Monopoly Power, Price Discrimination, and Access to Biotechnology Innovations

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Price discrimination and monopoly power in the provision of an intellectual property (IP) protected innovation are analyzed. A general analytical model parameterized with data from the US introduction of Bt cotton is used to examine welfare transfers from the imposition of price discrimination. When two markets are being served under a one-price policy, total welfare increases from price discrimination because monopolist gains exceed farmer losses. If only one market is being served under a one-price policy, farmers in the new market and the innovator gain, while farmer welfare in the existing market is unchanged.

Key words: agricultural biotechnology, intellectual property protection, monopoly, price discrimination, welfare distribution.

The private sector has dominated the development and delivery of transgenic, or GMO, crop varieties in all countries except China. The commercialization of GMOs has been highly concentrated. Just four crops (cotton, soybeans, maize, and canola) account for virtually all of the GMO area; 97% of world area occurs in five large countries, and 96% of world investment occurs in industrialized countries (James, 2002). Because GMOs originate in the private sector, they are subject to intellectual property (IP) protection. This confers limited monopoly power to innovators and affects research and development (R&D) investment incentives, pricing strategies, and the availability of technology. When the monopolist/innovator is able to prevent buyers from reselling their product, they may be able to price discriminate to accentuate the effects of monopoly power.

In this paper we examine the welfare effects of monopoly and price discrimination in the marketing of biotechnology discoveries. Two main issues are examined. The first issue is the general case of the distribution of benefits when the attempt to price discriminate is added to the effect of intellectual property rights (IPR)-induced monopoly power. Secondly, the effect of price discrimination on the availability of technology in small markets is examined. We demonstrate that even though price discrimination is often considered to be an unwanted market distortion, it may increase total welfare by increasing total output and by making goods available in markets where they would not appear otherwise. The policy implication is that in some cases, allowing price discrimination may be a desirable policy for encouraging private-sector investment in small markets. Several empirical studies have shown that farmers can receive significant benefits from private-sector pro-

vision of improved inputs, even in the presence of monopoly power (e.g., Falck-Zepeda, Traxler, & Nelson, 2000; Jefferson-Moore & Traxler, in press; Oehmke & Wolf, 2004; Qaim & Traxler, 2005), but the effect of price discrimination has not been examined within this context.

At present, the majority of biotechnology investments occur in developed countries (Table 1), and about 70% of that investment is from private sources. Few developing countries currently have access to biotechnology products, and virtually all biotechnology products used in developing countries today are spillovers from developed countries.

Monopoly Pricing and Price Discrimination

A monopoly does not always lead to inefficient production due to price-setting behavior. Marginal cost pricing under perfect competition does not guarantee efficiency, because revenues from marginal cost pricing may not always cover total costs and may reduce future investment (Varian, 1996). Robinson (1933) pointed out that the comparison between monopoly and competitive output levels under similar cost structures may be flawed, because a monopolist can only exist in an imperfect market. In addition, the monopolist may have a different cost structure, including a downward-sloping marginal cost curve, from that of the (long run) total cost structure of the perfectly competitive market (Robinson, 1933). Moschini and Lapan (1999) also showed that if the efficiency of the improved seed compared to the conventional variety is high enough, then the monopolist price measured in efficiency units may be lower than the price of conventional seed when measured in efficiency units.

Under certain conditions, it is possible for a monopolist to price discriminate. For the monopolist to take

Table 1. Estimates of global R&D expenditures on crop biotechnology, 2001.

Funding source		Expenditures ($ million)
Industrial countries (96%)	Private (70%)	3,100
	Public (30%)	1,120
	Total	4,220
Developing countries (4%)	China	115
	India	25
	Brazil	15
	Others	25
	Total	180
World total		4,400

Note. Data from James (2002).

advantage of the different valuation of the output by consumers, arbitrage opportunities must be absent, and the market must be segmented.

The output level and welfare impact of adding price discrimination to monopoly power has received a significant amount of attention dating back to Pigou (1920) and Robinson (1933) with substantial recent contributions from Varian (1985, 1996), Schmalensee (1981), and others. Few general conclusions can be drawn from the literature, but the change in output and welfare induced through price discrimination can be analytically determined for any given case. Robinson showed that differences in "concavities" of the marginal revenue curves of the separate markets is necessary for price discrimination to lead to an increase in total output. She went on to say that whenever total output produced under discrimination is higher than under simple monopoly, society is better off, and in situations where total output under discrimination and simple monopoly are the same, society may be better off depending on the tradeoff between welfare of the "weak" (more elastic) markets compared to the "strong" (less elastic) markets. A number of studies, including Schmalensee (1981), Varian (1985), Shih, Mai, and Liu (1988), and Layson (1988) have attempted to refine these claims.

