AGRICULTURE

A Worrisome Crop?

Is there market power in the U.S. seed industry?

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The Obama administration has promised to strengthen antitrust enforcement and to reverse the more laissez-faire guidelines of the previous administration. In this context, the U.S. Department of Justice has recently focused its attention on certain agricultural industries, including the U.S. seed industry. The primary areas of concern are the growing level of market concentration and the potential use of market power by seed firms.

Markets are said to be concentrated if a few firms hold a relatively large share of the market, and high concentration is one of the criteria used by federal antitrust authorities when they evaluate the competitive conditions of a particular market. Firms in a highly concentrated market may be able to exert market power and raise prices above a competitive level, to the detriment of buyers. However, high concentration does not necessarily imply the exertion of market power. Economic theory predicts that prices may be kept at or near competitive levels under the threat of entry by new suppliers, even in industries that are highly concentrated. Also, the market may be contestable and remain relatively competitive if potential entrants do not face costs that existing firms can avoid, there are no inherent legal barriers to entry, and entry and exit are relatively costless (i.e., there are no sunk costs).

Several economists have noted that firm entry in the U.S. seed industry may be limited by large entry costs due to high research and development investments and regulatory compliance costs as well as by the complexity of intellectual property rights. These circumstances could limit market contestability and increase the likelihood that firms exert their market power.

At the same time, other authors have noted that the presence of some market power in the U.S. seed industry may not be completely undesirable. Seed firms engaged in the development of new genetics and biotech traits are expected to charge prices above marginal costs in order to recoup the fixed costs of R&D. Without the existence or the prospect of earning prices above marginal costs due to market power, the seed firms would have no incentive to use more efficient technologies, improve product quality, or introduce new seed varieties and biotech traits. Therefore, some authors have proposed that the key question to be addressed is whether concentration and potential presence of market power in the seed industry permits firms to make profits well above those necessary to recoup their R&D investments.

In this study, we report empirical measures of price mark-ups attributable to market power in the U.S. seed industry between 1997 and 2008—a period characterized by the vertical integration of leading multinational biotechnology firms in this industry. We then calculate the revenues from the estimated mark-ups, compare them with approximate measures of aggregate R&D expenditures in the industry, and draw conclusions about their proportionality over the period of analysis. These results provide insight on the dynamic efficiency of the industry.

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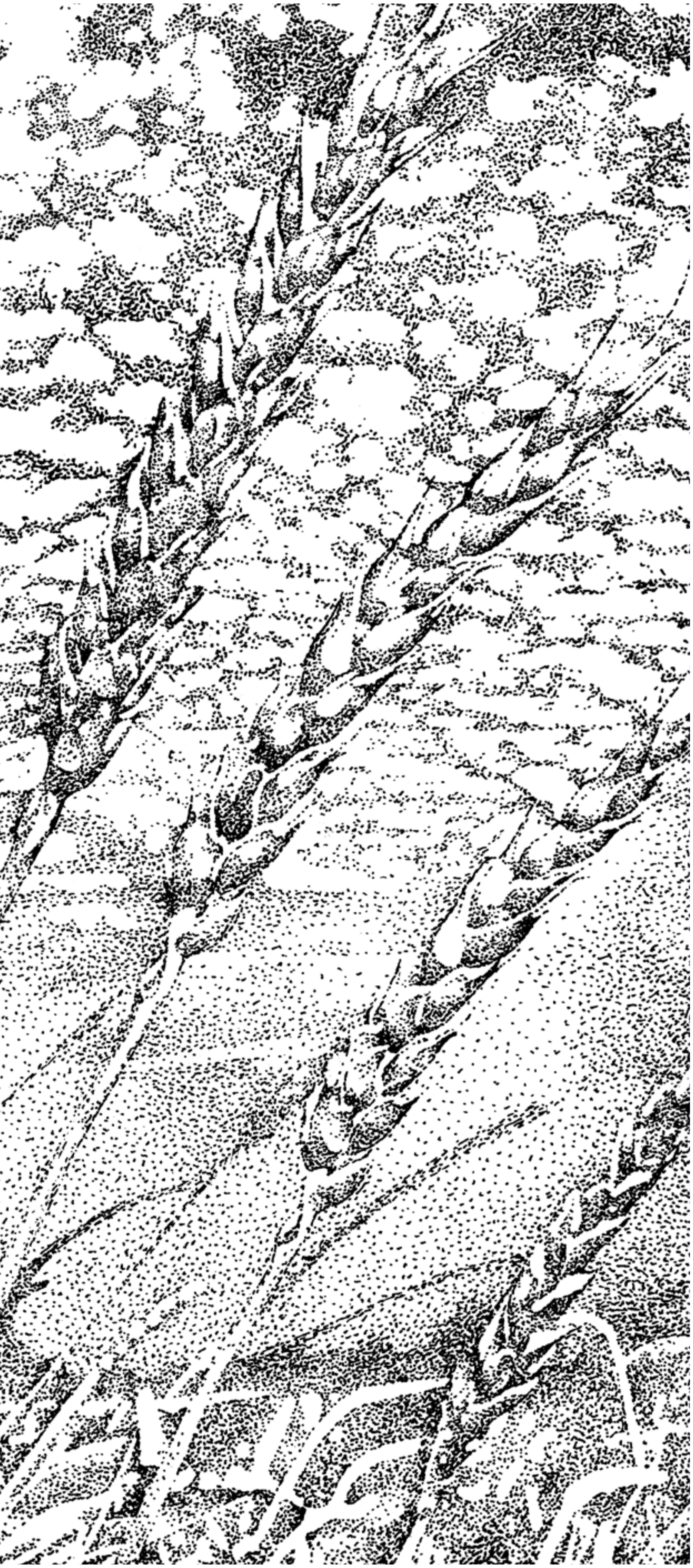


