SURPLUS DISTRIBUTION FROM THE INTRODUCTION OF A BIOTECHNOLOGY INNOVATION

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We examine the distribution of welfare from the introduction of Bt cotton in the United States in 1996. The welfare framework explicitly recognizes that research protected by intellectual property rights generates monopoly profits, and makes it possible to partition these rents among consumers, farmers, and the innovating input firms. We calculate a total increase in world surplus of $240.3 million for 1996. Of this total, the largest share (59%) went to U.S. farmers. The gene developer, Monsanto, received the next largest share (21%), followed by U.S. consumers (9%), the rest of the world (6%), and the germplasm supplier, Delta and Pine Land Company (5%).

Key words: biotechnology, Bt cotton, genetically modified organisms, rents, surplus.

The laws and enforcement of intellectual property rights (IPR) for biological innovations have been strengthened over the past two decades so that protection is now similar to that afforded to discovery in other sectors. IPR laws provide inventors with limited monopoly power, increasing their ability to appropriate the surplus created by their research effort. This strengthened incentive has spurred private investment in the seed sector, such that twice as many plant breeders are now employed in the private sector as in the entire public sector (Fuglie et al., Frey). Coincident advances in biotechnology science have resulted in the introduction of at least 48 transgenic cotton varieties since 1996, and more than 300 soybean varieties. While acknowledging the positive incentive of increased appropriability, concern has also been expressed over the effects of these legal and scientific changes on seed industry structure and the welfare of farmers (Butler and Marion, Doyle, Kloppenburg).

In this paper we analyze the welfare effects of the introduction of the first transgenic crop varieties to be grown widely in the United States. Two cotton varieties, NuCOTN 33B and NuCOTN 35B containing the Bollgard™ (Bt) gene, were introduced commercially in 1996 through a licensing agreement between the gene discoverer, Monsanto, and the leading cotton germplasm firm in the United States, Delta and Pine Land Company (D&PL). The Bt gene causes the cotton plant to produce a protein that is toxic to certain species of Lepidopteran insects, significantly reducing chemical pest control costs in infested areas (Davis et al.). Bt cotton also offers farmers increased certainty of control because it is effective against insects that have developed resistance to certain chemicals, notably pyrethroids. We partition surplus among economic agents in the seed cotton and cotton lint markets. Consumer surplus in the cotton lint market is estimated for U.S. domestic and rest of the world (ROW) markets. In the seed cotton market we partition surplus among the gene supplier (Monsanto), the germplasm supplier (D&PL), and farmers in 30 U.S. cotton production regions. The objective of this study is not to estimate a rate of return to research, but rather to focus on the distribution of benefits among the different economic agents in the first year of Bt cotton adoption in the United States.

Most past studies of agricultural research impacts have considered innovations pro-
duced by the public sector and introduced into perfectly competitive agricultural markets. Under such conditions, total welfare changes can be measured in the output market as the sum of changes in producer (farmer) and consumer welfare, and there will be no change in profit to the innovator. Empirically these welfare effects can be measured using economic surplus methods summarized in Alston, Norton, and Pardey. The economic surplus approach requires the researcher to estimate a technology-induced supply shift, generally from experimental or producer survey data. We draw on a recent approach presented by Moschini and Lapan to modify the Alston, Norton, and Pardey framework in order to model a case in which IPR protection imparts temporary monopoly power in the introduction of an innovation in the input market. Within this framework monopoly profit must be included when measuring welfare changes.

Background on the Introduction of Bt Cotton

The transgenic Bt cotton that was sold in the United States in 1996 was developed through a strategic alliance between Monsanto and the dominant U.S. seed cotton firm, D&PL. The elite commercial germplasm for the transgenic varieties was provided by D&PL from two recurrent parent varieties: DP5415, a mid-season variety, and DP5690, a full-season variety, both popular in the Mid-South and Southeast.

The Bollgard™ gene was developed by Monsanto in the 1980s from a soil microorganism, Bacillus thuringiensis kurstaki, long known to produce a protein that is toxic to certain species of Lepidoptera when ingested. The commercially important lepidopterans in the cotton industry are the tobacco budworm, cotton bollworm, and pink bollworm, which together accounted for an estimated $391 million in cotton losses and treatment expenses in the U.S. in 1995, and $699 million in 1996 (Williams 1996, 1997). Genes from the Bacillus microorganism were spliced into Agrobacterium tumefaciens, a bacterium that has the ability to inject some of its genes into plant cells. The most receptive cotton variety to effect this transfer was an obsolete variety known as Coker 312. Monsanto scientists increased the expression of the Bt protein in Coker 312 a thousandfold to achieve the level necessary for commercially viable insect control. Monsanto then chose D&PL, as its seed partner to provide elite parent lines for the four generations of back-crossings necessary to replace the Coker traits with improved high-yielding characteristics.