A review of these studies indicates that whether discrimination leads to an increase or decrease in social welfare is an empirical question. Knowledge of the shape of the demand and marginal revenue curves and the magnitude of the demand elasticities (and to some extent, the shape of the marginal cost curve) help to determine the sign and magnitude of the change in welfare. However, it is unequivocal that with price discrimination, total output and welfare will increase if small (niche) markets that would otherwise be priced out of

the market for the technology enter the market at the lower discriminated price (Varian, 1996).

Three types of price discrimination are discussed in the literature. We assume third-degree price discrimination in the market for cotton seed.[1] Here, buyers may be grouped into a number of separate segments. Each segment pays a different price for the same output. The more elastic group pays a lower price than the less elastic markets. With regard to the welfare implications of third-degree price discrimination, the seller captures more of the benefits and possibly less deadweight loss than a nondiscriminating monopolist. In addition, there is a redistribution of benefits among buyers—from the less elastic to the more elastic markets.

Price Discrimination in the Seed Market

The sunk or fixed costs of developing an innovation such as herbicide tolerance are often large. However, once developed, the marginal cost of producing additional improved seed is very small. The laws and enforcement of intellectual property rights (IPR) have provided innovating firms with some monopoly power in the market for seeds (Falck-Zepeda et al., 2000), allowing the innovating firms to set a price higher than marginal cost. This provides a powerful incentive for private-sector innovation, for without monopoly power innovators may not be able to cover their total costs, thus restricting the range of technologies available to farmers. In the section that follows we present a model that compares the welfare consequences of price discrimination versus a one-price policy for an IP protected innovation suitable for two separated markets. The implication is that if the ability to price discriminate is restricted through natural arbitrage or commercial policy, total welfare may be less.

Bt cotton presents a case of potential price discrimination. Monsanto has been essentially a monopoly supplier of Bt cotton because it owns the patents to the key genetic events—even though a number of seed companies sell a number of different varieties of Bt cotton,

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1. *We model third-degree price discrimination, which may occur when markets are characterized by different demand schedules and when few arbitrage opportunities exist. To some extent, this form of price discrimination is curently employed by innovators who charge lower prices in some (small and more elastic) foreign markets than in (large and less elastic) domestic markets. First- and second-degree price discrimination, characterized by charging a different price for each unit and by charging different prices depending on the quantity purchased, are not likely to occur in the cotton seed market.*

they all rely on the same genetic event. (In 2003, Dow and Syngenta each successfully petitioned for deregulation of a genetically modified Bt cotton variety, which may erode Monsanto's monopoly position.) The potential for a monopolist to price discriminate in Bt cotton exists for two reasons. First, upland cotton varieties tend to react to small agro-climatic variations, restricting possibilities for spatial arbitrage. This allows a certain amount of price discrimination by geographic area. Second, Monsanto (or other companies) could require the farmer to sign a technology contract with a "no resale" clause in it, effectively segmenting the market.

The Model

Assume that the price-discriminating monopolist faces two or more demand schedules that describe the monopolist's markets: $Q_1 = Q_1(P)$ and $Q_2 = Q_2(P)$. With price (P), total demand faced by the monopolist is then

$$Q_T = Q_1(P) + Q_2(P). \tag{1}$$

The nondiscriminating monopolist maximizes profit such that

$$MR_T = P\left(1 + \frac{1}{\eta_T}\right) = c'(Q_T) = MC(Q_T), \tag{2}$$

where MR_T is the marginal revenue of total demand, $MC(Q_T)$ is the marginal cost of production, and $\eta_T = \partial Q_T P / \partial P Q_T$ is the elasticity of total demand. The profit-maximizing total quantity produced by the nondiscriminating monopolist is

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\begin{aligned}
Q_T(P) &= Q_T\left(\frac{\eta_T c'(Q_T)}{\eta_T + 1}\right) \\
&= Q_1\left(\frac{\eta_T c'(Q_T)}{\eta_T + 1}\right) + Q_2\left(\frac{\eta_T c'(Q_T)}{\eta_T + 1}\right).
\end{aligned}
\tag{3}
$$