Structural Evolution

Understanding the structural evolution of the U.S. seed industry can help put in context the current considerations of concentration and market power. Since the emergence of a commercial seed industry in the United States over 150 years ago, assets have changed hands frequently and most of today's leading seed companies are the products of mergers and acquisitions. Until the late 1960s, assets in the seed industry were primarily traded among seed companies. Starting in the 1970s, however, petrochemical and pharmaceutical multinational companies became primary acquirers. Much of this activity has been traced to the introduction of the Plant Variety Protection Act of 1970, which promised to increase returns from plant research and attracted R&D-minded multinationals. However, this wave of mergers and acquisitions had little subsequent discernible impact on the structure of the seed industry because the petrochemical and pharmaceutical multinationals mainly acquired and merged small and medium-size regional seed companies, which lost market share over time. Both independent market leaders (e.g., Pioneer, Dekalb) and smaller regional and local seed companies maintained their market positions despite the significant capital resources of the new multinational entrants.

Significant consolidation in the U.S. seed industry did not occur because the cost advantages of operating at higher production levels (i.e., economies of scale) were limited and barriers to entry were rather low. In principle, large investments in breeding research and specialized know-how implied that potential scale economies could be significant. Indeed, only a few large seed companies maintained extensive breeding efforts and developed proprietary varieties. Further, substantial time lags between genetic research and commercialization of improved varieties created potential entry barriers. Yet the need for geographic adaptation of all new seed varieties placed bounds on R&D scale economies. Importantly, it also created commercial opportunities for specialized breeding (foundation seed) companies, which minimized entry barriers. They developed and broadly licensed proprietary varieties to a large number of small regional and local seed companies, which in turn adapted them to their local conditions.

The potential economies of scale in distribution and marketing of seeds were even more limited. With crop yields being the primary differentiating factor among seed brands, smaller regional companies could effectively compete against much larger national and multinational firms with extensive marketing and distribution networks. The regional seed companies produced and distributed a small number of varieties within limited geographic regions where they demonstrated competitive yield performance. The regional firms were often relatively more profitable as they were able to avoid the excessive inventory costs that frequently hampered the national firms.

By the early 1990s, many of the multinational firms that led the mergers and acquisitions activity in the previous two decades had divested their seed assets. A handful of multinationals with significant investments in biotechnology, however, maintained or expanded their presence in the U.S. seed industry.

The 1990s | Since the advent of agricultural biotechnology research in the mid-1970s, superior seed genetics (germplasm) were recognized as an essential complementary asset for delivering new biotechnologies. For the commercial introduction of a new biotech product to be successful, the intellectual property, the biotechnology know-how, and the seed germplasm base had to be coordinated. This need for coordination led to a wave of strategic mergers and acquisitions.

