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Innovation, Integration, and the Biotechnology Revolution in U.S. Seed Markets

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The importance of seeds dates back at least ten thousand years to the rise of agriculture. Indeed, the origin of agriculture is associated with the selection and planting of seeds that eventually contributed to large increases in food production. Over the last century, advances in breeding and hybrid seed development and the rise of modern genetics have put the selection of seeds on a firm scientific basis. Advances in biotechnology have enabled the production of genetically modified (GM) crops with specific, desirable traits not found in their parents. The first generation and most common GM traits generate either resistance against one or more insects, or tolerance to specific chemical herbicides. Emerging GM traits address a broader array of consumer and producer market demands including nutrition enhancement, drought tolerance, and protection from plant disease. While the use of GM technology remains controversial in some countries, the rapidly advancing biotechnology seed industry has contributed to improved agricultural productivity and had a major impact on the production, delivery, and pricing of agricultural seeds and other inputs in the United States and around the world. These current and emerging changes are likely to reshape much of the global agricultural production system in ways that generate both excitement and caution.

In this article, we discuss the major trends and our key research findings on the pricing, trait bundling, efficiency, and the potential effects of market power in the U.S. seed industry. The research, documented in six detailed reports (Shi, Chavas and Stiegert, 2009, 2010a, 2010b; Shi and Chavas, 2010; Shi, Stiegert, and Chavas, 2010; and Stiegert, Shi, and Chavas, 2010), utilizes nationwide farm survey databases collected in the United States by Dmrkynetic Inc. The data cover annual farm-level purchases and prices of corn, soybean, and cotton seeds from 2000 to 2007. The data allow the documentation of several key and important characteristics in the evolution, pricing, and industrial structure of the seed industry. The research provides empirical results on seed markets that relate to trait bundling and bundle pricing, product differentiation, and price discrimination.

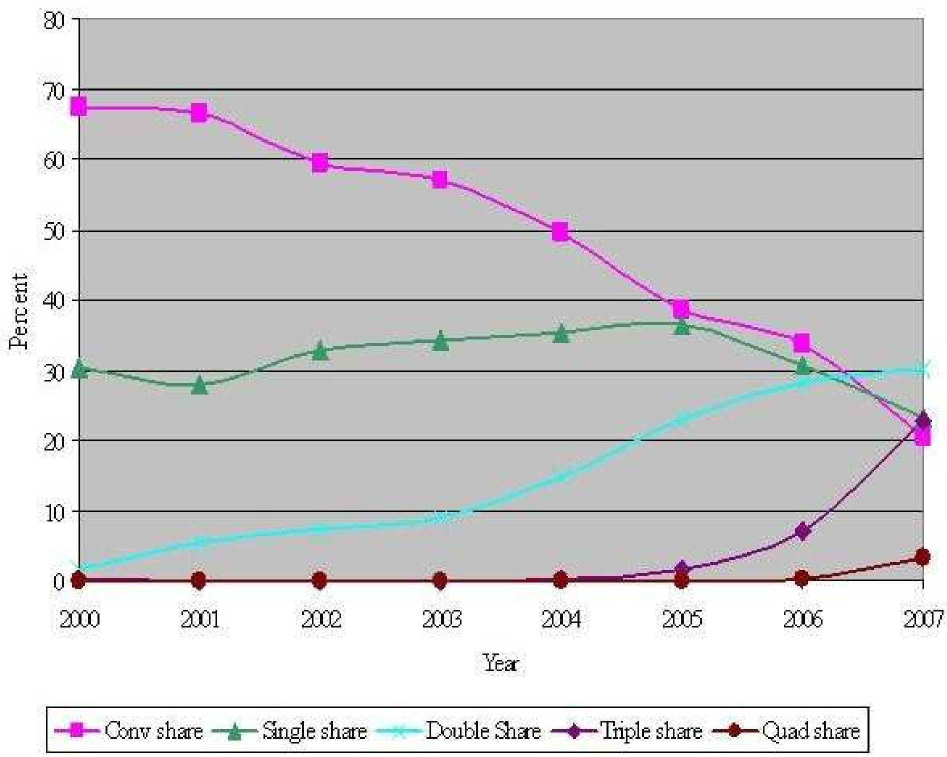
Discussion of the Industry

GM crops were commercially produced beginning in the mid-1990s. From 1996-2008, production of GM crops grew from 4.2 million acres in six countries to 309 million acres in 25 countries (James, 2008). GM production is primarily concentrated in six countries (United States, Argentina, Brazil, India, Canada, and China) that planted about 95% of the global GM cropland (James, 2008). Before 2000, early development of commercially viable GM seeds incorporated only a single genetic trait, specifically an insect-resistance trait for cotton and corn, and a herbicide-tolerance trait for soybeans. The development and rapid adoption of double, triple, and quadruple stacked GM seeds with multiple genetic traits primarily occurred since 2000.

