AGRICULTURAL BIOTECHNOLOGY AND INDUSTRY STRUCTURE

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In the last ten years the seed and pesticide industries have undergone a substantial number of structural changes. These changes are due to a number of factors, some of which are common to all industries and some of which are specifically tied to the biotechnology that is increasingly important in the seed and chemical industries. The focus of this paper is on these latter linkages. The horizontal mergers and acquisitions can be linked to R&D costs, economies of scale and scope created by intellectual property rights, and to regulatory costs, while the increased vertical linkages are connected to product complementarity and to the difficulty in enforcing certain types of intellectual property. In other cases, the rise of better-defined intellectual property rights has been a factor in the joint ventures and strategic alliances that have occurred. The pricing behavior of the large firms in the seed and chemical industries appears to be strategic in nature, with pricing being influenced by competition from other products and the value created by their products. There is substantial evidence of price discrimination, whether it is in the form of TUAs, differential pricing, or tied sales. The major impact of this strategic pricing is not on the total economic surplus created as a result of R&D, but rather on the distribution of this surplus.

Key Words: biotechnology; consolidation; chemical and seed industries; intellectual property rights; industry structure; strategic pricing.

In the last ten years the seed and pesticide industries have seen a substantial number of mergers and acquisitions and an increase in vertical and horizontal integration. The purpose of this paper is to examine the reasons for the structural changes that are underway in the seed and chemical industries, to review the literature on concentration in the seed and chemical industries, and to explore the importance of concentration for these industries. The paper first examines the changing structure of the seed and pesticide industry, detailing the horizontal and vertical changes that have occurred. The paper then examines the theoretical and empirical literature on the factors affecting the horizontal and vertical structure, followed by a review of the effects of concentration. The paper concludes with a short summary.

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The Changing Structure Of The Agricultural Biotechnology Industry: Horizontal Structure

Table 1 presents world sales of the top ten pesticide and seed firms for 1997 and 1999. Longer-term time series data on the structure of the chemical and seed company are difficult to obtain. In one of the few published papers to provide this data, Ollinger and Fernandez-Cornejo (1998) provide Concentration Ratio data (CR4) for the United States pesticide industry over the period 1972-1989. During this period, the CR4 oscillates, moving from a high of 50% in 1973 to a low of 37% in 1982, and then rising to 48% in 1989. These values are consistent with the pesticide CR4 value presented in table 1.

Although detailed data are not available for the 1990s, there is evidence that the structure of the seed and chemical industry remains dynamic. Table 2 outlines the consolidation activity of the ten most active biotechnology firms. Mergers and acquisitions are a key component of the new business relationships that have emerged. Figure 1 illustrates that these mergers and acquisitions are the latest in a series of merger and acquisition waves. As Kalaitzandonakes and Hayenga (2000) note, firm entry in the crop biotechnology industry peaked in the early 1980s, with production innovation continuing throughout the 1980s. Oehmke *et al*. (1999) also discuss the cyclical pattern in mergers in the biotechnology industry.

Aggregate market figures mask the much higher concentration that exists in specific markets (Sexton, 2000). For example, in 1998, Monsanto and Pioneer-HiBred (now owned wholly by DuPont) controlled 15% and 39% of the US seed corn market, respectively. These two same companies controlled approximately 24% and 17%, respectively, of the purchased soybean seed market. For the US cotton market, two companies, Delta & Pine Land and Stoneville, had 71% and 16%, respectively, of the seed market (Kalaitzandonakes & Hayenga, 2000).

The determination of the relevant market concentration is not always done on the basis of output markets. The Federal Trade Commission has used innovation competition to assess the impact of mergers. Examining competition in innovation is designed to focus attention on the impact of a merger on innovative activity. Using data on field trials underway each year, Brennan Pray, and Courtmanche (2000) calculate a CR4 ratio at the R&D stage. In 1988, the four largest firms had 87% of the field trials. The CR4 ratio declined to a low of 63% in 1995, then rose steadily over the next few years to reach 79% in 1998. This concentration at the R&D stage is matched by concentration in terms of the number of patents held. The top four firms held 41% of the corn patents (up to 1996), 53% of the soybean patents (up to 1997), 77% of the tomato patents (up to June 1997) and 38% of the Bt patents (up to 1998) (Brennan, Pray, & Courtmanche, 2000).