Strategies to vertically integrate seed and biotechnology assets are as old as the agricultural biotechnology industry itself. For example, biotechnology pioneers like David Padwa (founder of the early biotechnology start-up Agrigenetics) began to acquire regional seed companies in 1975 in order to finance biotechnology research and deliver its products to the market. Other leading biotechnology start-ups (e.g., Calgene, Biotechnica International, and Mycogen) had similar strategies and acquired a number of firms in the seed industry in the 1980s and 1990s. Multinationals Monsanto and DuPont, which acquired the two largest independent seed firms, were latecomers in the seed industry. In the late 1990s, both of those companies reversed their longstanding strategies to become technology providers in favor of becoming more vertically integrated firms.

Vertical integration into the seed business and ownership of germplasm became a primary strategy of agricultural biotechnology firms for profiting from their innovation.

One reason that vertical integration became a dominant strategy among biotech companies was that the first agricultural biotech products to reach the market demonstrated a low degree of appropriability. That is, biotech companies were unable to secure appropriate returns on their R&D investments through relationships with seed companies governed only by contract. Intellectual property rights overlapped and were heavily contested. A number of multiparty intellectual property disputes for key technologies (e.g., insect and herbicide resistance) reached the courts and amply demonstrated the lack of definitive intellectual property rights among biotechnology leaders. Similarly, a relatively large number of biotechnology companies pursuing similar commercial biotech products provided evidence of significant imitation.

High-quality proprietary seed germplasm was therefore in a relatively strong position. Given short supplies and significant development lags, germplasm could command a significant share of the innovation profits forthcoming from weakly appropriable agricultural biotechnologies. Under such conditions, vertical integration into the seed business and ownership of germplasm became a primary strategy of agricultural biotechnology firms for profiting from their innovation. Of course, some of the prospective profits from biotechnology were transferred to seed assets and capitalized in the lofty prices paid for firms in relevant mergers and acquisitions.

The low appropriability position of agricultural biotechnology relative to complementary germplasm assets was one economic factor arguing for biotechnology firms vertically integrating into the seed business. Another factor was the relatively high transaction cost for coordinating biotechnology and germplasm through contracts. Early in the innovation cycle, there were significant impediments to structuring complete contracts that would distribute value appropriately among contracting parties and motivate appropriate behavior. Because of significant time lags in the development of high-yielding germplasm with desirable traits, contracts that coordinated biotechnology and seed assets had to be constructed years before reaching the market. Such contracts were necessarily incomplete, as it was impossible to predict all relevant technological and commercial possibilities being created. Accurate valuations of the individual contributions of the interdependent biotechnologies and germplasm to the final technological advance (e.g., higher yields) were also difficult to assess. Incomplete contracts would predictably lead to costly renegotiations, disputes, and delays. On the other hand, ownership of both technological and seed assets allowed firms to bypass such costs, providing additional economic reasoning for vertical integration of such assets.

Structural change and concentration | Motives aside, the vertical integration of the biotechnology firms substantially changed the ownership structure of the U.S. seed industry. A number of medium and large independent seed firms (e.g., Pioneer, DeKalb, Northup King, and Golden Harvest) became part of integrated multinational firms (e.g., DuPont, Monsanto, and Syngenta) with assets in biotechnology and other markets.

While the changes in the ownership structure were drastic, the changes in the level of concentration of the U.S. seed industry were quite moderate. Since the early 1990s, the four-firm concentration ratio and the eight-firm concentration ratio have been fairly stable. Other measures of industry concentration also indicate similar patterns in the U.S. seed industry. The Herfindahl-Hirschman Index, which is the sum of squared market shares for all firms in an industry, takes values between zero and 10,000, and higher values indicate increasing market concentration. As shown in Figure 1, the index values for the U.S. seed industry over the period 1992–2008 have stayed close to 1800, which is typically assumed to separate moderate and high levels of concentration in industries. This threshold level for HHI was reached or exceeded in 1992, 1994, 1996, 1999, 2000, 2007, and 2008.

Under the moderate to high levels of industry concentration depicted in Figure 1, two key questions emerge: Do firms in the U.S. seed industry have significant market power? If so, to what extent do they exercise that power? To answer those questions, we first review the existing literature on this topic in the next section. Then, we present our own estimates of market power and the level it is exercised in the U.S. seed industry.