Government regulations, farm demand, and consumer demand affect the adoption and spread of GM technology in agriculture. GM seed development is a multi-year process involving many test trials conducted by biotechnology firms and leading to commercializing a handful of selected varieties. Biotechnology advances essentially piggyback on conventional breeding selection that supplies viable seeds to farmers. The commercial value of GM technology is suggested through the price premiums paid by farmers for GM seeds compared to the price of conventionally bred seeds. We document several of the key strategies employed by seed and biotech firms to price seeds in ways that both spur adoption and capture some of the economic benefits generated by advances in GM technology.

Research and development (R&D) expenditures on new and patentable genetic traits and seeds are an important part of the production cost of seeds. Over the last few decades, private sector R&D expenditures in agriculture have increased sharply, as applications of new biotechnologies have become associated with exclusive property rights for genetic traits. This has contributed to an increase in seed prices (Krull, Prescott, and Chum, 1998). However, the institutional arrangements for how R&D costs translate to seed prices vary across crops. The development of hybrid corn has a long history of private sector involvement primarily because hybrid vigor is not maintained in seeds from the previous year's harvest. Cottonseeds have also been developed primarily through private sector R&D. Corn and cottonseed pricing is structured to pass R&D costs on to farmers. In contrast, hard wheat seed R&D is conducted predominantly in the public sector and funded by upfront investments through commodity check-off programs. As a result, the prices of hard wheat seeds usually only reflect a small fraction of the total development costs. Soybean seed development has transitioned since the 1980s from large public R&D, much like hard wheat, to being almost fully privatized (see Heisey, Srinivasan and Thirtle (2001) for more a detailed discussion).

Over the last few decades, horizontal and vertical merger activities in the agricultural biotechnology and seed industries have contributed to the development of a concentrated and complex industry (Fernandez-Cornejo, 2004). The U.S. biotechnology seed industry has received extensive utility patent protection under American law since the 1980s. This patent protection has effectively precluded antitrust oversight of the use of those rights despite the presence of high concentration in the GM seed markets. Biotechnology firms have also vertically integrated downstream to the seed industry while licensing patented traits to other seed companies that in turn offer GM seeds. In this setting, vertically integrated biotech-seed firms compete for seed sales against independent seed firms licensing the same traits. How and to what extent these licensing arrangements extend or limit competition is an emerging issue. This is illustrated in a patent infringement case (Monsanto v. DuPont) that focuses on contract terms that prohibit Monsanto's licensees from stacking its genes with other patent holders' traits (Kilman, 2009).



Source: Dmrkynetec TraitTrak dataset.

Figure 1. Percentage of U.S. Acreage Planted in Conventional and GM Corn Seed, 2000–2007.

In cotton, Syngenta has received permission to include the Monsanto *Bt* gene and a herbicide tolerance gene from Bayer Crop Science. This is due to an antitrust settlement in May 2007 that imposed conditions on Monsanto's vertical acquisition of Delta Pine & Land to terminate all provisions in its cotton seed licenses that restrict trait stacking of genes from different sources.

The GM seed market has seen tremendous growth and change over the last decade. Using Dmrkynetic data, Figures 1-3 show the adoption rate of GM corn, soybean, and cotton seed, respectively. The acreage share of GM seeds is now over 80% for each of these crops. However, the growth patterns for single-trait and stacked GM seeds are strikingly different across crops. For corn, the rise in stacked seeds outpaced the adoption of single-trait seeds especially after 2005, while in soybeans, the single-trait seeds remain dominant over the whole time period.