Concentrated markets do not necessarily imply the presence of market power. Baumol, Panzar and Willig (1992) stress that firms will not be able to exercise market power if the market is contestable. The key requirements for market contestability are: (a) Potential entrants must not be at a cost disadvantage to existing firms, and (b) entry and exit must be costless. For entry and exit to be costless, there must be no sunk costs. Sunk costs are expenditures that cannot be recouped once they are incurred—examples include expenditures made to obtain regulatory approval, expenditures on advertising, and expenditures on R&D. If there are no sunk costs, potential entrants can use a hit-and-run strategy in which they enter an industry, undercut the price of the incumbents, reap the profits and exit before the incumbents have time to retaliate. In anticipation of entrants acting in this manner, the incumbents forestall entry by keeping price at average cost. The consequence is that, even in an industry that is highly concentrated, prices can be kept at or near competitive levels.

Table 1: World Sales of Top Ten Pesticide and Seed Companies.

Company	1997 Pesticides	1997 Seed	1999 Seed	1998 Plant Biotech
	Millions $			
DuPont (Pioneer) USA	2,518	1,800	1,850	---
Pharmacia (Monsanto) USA	3,126	1,800	1,700	88 %
Syngenta (Novartis) Switzerland	4,199	928	947	4 %
Groupe Limagrain (France)	---	686	700	---
Grupo Pulsar (Seminis) Mexico	---	375	531	---
Advanta (AstraZeneca and Cosun) UK and Netherlands	2,674	437	416	---
Sakata (Japan)	---	349	396	---
KWS AG (Germany)	---	329	355	---
Dow USA	2,200	---	350	---
Delta & Pine Land (USA)	---	---	301	---
Adventis Group (Hoechst/Rhone-Poulenc)	4,554	---	---	8 %
Bayer	2,254	---	---	---
American Home Products	2,119	---	---	---
BASF	1,855	---	---	---
Sumitomo	717	---	---	---
Agribiotech	---	425	---	---
KWS	---	329	---	---
Takii	---	300	---	---
Total World Sales	30,900	23,000	24,700	---
CR4	47 %	23 %	21 %	100 %
CR10	85 %	32 %	31 %	100 %

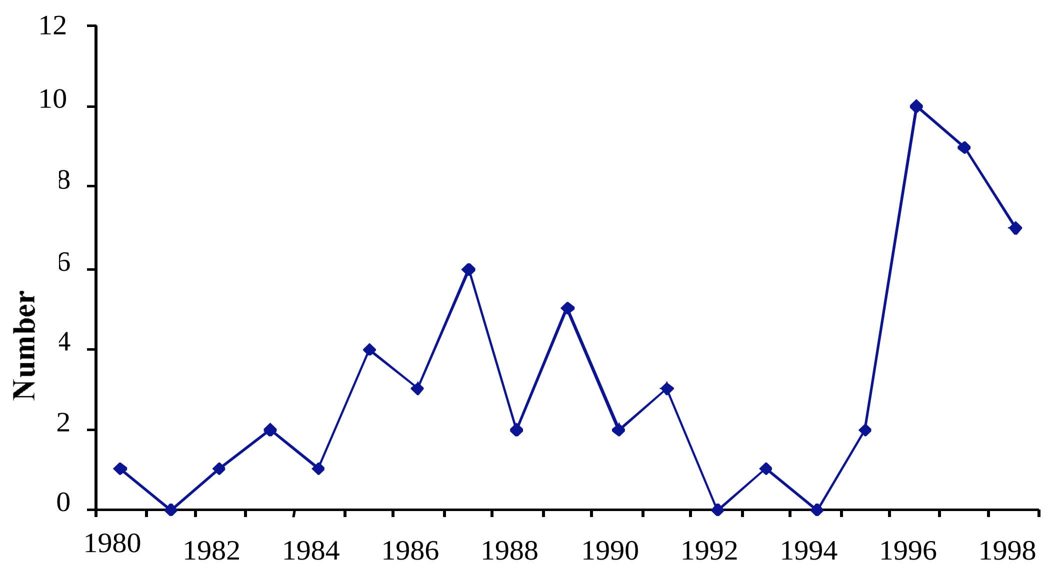
Note. From "Impact of Industry Concentration on Innovation in the US Plant Biotech Industry," by M.F. Brennan, C.E. Pray, and A. Courtmanche, 2000, In Transitions in Agbiotech: Economics of Strategy and Policy, W.H. Lesser (Ed.). Storrs, CT: University of Connecticut. Dashes indicate data not applicable.