The price-discriminating monopolist maximizes profits when $MR_1 = MR_2 = MR_T = MC(Q_T) = c'(Q_T)$, so for market i,

$$MR_i = P_i\left(1 + \frac{1}{\eta_i}\right) = c'(Q_T) = MC(Q_T) \tag{4}$$

where $\eta_i = \partial Q_i P_i / \partial P_i Q_i$ is the elasticity of market i demand. Thus, the profit-maximizing total quantity produced by the discriminating monopolist is

$$Q_{DT}(P) = Q_1\left(\frac{\eta_1 c'(Q_T)}{\eta_1 + 1}\right) + Q_2\left(\frac{\eta_2 c'(Q_T)}{\eta_2 + 1}\right). \tag{5}$$

As shown by Robinson (1933), Schmalensee (1981), and Varian (1985), there is an increase in welfare from a simple monopoly to a price-discriminating monopoly only if total quantity produced increases. Welfare change is the sum of monopoly profit and consumer surplus changes.[2] Consumer surplus changes are the change in the area beneath the respective demand curves as a result of the price changes, and monopoly profit is the product of the difference between the technology fee and average cost (or marginal cost, because we model constant marginal cost) and the quantity of seed demanded by the market.

Welfare Calculations

To calculate the distribution of benefits from price discrimination we follow the general procedures outlined in Alston, Norton, and Pardey (1996). Farmer benefits from discrimination are the change in consumer surplus—the area beneath the respective input demand curves and above the market price. Benefits to the innovator are taken to be the change in monopoly profit—the area above the marginal cost curve and the below the price in each market.

If the output market is competitive, the change in consumer surplus measured in the input market is equal to the change in total surplus in the output market (Jacobsen 1979; Schmalensee, 1976). For this study, we assume that farmers sell their output in a competitive market, so total welfare change from the introduction of the improved technology is the sum of the change in monopoly profit in the intermediate (seed) market and the change in consumer surplus in the input market (Moschini & Lapan, 1997). Also, Just and Hueth (1979) showed that when demand curves are estimated econometrically without including prices in other linked markets, the demand obtained is equivalent to a general equilibrium demand curve, and thus the welfare areas calculated in the seed market comprise the total welfare change within the system.

Data

We use data from Hubbell, Marra, and Carlson (2000) empirically to examine the case of potential price dis-

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2. *Benefits to cotton producers are referred to as consumer surplus, because we are dealing with the market for seed.*

crimination in Bt cotton. Hubbell et al. (2000) presented, using data for 1996, the Bt cotton demand of cotton growers in Alabama, Georgia, North Carolina, and South Carolina divided into two regions (Upper South and Lower South) with different levels of insect resistance to pesticides and therefore with two derived demand curves. The objective of their study was to simulate the costs of reducing conventional insecticide applications through subsidization of Bt cotton. The total Bt cotton seed demand for the region comprises the Upper South (North Carolina and South Carolina) with no resistance experience (US/NR) and the Lower South (Alabama and Georgia) with some resistance experience (LS/R). Demand for Bt cotton is less elastic when insects are resistant to chemical pesticides. Data for Hubbell et al. (2000) were obtained from a survey of cotton growers conducted in 1997. From Hubbell et al. (2000), Bt cotton demand was:

$$BTACRES = \Pr(z(p))(BTPROP(v(p)))(TOTCOT), \quad (6)$$

where *BTACRES* is the number of acres planted to Bt cotton, $\Pr(z(p))$ is the probability that a farmer adopts the Bt cotton technology at price p, *BTPROP* is the proportion of cotton land planted to Bt cotton once the decision is made to adopt, and *TOTCOT* is the total cotton area in the region. Further, the probability of adoption is calculated as $\Pr(z(p)) = 1 - \Phi(z(p))$, where $\Phi(z)$ is the standard normal cumulative density, and $z(p) = \mathbf{x}'\beta + \alpha(\Delta y - p)$ was estimated to obtain estimates of β and α, the coefficients of the variables of farm and farmer attributes ($\mathbf{x}$) and price, respectively. Farm and farmer attributes included in the $\mathbf{x}$ vector were total acres planted to cotton, share of income from cotton, percentage damaged bolls in 1995, operator's age, number of years of growing cotton, and dummy variables for insect resistance to conventional insecticides experienced in 1995, farm location, and college education by the operator.

The proportion of cotton land planted to Bt cotton was estimated as $BTPROP(v(p)) = \mathbf{w}'\gamma_w + \gamma_p p + \gamma_\lambda \lambda$, where $\mathbf{w}$ is the vector of farm and farmer attributes and $\lambda(z(p))$ is the Mills ratio included as a variable, because *BTPROP* is only observed for those farmers who either adopted in 1996 or indicated their willingness to adopt at the hypothetical technology fee. Farm and farmer attributes included in the *BTPROP* equation were share of income from cotton, percentage damaged bolls in 1995, number of years growing cotton, and dummy variables for insect resistance to conventional insecti-

cides experienced in 1995, farm location, and college education by the operator.