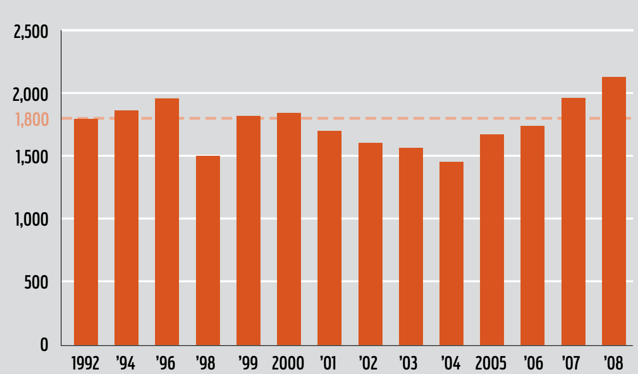
Empirical Estimates of Market Power

There is limited empirical evidence on the presence of market power in the U.S. seed industry. A handful of recent studies have examined the pricing decisions of seed firms based on new empirical industrial organization–type models of the firm's profit function. In a 2002 paper, Fernandez-Cornejo and Spielman constructed a profit function for a representative seed firm and used the profit-maximizing conditions to derive a model of the firm's price-cost margin as a function of the industry HHI statistic, cost indices, the responsiveness of buyers to changes in seed prices (i.e., the elasticity of demand), and the responsiveness of seed firms to the prices charged by other seed firms (i.e., the conjectural elasticity). Based on industry-level data, the authors found that the direct market power effect on the price-cost margin was positive but not significantly different from zero. Also, an increase in market power tended to reduce the processing costs and R&D costs, but the latter effect was not significantly different from zero. Thus, the authors concluded that the primary effect of increasing market power on seed margins is the improved processing cost efficiency.

In a 2008 paper, Shi, Chavas, and Stiegert used farm-level observations on seed price, quantity, and location from 2000 to 2007 to estimate a model of the implicit value associated with individual traits in hybrid seed corn. The model incorporates a generalized form of the HHI statistic to account for the local pricing effects associated with differentiated (i.e., multiple trait) products in the corn seed market. The authors found that three of the four main biotech traits (corn borer and rootworm resistance and two forms of herbicide tolerance) attract significant price premiums and that roughly 8 percent of the price of seed corn is associated with market power held by the seed companies.

FIGURE 1

Herfindahl-Hirschman Index (HHI) for U.S. Seed Corn Industry 1992–2008



SOURCE: DMR Kynetecs, various years

A few studies have examined the possibility of market power by analyzing the seed buyer's decision process. Their findings highlight the importance of farmer-specific and regional difference in the values assigned to particular seed traits. In a 2002 paper, Alexander and Goodhue used a calibrated model of a representative buyer's decision to adopt seed corn varieties with four specialized traits (high yield, insect resistance, herbicide tolerance, and high oil content). They then used the model to simulate the net revenue and break-even yield for each seed type under various cropping conditions and found that the herbicide-tolerant seed was roughly priced at the producer's reservation price. That implies the seller could be exerting market power and extracting the full consumer surplus from homogeneous buyers. In contrast, insect-resistant seeds were priced below the buyer's reservation price so that the farmer captured some of the surplus and the seller was not exerting full market power. In conclusion, the authors noted that the likely heterogeneity among seed corn buyers would reduce the seller's ability to exert market power and capture the farmers' surplus value from the hybrids.

Producer heterogeneity and the implied differential valuation of seeds and biotech traits were empirically demonstrated by Useche, Barham, and Foltz in a 2009 paper. Using a discrete choice model, the authors found that the estimated value assigned to particular biotech traits varied broadly across regions and among individual farms.

The existence of only limited empirical evidence on the presence of market power in the U.S. seed industry is not surprising because there are some unique analytical challenges. From the supply side, the marginal cost structure of the seed firms is difficult to model because a large share of total costs are fixed, including plant breeding costs, biotechnology R&D, regulatory compliance costs, advertising, and other marketing and promotion costs. Many of those fixed costs are associated with relatively lumpy capital assets like seed processing plants and research laboratories, so the fixed cost component of total cost tends to exhibit substantial step-like character as total output increases. Consequently, the marginal costs of production can remain relatively small over a wide range of production levels. Also, the variable cost component may be very different across firms, and factors that affect the heterogeneity in variable costs include all of the potential influences on field production of seed (yields, weather, and grower premiums), post-harvest seed conditioning (seed drying and cleaning), additional treatments (fungicides), and distribution costs. As well, finished seed products may be stored between seasons and the marginal costs of seed include inventory control costs such as warehousing charges, interest (time value), seed loss due to deterioration, and obsolescence of products. Finally, production costs may be reduced when two or more biotech traits are embedded in a given hybrid, and supply-side studies of seed firms must allow for the impact of bundling those traits on the cost structure.