In 1996, the first year of commercial availability, Bt cotton was planted on 1.8 million acres or 14% of the acreage in the United States (Williams 1997). All adopting farmers paid Monsanto a technology fee of $32.00 dollars per acre. Adopting farmers also paid D&PL an average of $2.00 per acre more for Bt seed as a seed premium over conventional varieties. The rate of adoption varied substantially among states (table 1). For example, in Alabama the adoption rate was 74%, whereas in New Mexico, Virginia, Missouri, and parts of Texas the adoption rate was less than 1%. The highest adoption rates occurred in the South, where the two varieties were best adapted, and where the highest per acre losses from lepidopteran insects occur.

Several reasons may be hypothesized for the different adoption rates. Varieties are agro-climatically specific, and thus the two varieties released by D&PL may not have been appropriate for the low-adopting regions. Also, farmers may have had differential expectations of the probability of losses due to budworms and bollworms in 1996. For example, in some regions budworms had become resistant to conventional pyrethroid insecticides (Hardee and Herzog), making Bt cotton an expedient control alternative. Other regions, such as those actively participating in the Boll Weevil Eradication Program, could achieve coincidental control of bollworms and budworms through the use of broad-spectrum chemicals needed to control other pests. Finally, D&PL was unable to produce enough seed to meet demand in 1996.

We model the introduction of Bt cotton as occurring in a large open-economy with no technology spillovers (Alston, Norton, and Pardey, p. 213). The United States in 1996 had a significant presence in world trade of cotton, producing approximately 20% of world cotton and representing 40% of world trade (USDA/ERS). This significant trade presence influences world prices, but there were no technology spillovers to foreign producers.
because Bt cotton was available commercially only in the United States in 1996. This will change as Bt technology is introduced to world seed markets (Pray and Fuglie).

### Measuring Surplus Generated by IPR-Protected Innovations

Moschini and Lapan provide a framework for studying welfare changes under conditions where the innovator behaves as a monopolist. In their model the innovation is generated by an input firm which, through patents or trade secrecy protection, acquires a temporary monopoly, giving the firm the power to set the price above its marginal cost of producing the input. The introduction of the new input—Bt cotton seed in the case examined here—is assumed to leave the perfectly competitive nature of the downstream farm output market unchanged. A shortcoming of the welfare measures employed in previous studies of public agricultural innovations, such as the studies cited in Alston, Norton, and Pardey, is that they do not apply to IPR-protected innovations because they ignore monopoly profits occurring in the input market.

Moschini and Lapan develop their model by relating the production function, \( y = g(x_1, z) \), for the new technology to the old production function \( y = f(x_0, z) \) using a factor augmentation specification: \( f(x_1, z) = g(\alpha x_1, z) \), where \( x_1 \) is the new input (a Bt cotton variety), \( x_0 \) is the old input (a conventional variety), \( z \) are other inputs, and \( \alpha \) represents the efficiency of the improved input so that \( \alpha x_1 \) is the amount of the improved input in “efficiency units” of the old \( x \) input. This allows the new, more productive, factor
to be measured in the same physical units as the pre-innovation input. Using primes to designate quantities measured in efficiency units, the pre-innovation technology input quantity can be written as $x_0' \equiv x_0$, and the post-innovation technology input quantity is $x_1' \equiv \alpha x_1$. The input price represented in efficiency units is $w'$ so, in efficiency units, $w_0' \equiv w_0$ and $w_1' \equiv w_1/\alpha$. Using $p$ to represent the price of cotton lint, the indirect profit function in efficiency terms becomes

\begin{equation}
\pi(p, w', r) = \max_{x', x} \{ pf(x', z) - w'x' - rz \}.
\end{equation}

Applying Hotelling’s lemma to the indirect profit function yields the general expressions for output supply $y^*$ and the input demand curve $x^*$:

\begin{align*}
(2a) \quad & y^* = \pi_p(p, w', r) \\
(2b) \quad & x^* = -\pi_w(p, w', r)
\end{align*}

where the subscripts $p$ and $w'$ in $\pi$ refer to the partial derivatives. For farmers using a conventional variety, profit would be given by $\pi(p, w_0, r)$, output supply by $y^* = y(p, w_0, r)$, and input demand by $x^* = x(p, w_0, r)$. Using the new input, profit would be denoted as $\pi(p, w_1/\alpha, r)$, output supply by $y^* = y(p, w_1/\alpha, r)$, and input demand by $x^* = (1/\alpha)x(p, w_1/\alpha, r)$.