Results and Discussion

Using the demand curves for US/NR and LS/R from Hubbell et al. (2000), we determined the profit-maximizing discrimination prices and quantities for each region when the innovator (monopolist) is able to discriminate. The marginal cost of the innovator was estimated from the technology fee and the total demand elasticity (using Equation 2). The elasticity of total demand at a given price was estimated as

$$\eta_T = \frac{Q_{US/NR}\eta_{US/NR} + Q_{LS/R}\eta_{LS/R}}{Q_T}. \quad (7)$$

Given the demand function in Equation 6, elasticity of demand in market i = US/NR, LS/R is

$$\eta_i = p \times \left[\left(\frac{\partial \Pr(z_i)}{\partial p} \right) \times BTPROP(v_i) \right. \quad (8)$$
$$\left. + \left(\frac{\partial BTPROP(v_i)}{\partial p} \right) \times \Pr(z_i) \right] \times \frac{TOTCOT_i}{BTACRES_i}.$$

At the observed market price in 1996 of \$32/acre, the elasticity of total demand was estimated as –2.1, which results in an implied marginal cost of \$16.88/acre.

We assume constant marginal cost and the same cost structure whether or not discrimination occurs.[3] By equating the individual marginal revenues to estimated marginal cost of total production, we obtained the profit-maximizing prices that the price-discriminating innovator can charge in each market. Figure 1 presents an initial situation under monopoly pricing (selling quantities *a* and *b* in the two markets), where total marginal revenue equals marginal cost, and shows the potential change from uniform pricing to price discrimination. Because US/NR is the more elastic market, the innovator charges a lower price (at point *c*) and sells more (from point *b* to point *f*) to farmers in that region

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3. *This is assumed to simplify the analysis, but even if this were not true, the relevant marginal cost for determining the discriminating prices and quantities for the two regions is the marginal cost of total production. Thus, assuming constant marginal cost is not a limiting assumption. However, if the cost structure of the innovator changes if they are allowed or able to discriminate, then the shape/slope of the marginal cost would be significant.*
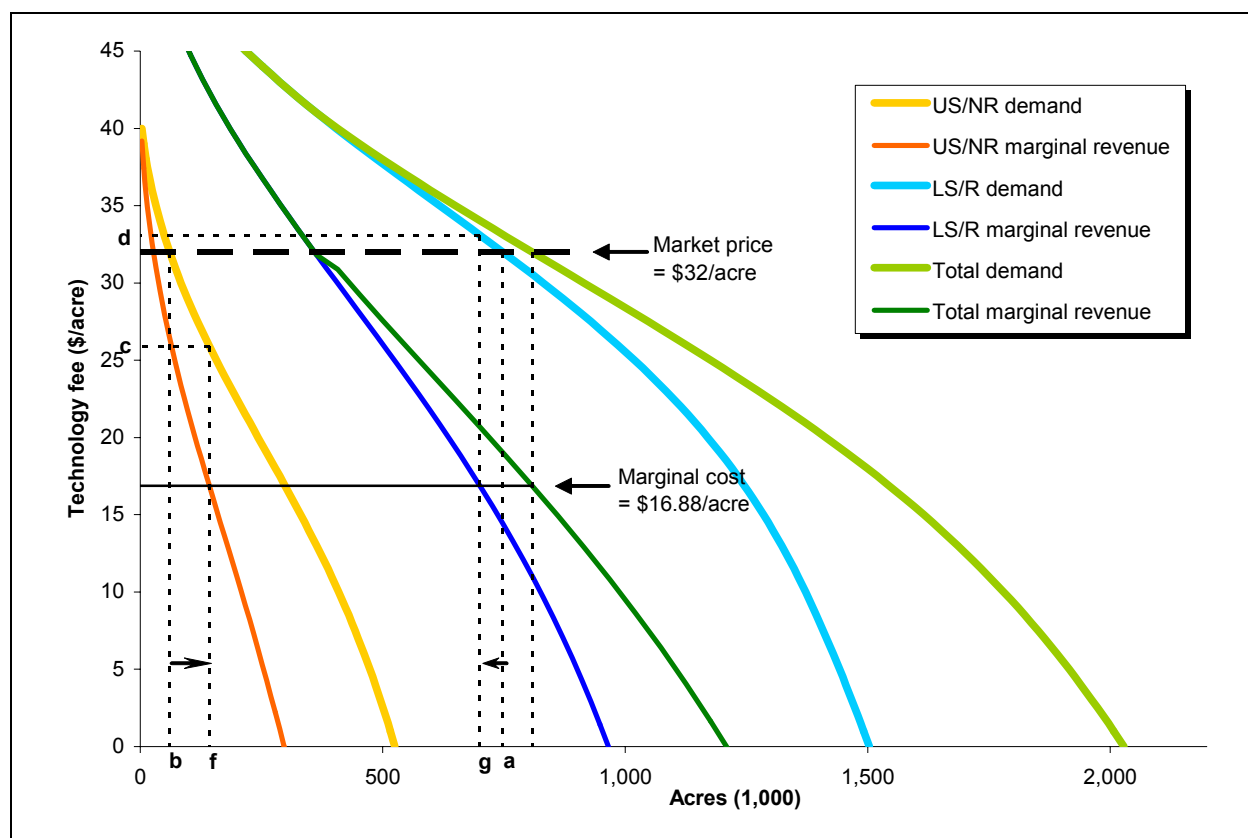
Figure 1. Effects of price discrimination of Bt cotton seed in Southern United States.
Note. Data from Hubbell et al. (2000) and authors' computations.