Modeling demand | The task of modeling the demand side of the seed industry is equally complex. First, the demand for seed is derived from the demands for crop products. Accordingly, the derived demand depends on farmers' willingness to pay for seed that generates profit from the field crops as well as the final consumers' willingness to pay for the end products, and those values are driven by the traits embedded in the hybrids (e.g., length of the growing season, crop yield and quality potential, insect resistance, herbicide tolerance). As previously noted, several researchers have recognized that the values may be highly heterogeneous and vary substantially across regions, seed firms, and farmers.

The demand side may also exhibit regular temporal patterns in seed prices that are associated with hybrid life-cycle effects. Since seed products are both storable and differentiated, at any point in time the number of hybrids or varieties that are available in the market includes a mix of relatively old and new germplasm and biotech traits. Accordingly, buyer willingness to pay for a particular hybrid depends on the other products available on the market, and the equilibrium price for a particular hybrid may change over time as it moves from market introduction to the end of its life cycle.

Given the modeling challenges, we construct models of the derived demand for corn and soybean seed that represent the price of seed as a function of the quantity of seed purchased and the expected crop price just before planting time (e.g., the average January–March price of the December corn futures contract on the Chicago Board of Trade) plus controls for hybrid life-cycle effects, trait effects, and regional effects. There are 10 distinct biotech traits in corn hybrids aside from conventional corn, and these are based on herbicide tolerance (Roundup Ready, Liberty Link, and IMI), corn borer resistance, and rootworm resistance, plus combinations (stacks) of two or more of those traits. Also, there are three distinct soybean variety traits that provide herbicide tolerance (Roundup Ready, sulfonylurea-tolerant, and a combination of those two traits) and account for about 69 percent of the observed sample. The data used to estimate the derived demand models are annual observations for 6,170 corn hybrids and 4,232 soybean varieties that were sold in the United States from 1997 to 2008, and the data were acquired from DMR Kynetecs.

Among the key results that we derive from the fitted demand models are the price flexibility coefficients for corn and soybean seed, which measure the responsiveness of seed prices to changes in quantity demanded. Under profit-maximizing behavior, we know that the absolute value of the flexibility coefficients provide upper bounds on the Lerner index, which is the ratio of the product price (P) minus marginal cost (MC) to the price, L = (P – MC) ÷ P. The Lerner index is zero under marginal-cost (perfectly competitive) pricing and increases from zero as the price increases above marginal cost. Hence the Lerner index is a measure of the price mark-up imposed by firms in the market, and we can use the estimated flexibility coefficient to measure the overall degree of market power exerted by the seed firms in the U.S. market.

The estimated corn model explains about 32 percent of the observed variation in the seed corn prices, which is reasonably good performance for a very large data set. From Table 1, the estimated flexibility coefficient for the corn seed price is –0.146, which implies that the upper bound on the corn seed mark-up (Lerner index) is roughly 14.6 percent in the U.S. market. The hybrid life-cycle component in the estimated model indicates that the initial price of corn seed starts low, increases until the hybrid's fourth year on the market, and then declines until the hybrid is removed from the market. Finally, the values associated with the individual biotech traits are positive and statistically significant. For example, herbicide-tolerant hybrids earn a premium that is roughly 20 percent higher than the price of conventional seed corn, and corn borer– and rootworm-resistant hybrids have premia that are roughly 23 percent and 29 percent higher than conventional corn (respectively). We also find that hybrids with multiple (stacked) traits earn higher premia, but the value of the