Table 2: Consolidation Activity for the Ten Most Active Biotechnology Firms, 1998.

Company	Mergers	Acquisitions	Joint Ventures	Other	Total
Monsanto	1	15	4	17	37
AgriBiotech	1	30	0	5	36
Novartis	3	21	1	0	25
AgrEvo/Aventis	2	15	3	2	22
AstraZeneca	0	14	1	1	16
Limagrain	0	15	0	1	16
Empressa La Moderna	1	10	0	5	16
Rhone-Poulenc Agro	3	6	2	2	13
DuPont	0	3	2	8	13
DeKalb Genetics	0	11	0	0	11

Note. From "Impact of Industry Concentration on Innovation in the US Plant Biotech Industry," by M.F. Brennan, C.E. Pray, and A. Courtmanche, 2000, In Transitions in Agbiotech: Economics of Strategy and Policy, W.H. Lesser (Ed.). Storrs, CT: University of Connecticut.

Figure 1: Mergers and Acquisitions by Diversified Biotechnology Firms.



Note. From "Structural Change in the Biotechnology and Seed Industrial Complex: Theory and Evidence," by N. Kalaitzandonakes and M. Hayenga, 2000, in Transitions in Agbiotech: Economics of Strategy and Policy, W.H. Lesser (Ed.). Storrs, CT: University of Connecticut.

However, if sunk costs are present, firms entering an industry are unable to exit again without losing a portion of their investment. As a result, hit-and-run strategies are much less profitable and incumbents are able to keep price above average cost. Thus, with sunk costs, markets are not contestable and market power is once again an issue. As discussed below, sunk costs appear to be a key feature of the seed and chemical markets.

The Changing Structure Of The Agricultural Biotechnology Industry: Vertical Structure

In addition to becoming larger through growth and horizontal integration, the major agrochemical companies have restructured themselves in other ways. One of the major changes is increased vertical integration—for example, the combining of seed, chemical and biotechnology activities within the same firm. Although some companies initially tried to include pharmaceutical and biotechnology components within the life science model, practically all of them have now divested their agricultural operations (see King, 2001; Chataway, 2001; Bijman, 2001a, 2001b for details on recent actions). A further element of this internal restructuring is the increased use of strategic alliances.

Many countries have had their own local seed companies that have over the years developed seed for a specific geographical market and operated sales and distribution systems. The major biotechnology companies are increasingly purchasing these seed companies as a source of seed material in which to insert the genes for herbicide or insect resistance (Kalaitzandonakes & Hayenga, 2000). As an example, in 1997, Monsanto acquired a 30% share of the Brazilian corn seed market with the acquisition of Sementes Agroceres. With its 1998 purchase of Cargill's international seed division, Monsanto now controls over half the Argentine maize seed market. In 1998, Dow AgroSciences acquired Morgan Seeds, Argentina's second largest corn seed company, and Brazil's Dinamilho Carol Productos Agricolas, another key South American corn seed company. Phytogen (majority owned by Dow Agrosciences) acquired a major cottonseed breeding program in the Chaco province of Argentina. In 1998, Mexico-based Empresas La Moderna (ELM) bought two South Korean vegetable seed companies and Nath Sluis (agricultural biotech company) of India (Action Group on Erosion, Technology and Concentration [ETC], 2000).

