allocation of the surplus between Brazilian consumers and producers is not known, so that the tax-supported breeding at Embrapa could largely be a transfer of benefits from Brazilian taxpayers to producers.

More significant for planning at Embrapa, the combined strategy with Pharmacia yields the highest Brazilian welfare surplus, while the Pharmacia-only strategy yields the lowest. If Embrapa emphasizes its public role in negotiations, it will seek the joint agreement even if most of the monetary benefits were to be directed to Pharmacia.

Implications for Management Decisions in the Public and Private Sectors

Our results show that the marginal contribution to Pharmacia of licensing the Embrapa varieties is, at the limit, rather modest, $535.1 − $503.5 = $31.6 million

Table 4. Computed Bargaining Limits for Licensing Embrapa Soybean Varieties to Pharmacia[a]

	Share		*Total Surplus Change*	
	100%	*50%*	*100%*	*50%*
Non-Cooperative				
Embrapa alone	591.4	295.7	41.4	20.7
Pharmacia alone	1007.0	503.5	25.4	12.7
Cooperative Combined E&P	1070.2	535.1[b]	51.5	

[a] Average annual seed sales and average annual total surplus change (Brazil), $ m.
[b] Equal share.

assuming equal sharing (Table 4). The dominant position is clearly the cooperative one, but what share of sales revenue might Embrapa seek? If Embrapa put an equal weight on sales and the surplus generated, then the value of the combined position would be $1,070.2 million + 51.5 = $1,121.7 million. If in the absence of an agreement Embrapa expected a maximum of a 50% market share, then the revenue it would be willing to cede to Pharmacia would be $1,121.7 million − 295.7 − 20.7 = $805 million. From Pharmacia's perspective, that sales figure would correspond to an 80% market share if operating in competition (805/1,007), which could be quite attractive. Those figures then could represent Embrapa's minimal acceptable position. Similar calculations can be made to establish other negotiating bounds.

We believe one of the factors delaying the licensing of national varieties to multinational agbiotech firms is uncertainty over the value of the improved materials. The procedure presented here provides a mechanism for estimating values to both parties, and hence for establishing bargaining positions. This may assist in advancing the negotiating process. Other stumbling blocks exist as well. One is the understandable suspicion with which many developing-country policymakers view the economic power of major multinationals. Slowly, that position seems to be adjusting to the inevitability of seeking private sector cooperation as public funding continues to atrophy. Another factor is more recent—the uncertainty of market access for GMOs. Calculating the effects of a lower world price for GMOs can be accommodated readily within our model by adjusting world price and share estimates. Developing those new estimates though is another matter. Another factor particular to Brazil is the banning of GMO soybean production by the state of Rio Grande do Sul. As for Embrapa and Pharmacia, word is that negotiations continue, recently to include the possibility of Embrapa licensing Pharmacia's technologies rather than vice versa.

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