Farmers will adopt the new variety if the price in efficiency units of the new input is less than that of the old input: $w_1/\alpha \leq w_0$. In other words, farmers will adopt a biotechnology variety if the value of the cost reduction plus the increase in yield is greater than the price differential between varieties.

Let $D(p)$ represent the demand for cotton lint, and let the output equilibrium price be denoted by $p^* \equiv p(w', r)$ and thus the equilibrium price is given by $D(p^*) = y(p^*, w', r)$. It is reasonable to assume that both types of seeds are produced at a constant marginal cost $c$, and that prices of other inputs are exogenous to the cotton sector. Then profit of the innovating firm is given by the formula $(w_1 - c)x_1 = (w_1' - c/\alpha)x_1'$ in efficiency units. Because of IPR protection the firm is able to charge a monopolistic price $w_1''$. Therefore the derived demand for biotechnology varieties and the monopoly price measured in efficiency units are

\begin{align*}
(3) \quad & \chi(w') \equiv x(p(w', r), w', r) \\
(4) \quad & w_1'' = \arg \max \{ (w_1' - c/\alpha)\chi(w_1') \}.
\end{align*}

The monopolist faces a downward-sloping demand curve, so is able to price the new input above her marginal cost. Because of her price-setting ability, the monopolist will not pass all surplus on to the final market and single market welfare measures do not capture all economic surplus. Total welfare must be measured in both the cotton lint market and the cotton seed market to account for the monopoly profit induced by IPR. Therefore the total change in social welfare from the innovation is

\begin{equation}
\Delta SW = \int w(w') dw' + \left( w_1'' - \frac{c}{\alpha} \right)x_1''.
\end{equation}

The first term on the right hand side is the change in Marshallian surplus. The welfare change in this market occurs because the new input is more efficient, causing the efficiency equivalent price to be less than the price that prevailed before the innovation. The second term, the difference between the efficiency price charged by the monopolist and the marginal cost multiplied by the input quantity, measures the monopoly profit captured by the innovator.

Moschini and Lapan illustrate their model with a simulation example generated by assuming all producers use an identical production technology with decreasing returns to scale and constant elasticity of substitution. These assumptions generate a supply curve that passes through the origin, resulting in a “divergent” technology-induced supply shift. Under the identical producer assumption, the innovating monopolist prices the input at the producers’ (identical) marginal value product, rather than at the marginal cost as expected under perfect competition. The result is that producers’ cost of production is unchanged, there is no surplus to pass on to the output market, and all change in surplus is captured as monopoly profit.²

In empirical settings, the identical technology assumption is unlikely to hold because there will be a distribution of production relationships among producers. In the case of Bt cotton, lepidopteran pest pressure, yields, seeding rates, and other production characteristics vary widely among producers across the Cotton Belt, resulting in a downward-sloping aggregate derived demand curve, as illustrated in figure 1. Rectangle $c/\alpha abw_1''$ is the monopoly profit accruing to

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² In this model, producers and consumers capture some surplus when substitution elasticities are large.
Monsanto/D&PL, while area $w_i b d c$ is the Marshallian surplus, which can also be measured in the output market and which is distributed between lint consumers and cotton producers as shown in figure 2.

The Moschini and Lapan model provides a valuable theoretical framework for assessing the welfare impact of innovations that enjoy intellectual property protection. However, econometric implementation of the indirect profit function model would require data that are difficult to obtain, particularly for recent innovations. In particular, to analyze the impact of a recent innovation such as Bt cotton would require the use of cross-sectional data which are unlikely to contain sufficient price variability to obtain precise parameter estimates. On the other hand, a relatively large amount of primal production and financial information is available from surveys, controlled experiments, and company reports.