Factors That Affect Horizontal Industry Structure

Numerous factors are behind the wave of horizontal mergers and acquisitions described above. Some of these factors are common to all industries and have no specific link to the seed, chemical and agricultural biotechnology industries. Thus, the mergers and acquisitions in the seed and chemical industries are at least in part a result of the need to consolidate costs and rationalize industry capacity, a desire by the management of the firms involved to extend their sphere of influence, and a wish by some firms to pre-empt other firms from taking over valuable assets (Shy, 1996). MacDonald (2001) provides an overview of concentration levels in a number of US agricultural sectors, many of which have seen higher concentration in recent years.

There are at least two explanations for increasing concentration, however, that pertain specifically to the seed, chemical and agricultural biotechnology industries: (a) sunk costs, and (b) escalation strategies.

Sunk Costs

Two sources of sunk costs appear to be important in determining industry concentration: (a) intellectual property rights and R&D expenditures, and (b) the regulatory requirements that governments have introduced before the products of the R&D activity can be marketed.

On the empirical side, Ollinger and Fernandez-Cornejo (1998) examine sunk costs and regulation in the US pesticide industry. Using data over the 1972-89 period, they find that research costs and pesticide regulation costs negatively affect the number of companies in the industry, and that smaller firms are affected more strongly by these costs than are larger firms. Research and regulation costs also encourage foreign-based firms to expand into the US market and to force less profitable innovative firms to exit the market. Ollinger and Fernandez-Cornejo also point out that their results on the impact of regulatory costs generally match those found in other industries.

These empirical results can be linked to theoretical arguments concerning sunk costs and the economies of scale and scope that sunk costs tend to create. As Sutton (1991) outlines, the presence of sunk costs means that for firms to be profitable, price needs to be raised above marginal cost, typically by reducing the amount of competition (i.e., the number of firms). Sutton identifies two types of sunk costs: exogenous and endogenous. Exogenous sunk costs are those beyond the control of the firms in the industry. Regulatory costs are a good example of exogenous sunk costs. In contrast, endogenous sunk costs are firm-level strategic variables. Advertising and R&D are examples of endogenous sunk costs. The rest of this section examines the connections between intellectual property rights (IPRs), R&D expenditures, regulatory costs, and economies of scale and scope.

Economies of scale and scope are major factors in propelling industries towards concentration. Economies of scale exist when average costs fall as more output is produced; economies of scope exist when the total cost of producing two outputs together is less than the cost of producing the two outputs separately. Because economies of scale and scope mean that larger and diversified firms have lower average costs, there is clearly an incentive for firms to get large (Fulton, 1997; Lesser, 1998; Hayenga, 1998). Indeed, those that do not get large are vulnerable to being driven out of the market by larger and more cost efficient firms. Of course, there is a limit to how large firms can get. Although development and production costs may fall with an increase in the size of the firm, other costs—particularly those associated with administration—rise. Nevertheless, economies of scale and scope clearly create pressures for consolidation.

Economies of scale and scope are created as a result of investment in non-rival goods. Unlike rival goods—such as materials, labor, and energy—which can only be used in one place, by one person and at one time, non-rival goods can be used in more than one place and by more than one person, all at the same time. This feature of non-rival goods—that they can be used over and over again—means that output can be increased without having to increase all inputs. Consequently, economies of scale and scope are created (Romer, 1990; Fulton, 1997). Much of the expenditure on non-rival goods—examples include R&D and regulation expenditures—can be considered a sunk cost.

Intellectual property, of course, is a good example of a non-rival good. Indeed, ideas generally are considered non-rival goods. It is widely believed that many of the high-technology industries, including the biotechnology and information industries, are subject to increasing returns. Romer (1990) postulates that this is a result of the distinction between physical goods and ideas. Ideas are not scarce, and as such, any industry based primarily on the trade of intellectual property will not face diminishing returns in their primary resource, the idea. The protection of intellectual property, through IPRs, is designed to encourage innovation and to provide incentives for the development and diffusion of new products and technologies.