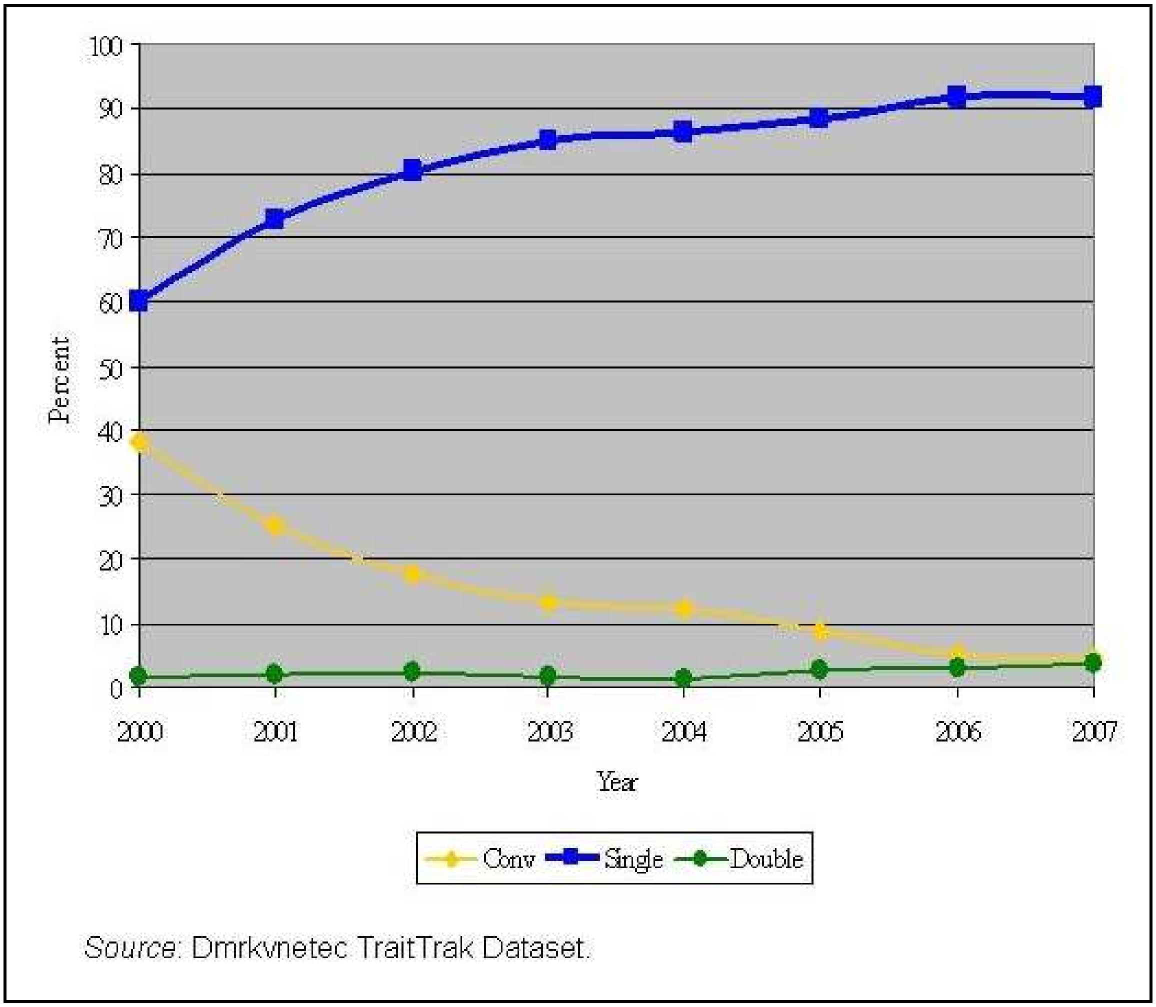
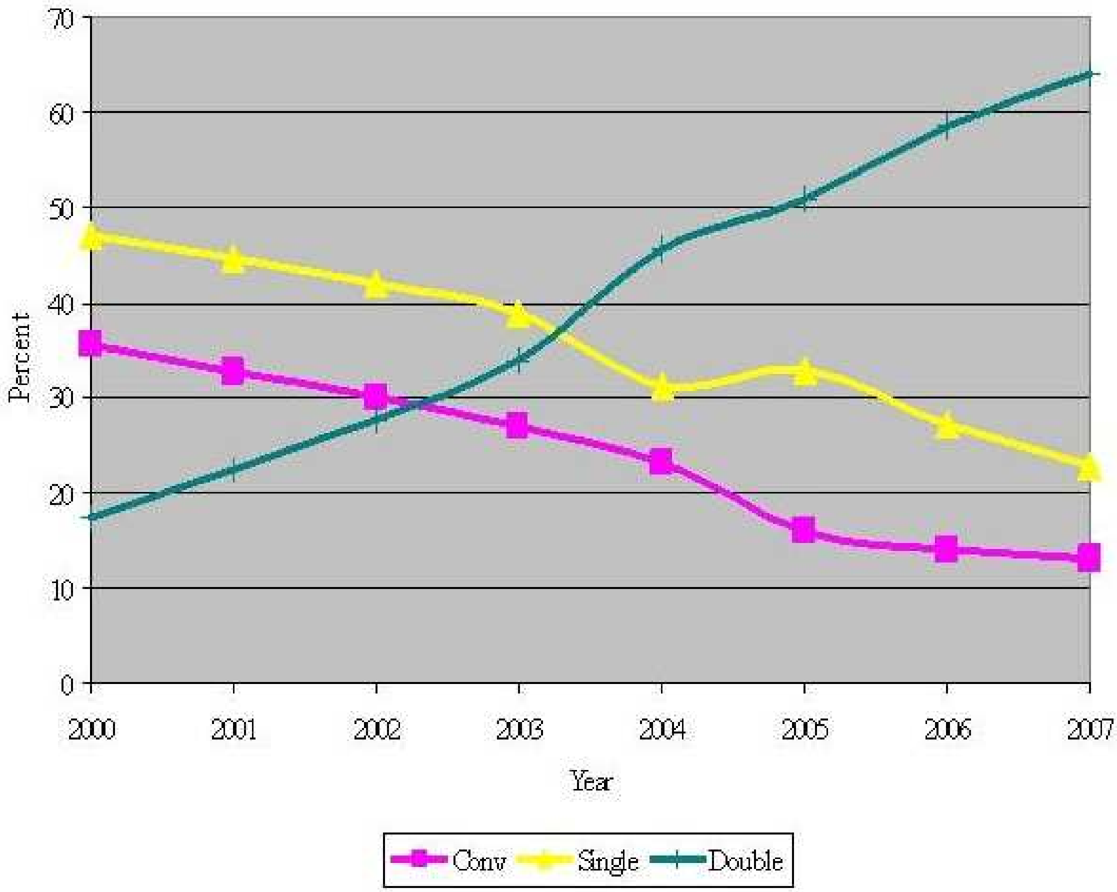