TABLE 1

Summary Results for the Estimated Model of Corn Seed Prices

Model Component	Estimated Value
Lerner Index (overall price-cost mark-up for all hybrids)	14.6%
Herbicide tolerance trait	20.1%
Corn borer resistance trait	23.5%
Rootworm resistance trait	29.4%
Corn borer and herbicide tolerance traits	36.4%
Rootworm and herbicide tolerance traits	40.1%
Corn borer and rootworm resistance traits	36.4%
Corn borer, rootworm, and herbicide tolerance traits	53.1%
Corn borer and two herbicide tolerance traits	52.7%
Rootworm and two herbicide tolerance traits	68.6%
Corn borer, rootworm, and two herbicide tolerance traits	77.9%

TABLE 2

Summary Results for the Estimated Model of Soybean Seed Prices

Model Component	Estimated Value
Lerner Index (overall price-cost mark-up for all varieties)	17.5%
Roundup Ready trait	53.8%
Sulfonylurea herbicide tolerance trait	-1.2%
Roundup Ready and sulfonylurea tolerance traits	56.8%

Notes: The Lerner Index value represents the overall mark-up (price relative to marginal cost) earned by all corn hybrids and soybean varieties. The estimated values for the individual traits represent the expected price premium associated with each trait (or combination of traits) relative to conventional corn hybrids and soybean varieties that do not have biotech traits. All of the reported estimates in Tables 1 and 2 are statistically significant at the 1% level except the sulfonylurea resistance trait in the soybean seed price model (Table 2).

combined trait is less than the sum of the individual traits, which provides evidence that the seed firms use bundled pricing strategies for hybrids with stacked traits.

The estimated soybean model explains about 52 percent of the observed variation in the soybean seed prices, which is expected because the soybean seed varieties are a smaller and more homogeneous group than the corn seed hybrids. From Table 2, we find that the estimated price flexibility for the soybean seed price is similar at –0.175, which implies that the upper bound on the soybean seed mark-up is roughly 17.5 percent. The fitted lifecycle component for soybean seed also indicates that the expected price reaches a peak price at about the fourth year on the market. Finally, we find that the estimated value for tolerance to the herbicide sulfonylurea is not statistically different from zero, but the Roundup Ready trait earns a premium that is about 54 percent above the price of conventional soybean varieties. Further, the estimated value of the combined Roundup Ready and sulfonylurea-tolerant traits (57 percent relative to conventional soybeans) is only slightly larger than the estimated premium for Roundup Ready soybeans.

It appears that the seed industry did not reach a point where revenues from mark-ups and premiums could be large enough to fully finance R&D and maybe other fixed costs until 2008.

Comparison of Revenues from Mark-Ups and Premiums to Fixed Costs

With price mark-ups for germplasm and premiums for biotech traits at hand, one way to measure the potential impact of market power in the U.S. seed industry is to compare the industry-level revenue stream from those mark-ups and premiums with the levels of R&D expenditures and other relevant fixed costs for the industry. Seed companies incur large fixed costs in the form of R&D expenditures, costs for improvements in quality control systems, regulatory expenses, marketing costs, and legal expenses. The revenue streams from mark-ups and premiums on traits must be large enough to pay for these fixed costs year after year, even though innovations and other efficiencies from such fixed expenditures may be realized many years later. Although complete data for such fixed expenditures are not available, we use an approximation by comparing the revenue streams from mark-ups and premiums associated with biotech traits to the R&D expenditures incurred by all seed companies with meaningful breeding and biotech research activities in the corn and soybean seed segment.

By necessity, the comparison is somewhat crude. The revenue from mark-ups and premiums in the U.S. corn and soybean seed market does not represent the total revenue inflow for the companies examined, some of which have meaningful sales in other seed markets (e.g., cotton, canola, sugar beets) and other countries. However, the U.S. corn and soybean markets are by far the largest and most profitable seed markets in the world and exhibit the most significant penetration of biotech traits. As such, they contribute an estimated 75 to 87 percent of global ag biotech revenues for the companies examined and hence the revenue stream from mark-ups and premiums in the U.S. corn and soybean seed markets provide a good first approximation of the relevant revenue stream. At the same time, R&D expenditures represent only a portion of the fixed expenses seed companies incur, though this portion is likely large. Finally, R&D expenditures are lumpy in nature and cannot be easily allocated among crops. As such, aggregate R&D expenditures overstate those incurred for corn and soybeans alone. Despite the limitations, a comparison of the revenue stream from mark-ups and premiums in the U.S. soybean and corn seed markets with the aggregate R&D expenditures incurred by the leading seed germplasm and biotech traits in these markets provide valuable insight on their proportionality and their overall direction over time. In turn, these insights help us to address the question on the degree of market power that is exercised in these seed markets.