An example illustrates the connection between intellectual property and economies of scale and scope. Suppose a biotechnology firm has some intellectual property, such as a particular gene that has been isolated. This intellectual property can be used over and over again as the firm expands its activities. For instance, if the company wishes to develop seeds for a new crop, it will not have to invest again in the research that isolated the gene. Although the development of a new seed will require additional lab and greenhouse space, labor, and materials, the expenditure on the technological advancements does not have to be made again.

A similar result occurs if the firm needs to invest substantial amounts of money in obtaining regulatory approval for a seed—although the production of additional units of the seed will require additional costs, the regulatory expenditures do not have to be made again. Once again, large companies typically have an advantage, because they are able to spread the costs of obtaining regulatory approval over more output. Thus, the greater the regulatory requirements in an industry, the more concentrated the industry is expected to be.

Intellectual property may also create economies of scope. Once a specific gene has been isolated—for instance, a gene that confers a resistance to a particular herbicide—this gene can then be put in a number of crops. Once again, the production costs of a number of products together will be less than if the products were produced separately.

To recap, R&D expenditures and regulatory costs are both sunk costs and a source of economies of scale and scope. Because economies of scale or scope mean that larger and more diversified firms have lower average costs, there is clearly an incentive for firms to get large (Fulton, 1997; Lesser, 1998; Hayenga, 1998). Indeed, those that do not get large are vulnerable to being driven out of the market by larger and more cost efficient firms. These theoretical results are supported by empirical observations in the US pesticide industry (Ollinger & Fernandez-Cornejo, 1998).

<u>Escalation Strategies</u>

An escalation strategy is one in which a company spends large amounts on R&D and engages in mergers and acquisitions to achieve a dominant role in the market—that is, the firm tries to leapfrog its competitors to become the dominant firm. Escalation can be a profitable strategy when there is a high degree of substitutability with competitors' products on the demand side, and there are scope economies on the supply side (Sutton, 1998). Both of these factors are present in the agricultural biotechnology industry.

As discussed above, the isolation of a gene that provides particular advantages and which can be inserted into a number of crops means there are scope economies on the supply side. There are also clear supply side scope economies associated with the enabling technologies that are required to use these genes. And on the demand side, herbicide and insect resistant seeds and the accompanying chemicals are clearly a substitute product for traditional seeds and herbicides and pesticides (Hayenga, 1998).

Firms engage in escalation strategies in a number of ways. Although internal growth through R&D is one way, the more common method is through consolidation via horizontal mergers and acquisitions. As the theory predicts, the combination of demand substitutability and supply side scope economies present in the seed and chemical industry appears to be linked with escalation strategies. Monsanto has clearly followed an escalation strategy, with Dow, Novartis, and others following similar strategies of making acquisitions and spending significant amounts on R&D (Bijman, 2001a, notes that agricultural seed companies typically spend 15% of turnover on R&D).

Factors That Affect Vertical Industry Structure

There are a number of factors at work that encourage increased vertical linkages in the agricultural biotechnology industry. These factors can be grouped into those that are connected with IPRs, and those connected with the substitutability and complementarity of biotechnology products.

Complementarity and Substitutability in Agricultural Biotechnology

Agricultural biotechnology has to date focused on the creation of crops that are resistant to particular insects (e.g., corn, cotton and potatoes) and herbicides (e.g., corn, soybeans, cotton, and canola). With new genetic coding, seeds have become both complementary and substitute products for chemicals. For instance, Roundup Ready® soybean seeds are complementary products to the glyphosate in Roundup®, and are substitute products for the herbicides traditionally used to control weeds in soybean crops.

There is some evidence that the direct market effects of product complementarity and substitutability are economically significant. For instance, in the US, the adoption of herbicide-tolerant soybeans was associated with small increases in yields and variable profits, and significant decreases in herbicide use. The adoption of herbicide-tolerant cotton in 1997 was associated with an increase in yields and variable profit, but was not associated with significant changes in herbicide use (Fernandez-Cornejo & McBride, 2000). Of course, looking at total herbicide use masks the fact that the introduction of herbicide-tolerant crops means that the demand for certain herbicides increased, while that of other herbicides declined.