Our strategy for estimating surpluses created by the introduction of Bt cotton and accruing to farmers, domestic and international consumers, and the innovators was the following: (a) the technology-induced cotton supply shift was estimated for each of the 30 cotton-producing regions using data on yield, cost savings net of increased seed costs, and adoption rates; (b) the impact of the new technology on world and regional prices was calculated; (c) Marshallian surplus distribution in domestic and international markets was estimated using procedures explained below; (d) monopoly profit accruing to Monsanto and D&PL was estimated.

We calculated Marshallian surplus using the economic surplus approach as presented by Alston, Norton, and Pardey. Their approach is well established in the agricultural economics literature and allows research-induced Marshallian surpluses generated in an output market to be partitioned between producers and consumers.

The Empirical Model

We modeled the introduction of Bt cotton as occurring in a large open-economy with no technology spillovers, and assumed linear supply and demand and a parallel shift in supply from the new technology (Alston,
shift to a percentage reduction in price, \( \varepsilon_{US} \) is the U.S. demand elasticity, \( \eta^EB \) is the absolute value of the elasticity of export demand (the ROW excess demand elasticity), and \( S_{US} \) is the share of U.S. production consumed domestically. Because all U.S. regions face the same world price, the relative price change is the same and, by invoking the Law of One Price, regional prices differed only by transportation costs.

The formulas for changes in domestic and ROW producer and consumer surpluses were

\[
\Delta CS_{US} = P_0 C_{US,0} Z (1 + 0.5 Z \eta_{US})
\]

\[
\Delta PS_{US} = P_0 Q_{US,0} (K - Z) \times (1 + 0.5 Z \eta_{US})
\]

\[
\Delta CS_{ROW} = P_0 C_{ROW,0} Z \times (1 + 0.5 Z \eta_{ROW})
\]

\[
\Delta PS_{ROW} = -P_0 Q_{ROW,0} Z \times (1 + 0.5 Z \eta_{ROW})
\]

\[
\Delta ROWS = \Delta CS_{ROW} + \Delta PS_{ROW}
\]

where \( \Delta CS_{US} \) is the change in consumer surplus in the United States, \( \Delta PS_{US} \) is the change in producer surplus in the United States, \( \Delta CS_{ROW} \) is the change in consumer surplus in the rest of the world. \( \Delta PS_{ROW} \) is the change in producer surplus for the foreign sector, \( \Delta ROWS \) is the change in rest of the world surplus, \( P_0 \) is the pre-innovation price, \( \eta_{ROW} \) is the absolute value of ROW demand elasticity, and \( \varepsilon_{ROW} \) is the ROW supply elasticity.

The estimate of the cost reduction induced by the introduction of the new technology is crucial to the economic surplus calculation and is often the most difficult variable to measure accurately. We combined information from surveys of farmers, on-farm experiment plots, and on-station experiment plots to refine our estimate (Benedict; Davis et al.; Gibson et al.; Rejesus et al.; Shaunak; Stark; Marra, Carlson, and Hubbell; Monsanto 1997a, 1997b; Zelinski and Kerby). The Bt varieties consistently out-yielded conventional varieties in controlled experiments and, except for North Carolina, had higher yields in producer surveys (table 1). Total pest control costs were also lower by 5% to 73%. Yield increases were converted to the equivalent cost-reduction by dividing the industry or experimental yield advantage by the elasticity of supply (Alston, Norton, and Pardey). The net pesticide cost change per ton was found by subtracting the technology.
fee and seed premium from the difference in pesticide cost between conventional and Bt varieties, and dividing the result by \((1 + \% \text{ change in yield})\). Values for the regional percent vertical shift \((K)\) were found by adding the equivalent yield cost-reduction and net pesticide cost change, and then multiplying by the adoption rate of Bt varieties in each region.