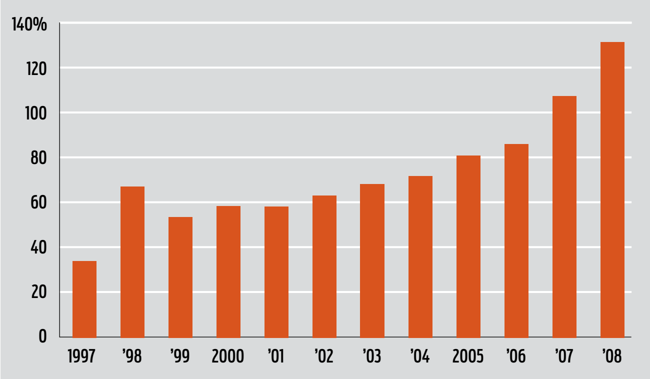
The estimated mark-ups and premiums from the fitted models presented in the previous section are used to estimate the revenue stream over the 1997–2008 period. Specifically, for each year of the analysis, the estimated mark-ups are applied on the total gross annual seed sales and the estimated premiums on the gross annual revenues of seeds with different biotech traits. As a result, the revenue stream from mark-ups and premiums increases over time as traits become more numerous, more valuable, and more broadly adopted.

R&D expenditures for all major developers of germplasm and/or biotech traits in the U.S. corn and soybean seed markets and for each year over the 1997–2008 period have been included in the aggregate figures used here. R&D expenditures of firms that were previously independent but were acquired or exited the industry are reflected in the aggregate. All R&D figures were compiled from industry reports, financial reports of individual companies, and other secondary sources. The resulting R&D expenditures are compared to the revenue stream from mark-ups and premiums of biotech traits by constructing a ratio of those revenue components to R&D investments. This index is illustrated in Figure 2.

The size of the constructed index varies over the period of the analysis from a low of 33 percent in 1997 to a high of 130 percent in 2008. The upward trend is expected as agricultural biotechnology entered its commercial phase in 1996 and matured over the next 13 years through the introduction of various biotech traits, especially in corn. Until 2005, ten years into the commercial

FIGURE 2

Comparison of Revenues from Mark-ups and Premiums to R&D Investments in the U.S. Corn and Soybean Industry 1997–2008



phase of agricultural biotechnology, revenues from mark-ups and premiums from the U.S. corn and soybean seed markets were less than 80 percent of R&D expenditures. Over this period of time, almost all of the revenues of the biotech industry were generated from these two seed markets, so these figures suggest that R&D investments were probably financed, in part, through other productive activities of firms, speculative capital investments, and other sources.

In more recent years, the introduction of more valuable traits (new traits and stacks) and their broader adoption have resulted in increased revenues that closed the gap with R&D expenditures (which were $2.4 billion in 2008). However, it appears that the seed industry did not reach a point where revenues from mark-ups and premiums could be large enough to fully finance R&D and maybe other fixed costs until 2008. Given that trait markets were already quite saturated by that time (i.e., adoption of biotech traits exceeded 87 percent and 92 percent in the U.S. corn and soybean markets, respectively), these levels suggest that revenues from mark-ups and trait premiums in the corn and soybean seed markets approached R&D expenditures only during the later stages of the commercial life-cycle for first-generation biotech traits.

Conclusion

R&D-driven industries tend to be concentrated, and the U.S. seed industry is no exception. Concerns about the presence and use of market power in such industries are not rare since products are differentiated, which allows firms to set prices and charge mark-ups that can be used to pay for R&D investments and other fixed costs. The balance between firm profits and investments in product quality and innovation is an important indicator of dynamic efficiency in the marketplace — and probably a more effective gauge of competition in dynamic and innovative industries. Because of the complex supply and demand structures of R&D-focused industries, estimation of market power and associated price mark-ups is not straightforward. Nevertheless, such estimations are essential if antitrust scrutiny is to enhance competition instead of stalling innovation. Our results suggest that, in the case of the U.S. seed industry concentration, moderate market power and dynamic market efficiency appear to coincide over our period of analysis. R

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