As Just and Hueth (1993) point out, strong demand complementarities mean that a single firm producing both chemical and biotechnology products can be more profitable than can separate firms producing these products. A single firm can be more profitable producing both of these products because this firm can price the products so that the use of the complementary product is encouraged. Thus, demand complementarities appear to be important factors in explaining the amalgamation of seed and chemical companies.

Intellectual Property Rights

The way in which organizations and contractual arrangements are structured is also influenced by IPRs. Intellectual property rights create pressures for either greater vertical integration or strategic alliances and contracting, depending on the nature of the intellectual property and the rights associated with it.

If IPRs are well defined, then transaction costs—those costs associated with negotiating, specifying, monitoring and enforcing contracts—are usually fairly low (Merges, 1998). As a result, contracting and strategic alliances are now more likely. Independent companies can efficiently and effectively operate alongside each other, each focusing on their specialty while at the same time having access to the intellectual property of the other firms through contracts, licenses or joint venture agreements. As table 2 shows, the major biotechnology firms have used joint ventures and other business relationships (e.g., licenses, research agreements), in addition to mergers and acquisitions.

Vertical integration, through mergers and acquisitions, is more likely if IPRs are not well defined. Intellectual property right issues, for instance, may help explain why multinationals have bought out local seed companies in some countries rather than license genes to them. In countries where intellectual property rights are not well protected, multinationals have opted for buyouts. As well, the buyout/licensing decision is dependent on the degree of appropriability of the technology and the relative strength of complementary assets (Kalaitzandonakes & Bjornson, 1997).

Vertical integration also becomes attractive when intellectual property rights create opportunities for exploitation. If IPRs give a company the ability to exert market power vis-à-vis the companies with which it trades, the up- or down- stream companies may be deterred from investing in new technologies or developing new products that would be traded with the dominant firm. The firms are deterred because of a concern that the dominant firm will appropriate the benefits from the innovations. To remedy the situation, the companies with the market power may decide to vertically integrate and take over the R&D and market development (see Hart, 1995, for a presentation of this "hold-up" problem). The decision by multinationals to integrate the sales and distribution systems of the local seed companies they purchased into their own businesses may be linked, in part, to a concern that the local seed companies will not have the appropriate incentives to maintain and strengthen their retail operations.

The nature of the vertical relationships in an industry can also be affected if intellectual property is associated with intangible assets. Intangible assets are those factors that are important to a transaction, but are difficult to specify and measure. For instance, transferring a new biotechnology process from one company to another may involve more than simply specifying the steps that are required. Often the precise timing of the steps or subtle nuances in how the steps are performed can affect the results in important and significant ways. In these situations, a simple licensing of the process to another firm may be relatively ineffective. To counteract these problems, technology providers typically supply transformation services along with the gene events that they are licensing. In other cases, the nature of the intangible assets may be one of the reasons why multinationals have bought out local seed companies rather than licensing the products to them.

Expected Results Of Concentration

Analyzing the behavior of seed, chemical and biotechnology companies is very difficult and no studies can be found to date that explicitly examine the pricing behavior of firms in these industries. Nevertheless, two broad conclusions can be drawn from the literature. First, pricing by the seed and chemical companies is largely strategic in nature. Second, these strategic decisions can have important impacts on the distribution of the benefits obtained from R&D.

Strategic pricing means that prices are actively chosen by firms rather than being determined exogenously. Factors important in strategic pricing include the value created by the products being sold, the degree of competition present in the industry, and the impact that prices might have on competition. Strategic pricing is closely linked to sunk costs, which are a key feature of the seed and chemical industries. Sunk costs have two important consequences for the pricing of a product: (a) Pricing will not be at marginal cost, and (b) pricing will typically not reflect average cost. The existence of substantial sunk costs and relatively low marginal costs mean that firms must have some ability to price above marginal cost if they are to have an incentive to undertake R&D expenditures. As well, sunk costs imply that the seed and chemical industry is not contestable and that the threat of entry cannot be relied upon to keep profits at normal levels.