and charges a higher price (at point *d*) and sells less (from point *a* to point *g*) to farmers in the less elastic market. With a marginal cost of about $16.88/acre, the innovator can charge about $25.92/acre in US/NR and about $33.09/acre in LS/R.

At the discriminatory prices, the number of acres cultivated to Bt cotton would increase from about 60 to 142 thousand acres in US/NR and decrease from about 747 to 701 thousand acres in LS/R. The total number of Bt cotton acres will increase by about 35 thousand acres. Table 2 shows the change in quantities, prices, and welfare in both markets after price discrimination. Under price discrimination, total welfare, computed as the sum of consumer surplus and monopoly profit, increases.[4] Welfare to farmers in US/NR increases by about 32%, while welfare to farmers in LS/R decreases by about 3% of the value of Bt cotton seed initially sold in each market. The monopolist's profits increase by 2%.

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4. *The demand functions are not linear, so the estimates of consumer surplus obtained are only approximations—but good approximations, because the price changes are not too large.*

Because both markets were being served under uniform pricing, welfare of farmers in one of the markets (in this example, LS/R) necessarily decreases under differential pricing.

Conclusion

In this paper, we analyzed the welfare effect of adding price discrimination to monopoly power in the provision of IP-protected innovations. The theoretical literature has produced few general results regarding the welfare implications of price discrimination, suggesting that empirical studies are needed. We presented a general analytical model which was parameterized using data from the introduction of Bt cotton in the southern United States. Results suggest that where both markets are being served under a one-price policy, there is a welfare loss to farmers in the less elastic market and gains to the innovator and farmers in the more elastic market.

In the Bt cotton case, the fact that the innovator (Monsanto) was not price discriminating at the time the data for this study were collected may have been due to the difficulty in preventing arbitrage between markets.

Table 2. Change in prices, quantities, and welfare under price discrimination.

Region	Price ($/acre)		Quantity (acre)		Welfare change ($)	Welfare change as a share of initial cost of seed (%)
	Initial	Discriminating	Initial	Discriminating		
Upper South	32	25.92	60,496	142,279	616,198	32
Lower South	32	33.09	747,499	700,551	-792,233	-3
Innovator	32		807,995	842,830	428,626	2
Total welfare change					252,590[a]	

Note. Data from authors' computations using Hubbell et al. (2000).
[a] *Differences due to rounding error.*

Spatial arbitrage is more difficult when the second market is in a developing country (niche) market because of the geographical separation of the two markets. In this situation, a policy of differential input pricing will benefit the innovator by helping defray the investment incurred by the innovators and may represent a path for assisting developing countries to gain access to new technologies generated by R&D efforts.

A more interesting case is that of a small market not being served under uniform pricing (for instance, the case of most developing countries) but that may obtain access to the technology under price discrimination. The ability to use price discrimination to market biotechnology innovations in separated markets may be more important for developing countries to access these innovations, even though this is a controversial subject. However, this is a potentially important strategy for providing access to needed technology that may benefit both the biotechnology industry and the small market countries. Without access to cost-reducing technologies, developing countries that compete with developed-country producers will see welfare reduced because of the output price-reducing impact of technological change. Putting in place conditions under which firms are able to price discriminate across international markets holds the potential to enhance developing-country access to private-sector technology.

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Authors' Notes