Since a variety of estimates for supply, demand, and export elasticities are available from published studies, it is not appropriate to treat them as deterministic when used in a simulation. Davis and Espinoza have recently proposed that stochastic simulation should be used to replace sensitivity analysis in equilibrium displacement models. We applied their method in modeling the distribution of values possible for the counterfactual price \(P_0\). Short- and long-run domestic elasticities of supply, \(\varepsilon_{US}\), have been estimated by Gardner and by Taylor. We used these three estimates to model \(\varepsilon_{US}\) as a triangular distribution with a minimum value of 0.30 (Gardner), a most likely value of 0.84 (Taylor, short run), and a maximum value of 1.61 (Taylor, long run). The domestic demand elasticity \(\eta_{US}\) was taken from an estimate by Kinnucan and Miao and was modeled as a normal distribution with a mean of 0.101 and a standard deviation of 0.041. For the export elasticity \(\eta_{EB}\), we used a triangular distribution with a minimum of 0, a most likely value of 1.62 (Duffy, Wohlgennant, and Richardson) and a maximum value of 4.0 (Duffy, Wohlgennant, and Richardson). For \(\varepsilon_{ROW}\), the ROW supply elasticity, we used the estimate of 0.15 from Sullivan, Wainio, and Roningen as the most likely value. Since they did not report standard errors for their estimates, we used 0 as the minimum based on theory and 0.26 as the maximum in the triangular distribution. The share of U.S. production consumed domestically, \(S_{US}\), was assumed to be deterministic, and \(K\) was derived from a formula that depended on the distribution of \(\varepsilon_{US}\).

Finally, the monopoly profit was calculated as \(Q_B(P_B - c)\), where \(Q_B\) and \(P_B\) are the quantity and price of Bt seed, and \(c\) is the marginal cost of producing seed. Once a commercial transgenic variety has been created, the seed reproduction process is identical for transgenic and conventional varieties. We assumed that the market for conventional seed cotton is competitive, so that the market price represents the marginal seed production cost \(c\). Details of the licensing agreement between Monsanto and D&PL were not known, but we were able to approximate the allocation of the monopoly rent between Monsanto and D&PL using information contained in D&PL and Monsanto annual reports for 1997. These reports indicated that Monsanto passed approximately $5.11 per acre back to D&PL for using their germplasm. Along with the seed premium, this provided D&PL with a gross revenue per acre of $7.11. Monsanto’s share thus was estimated at $26.89 per acre. These figures represent gross Bt revenue—no administrative, marketing, or IPR enforcement costs were deducted. The issue of whether or not to deduct development costs from the firm’s net return is not answered definitively in the literature. We assumed that development costs were sunk, and did not enter into the pricing decision. That is, if Monsanto/D&PL were to expand the market for Bt seed by another million acres, the only variable cost would be to produce more seed.

**Empirical Results**

Using the subjective prior distributions in the formula for \(P_0\), we conducted 50,000 iterations of the simulation. \(P_0\) was found to range from a minimum of $63.20 to a maximum of $64.47, with a mean of $63.41 and a standard deviation of 0.1189. The 95% confidence interval was (63.27, 63.63). Thus, the introduction of the 1.8 million acres of Bt cotton in the United States decreased world price by a mean of 0.41¢. The relatively modest change in price can be explained by the fact that Bt acreage represented less than 5% of the total world acreage planted to cotton.

Surplus estimates using the Alston, Norton, and Pardey approach in stochastic simulations (table 2) show a mean increase in surplus for U.S. farmers of $140.8 million. Adding in the additional rent extracted by Monsanto ($49.8 million) and D&PL ($13.2 million), the total producer surplus in the United States is $203.7 million. United States consumers gained an estimated $21.6 million, whereas ROW consumers gained approximately $36.5 million. ROW producers lost $21.6 million due to downward price pressure from the additional U.S. output.

There were also regional winners and losers from the introduction of Bt cotton. Clearly the new technology improved the
competitive advantage of farmers in areas of Alabama, Arizona, Arkansas, Georgia, South Carolina, and Mississippi where lepidopteran pest pressure is high. In general, the twelve regions with greater than 20% adoption (see table 1) had significant welfare gains. Farmers in Alabama alone captured 53% of the change in farmer surplus. This reflects the fact that Alabama had the most serious infestation of pyrethroid-resistant lepidopterans. The Texas High Plains region was the largest single loser due to lack of adapted varieties.

Surplus totals and shares are given in the second and third columns of table 2. We calculated a total increase in world surplus of $240.3 million for the first year of Bt cotton in the United States. Of this total, the largest share (59%) went to U.S. farmers. The gene developer, Monsanto, received the next largest share (21%), followed by U.S. consumers (9%), the rest of the world (6%), and the germplasm supplier, D&PL (5%).

**Summary and Conclusions**

In this paper we examined the introduction of Bt cotton in the United States in 1996. We presented an empirically tractable means of measuring the welfare effects of IPR-protected research that draws on the conceptual model of Moschini and Lapan and empirical measurement techniques presented in Alston, Norton, and Pardey. The method relies on cost of production data rather than price data, and allows surplus to be partitioned among consumers, farmers, and the innovators. An important aspect of the framework is that, unlike the analysis of public innovations, it recognizes explicitly that monopoly profit is a component of producer surplus.