There are a number of manifestations of these pricing strategies. One manifestation is found in the pricing of substitute products such as synthetic pesticides. For instance, the introduction of herbicide-tolerant soybean varieties led to a 50% discounting of the prices of post-emergence soybean herbicides by DuPont and American Cyanamid in 1997 and 1998. This price reduction substantially limited the flexibility of Monsanto to price Roundup Ready® soybeans and its related herbicide.

A second manifestation of this pricing behavior can be found in the various forms of price discrimination that exist in the seed and chemical industry. Included among the price discrimination practices are two-part pricing schemes, differential pricing to different groups of customers, and tied sales. An example of a two-part pricing scheme is the Technology Use Agreement (TUA). Although TUAs are being phased out, they were an important pricing feature in the industry. Under a TUA, farmers paid a set fee for the right to use the seed, as well as the cost of the chemical to which the seed is resistant each time they applied the chemical. Formally, TUAs are an example of second-degree price discrimination—farmers with greater weed control problems pay a smaller per unit price (the TUA is spread over a greater amount of chemical) than those with a smaller weed control problem.

A number of examples exist where seed and chemicals are priced differently to different groups of customers—that is, third degree price discrimination is practiced. Lindner (1999) provides the case of cotton, where the TUA fee was set substantially higher in Australia that in the United States. The differential price in Australia appears to be the result of a higher willingness to pay by Australian farmers. In a well-publicized case, the US General Accounting Office provided evidence of how Roundup Ready® soybeans are priced significantly lower in Argentina than in the US. The lower price in Argentina appears to be linked to the weaker intellectual property regimes in place in that country (Giannakas, *in press*).

In theory, price discrimination could also be carried out across geographical regions within a country. Evidence from the US and Canada suggests that differences do exist in farmers' willingness to pay. For instance, although herbicide-resistant technology is being adopted widely in some areas, it is being adopted less widely in others. In the Southern Seaboard, as an example, over three-quarters of soybean production is from herbicide-tolerant varieties; in contrast, the Northern Crescent region has much lower adoption rates for soybeans than the other regions (Fernandez-Cornejo & McBride, 2000). The adoption rate in Canada for herbicide-tolerant soybeans is also relatively low. In addition there is evidence that the cost of alternative weed or insect control packages and agronomic characteristics vary by region and by farmer (Carpenter & Gianessi, 1999; Klotz-Ingram, Jans, Fernandez-Cornejo, & McBride, 1999; Fulton & Keyowksi, 1999). Despite these differences in the willingness to pay, the price of biotechnology products appears to be similar across the US and across Canada. This lack of third-degree price discrimination may be due to an inability to avoid arbitrage between markets, or due to the perceived cost of implementing different prices in different geographical regions.

A further manifestation of strategic pricing decisions can be found in tied sales. In an examination of the tying of seed and chemical products, Hennessy and Hayes (2000) attempt to infer the structure of the market from the decisions made by the life science companies. They provide evidence that the behavior of Monsanto up to the 1998 crop year is consistent with Monsanto having a monopoly in Roundup Ready® technology, while facing substantial competition in the chemical (glyphosate) market. After 1999, the behavior of Monsanto is more consistent with a model in which Monsanto is involved in a duopolistic seed market and a relatively competitive chemical market.

The pricing decisions undertaken by the seed and chemical companies have important impacts on the distribution of the benefits obtained from R&D. To date, two papers have explicitly examined the impact of biotechnology products on producers, consumers, and life science companies. Falck-Zepeda, Traxler, and Nelson (2000) find that 26% of the total benefits accrue to the gene developer and the germ plasm supplier, while Moschini, Lapan and Sobolevsky (2000) find that 45% of the total benefits in their base case are captured by the innovator. In both cases, the benefit received by the innovator was dependent on the strategic pricing decisions they made. Moschini, Lapan and Sobolevsky also show that although the presence of market power did not reduce the overall benefits of the herbicide-resistant technologies, it did significantly affect the distribution of these benefits. For example, in their study, the surplus that accrued to the innovator due to strategic pricing was almost completely offset by a loss to consumers and producers.

The distributional impact is important because it raises questions about which groups are likely to benefit from the introduction of new technology, which in turn raises questions about the adoption and/or acceptance of new technology. In the presence of market power, both consumers and producers may be less willing to adopt or accept new developments in biotechnology because of the smaller share they obtain (Moschini, 2001; Giannakas & Fulton, *in press*). Given that adoption of genetically modified (GM) products has been very high in cotton, soybeans and canola, it is tempting to conclude that the benefit distribution has been such that both consumers and producers have received sizable benefits. This conclusion, however, does not automatically follow. Consumers may adopt the GM product simply because it is available (i.e., the producers have supplied it) and they see little if any difference between it and the traditional non-GM product. In such a case, and in the absence of significant price reductions, the consumers capture few benefits. On the producer side, those who adopt early are expected to benefit from the new technology. However, it is also possible that the rest of the producers may benefit less or even incur a net loss. Late adopters and non-adopters may lose if adoption results in an outward shift of the supply curve and a reduction in the price received by the producers. In such a case, a large portion of the benefits accrues to the consumers in the form of lower prices.

Moschini, Lapan and Sobolevsky (2000) further point out that the benefits captured by the innovator are a significant part of the benefits received by the country in which the innovator is located. When market power is zero, the home country receives only 22% of the total benefits; when market power is high the home country receives 58% of the benefits (assuming the innovation is adopted around the world). Thus, the encouragement of a highly concentrated innovating sector within its borders can also be part of a strategic trade policy for a country wishing to maximize the benefits it receives from biotechnology.

Concluding Remarks

In the last ten years, the seed and pesticide industries have seen a substantial number of mergers and acquisitions and an increase in vertical and horizontal integration. The structural changes underway in the seed and chemical industries are due to a number of factors. Some of these factors are common to all industries and have no specific link to biotechnology. For instance, the mergers and acquisitions in the seed and chemical industries are at least in part a result of the need to consolidate costs and rationalize industry capacity, a desire by the management of the firms involved to extend their sphere of influence, and a wish by some firms to pre-empt other firms from taking over valuable assets.

The horizontal mergers and acquisitions that have occurred in the seed and chemical industries can also be linked to R&D costs, economies of scale and scope created by intellectual property rights, and to regulatory costs. The increased vertical linkages in the industry are connected to the product complementarity that is increasingly present between seed and chemical products, as well as to the difficulty in enforcing certain types of intellectual property. In other cases, the rise of better-defined intellectual property rights has been a factor in the joint ventures and strategic alliances that have occurred.

The pricing behavior of the large firms in the seed and chemical industries appears to be strategic in nature, with pricing being influenced by competition from other products and the value created by their products. There is substantial evidence of price discrimination, whether it is in the form of Technology Use Agreements, differential pricing, or tied sales. The key impact of this strategic pricing is not on the total economic surplus created as a result of R&D, but rather on the distribution of this surplus (Sexton, 2000; Moschini, Lapan, & Sobolevsky, 2000).

Structure, strategic pricing and the distributional impacts of this pricing are important considerations of public policy. In particular, because a great deal of the structural issues in the industry are linked to intellectual property rights, the question arises as to the proper degree of protection that should be provided through IPRs. Intellectual property rights are granted to companies and individuals as an explicit element of public policy. They are specifically designed to encourage innovation and to provide incentives for the development and diffusion of new products and technologies. The empirical evidence suggests that the establishment and strengthening of property rights in agriculture has led to an increase in private investment in agricultural research (Moschini & Lapan, 1997). Intellectual property rights also provide benefits by creating economies of scale and scope, which in turn mean lower costs for those firms that can expand production. At the same time, IPRs can be linked to higher concentration, which in turn lead to deviations from marginal cost and average cost pricing. Intellectual property rights thus represent a tradeoff between the potential negative effects of market power and the benefits from greater R&D (Gallini & Trebilcock, 1998).

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