We estimated that Monsanto and D&PL received a relatively modest share of rents—approximately one-fourth of the total benefits generated. No comparable empirical studies have been published of rent distribution from innovations introduced where market power exists, nor does economic theory offer much guidance on the likely range of surplus shares in cases such as the one examined here. Therefore it is not clear whether the outcome observed here is in any way “typical” for IPR-protected innovations. Several characteristics of the Bt cotton introduction may have been important determinants of the rent distribution. First, Bt cotton was the first transgenic crop to be widely grown in the United States. It seems likely that Monsanto was seeking to demonstrate to shareholders that transgenic crops had the potential to be used over a large area, by many farmers. Hence, Monsanto may have chosen a low-price policy to expose the maximum feasible number of farmers to the technology and the licensing process, in order to pave the way for the introduction of future transgenic products. In 1996 there was considerable uncertainty on Monsanto’s part about the degree of farmer resistance to this new type of input, and similar uncer-

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**Table 2. Estimates of the First-Year Economic Surplus from the Introduction of Bt Cotton in the United States in 1996**

<table>
<thead>
<tr>
<th>Source of Surplus</th>
<th>Mean Surplus (Thousands of Dollars)</th>
<th>% of World Surplus</th>
<th>5% Confidence Limit of Estimate (Thousands of Dollars)</th>
<th>95% Confidence Limit of Estimate (Thousands of Dollars)</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S. farmer surplus</td>
<td>140,789,100</td>
<td>59</td>
<td>80,705,770</td>
<td>247,347,900</td>
</tr>
<tr>
<td>U.S. consumer surplus</td>
<td>21,551,710</td>
<td>9</td>
<td>14,227,800</td>
<td>33,100,260</td>
</tr>
<tr>
<td>Monsanto</td>
<td>49,784,145</td>
<td>21</td>
<td>9</td>
<td>33</td>
</tr>
<tr>
<td>Delta and Pine Land</td>
<td>13,153,051</td>
<td>5</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>ROW producer surplus</td>
<td>−21,555,080</td>
<td>−</td>
<td>−33,111,140</td>
<td>−14,228,500</td>
</tr>
<tr>
<td>ROW consumer surplus</td>
<td>36,531,770</td>
<td>−</td>
<td>24,114,430</td>
<td>56,119,140</td>
</tr>
<tr>
<td>Net ROW surplus</td>
<td>14,976,690</td>
<td>6</td>
<td>9,885,499</td>
<td>23,001,840</td>
</tr>
<tr>
<td>Total world surplus</td>
<td>240,254,696</td>
<td>100</td>
<td>172,087,500</td>
<td>357,017,600</td>
</tr>
</tbody>
</table>

*aMonsanto and Delta and Pine Land surpluses were assumed to be deterministic.*

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[3] USDA/ARS entomologists Hardee and Herzog summarized the 1995 Alabama situation: "With the numbers of budworms encountered in 1995 and their level of resistance to pyrethroids, carbamates and phosphates, cotton growers do not have the tools available to grow cotton economically in Alabama at this time. Hopefully, Bollgard varieties and new chemistries will become available in time to save the industry" (p. 643).
tainty on farmers’ part about the effectiveness of the new control method—both reasons to favor a penetration-pricing strategy. A second characteristic was Monsanto’s decision to set a single U.S. price, despite the large regional differences in the marginal value product of Bt seed technology. This meant that farmers in some areas would necessarily receive much larger per acre benefits than farmers in other areas. Nevertheless, Monsanto made no attempt to price discriminate, probably because it would not have been possible to prevent farmers from arbitraging spatial price differences with the two varieties introduced in 1996.

The size and distribution of benefits will undoubtedly change as Bt cotton varieties continue to diffuse in the United States, as Bt varieties are released in other countries, as substitute technologies for controlling pyrethroid-resistant lepidopteran pests appear, and as opportunities arise to price discriminate. It would be interesting to follow this study with similar studies of Bt corn and herbicide-tolerant soybeans to see if a similar first-year distribution of surpluses occurred. Another complementary follow-up to this study would be to track the disposition of the monopoly rents that were appropriated to see to what extent they were reinvested in research.

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References