Figure 2. Percentage of U.S. Acreage Planted in Conventional and GM Soybean Seed, 2000–2007.

For cotton, stacked seeds have had a steadily increasing market share. We also note that stacking is most prolific in corn with a range of double to quadruple stacks while only double stacking in present in soybeans and cotton.



Source: Dmrkynetec TraitTrak Dataset.

Figure 3. Percentage of U.S. Acreage Planted in Conventional and GM Cotton Seed, 2000–2007.

The market price of GM seeds reflects both the cost of producing the seeds and the farm benefits from using them. For a vertically integrated biotech-seed firm to remain viable in the long run, operating income—sales revenue less operating costs—must be sufficient to cover the fixed costs associated with seed and trait development, marketing and promotion costs, and the cost of financing. Meanwhile, seed prices must not exceed the farmers' net benefit from using the seed. Farmers have an incentive to use GM seed when it provides benefits from increased farm productivity and reduced production cost that exceed the additional seed cost. Given the oligopolistic structure of the biotech-seed industry, several strategies can be employed by firms to lower their costs, extract economic benefits from farmers and seed dealers, and increase adoption of GM seeds. The findings from our research reported in the next three sections provide insights into these strategies.

Trait Bundling and Bundle Pricing

Seeds are sold at a list price less a discount available at the point of sale. GM seed prices vary with trait stacking/bundling, perceived agronomic conditions in each region—pest infestations, rainfall, etc.—availability of substitute seeds, commodity prices, and farmer income. For bundled biotechnology traits in the corn seed market, Shi, Chavas and Stiegert (2010a) rejected standard component pricing of biotech traits, where the price premium for multiple-stacked seeds would be equal to the sum of the price premium for relevant single-trait seeds. They found strong evidence of sub-additive bundle pricing, where the price of stacked seeds is sold at a discount compared to component pricing. Similar results were obtained by Shi and Chavas (2010) in their analysis of the soybean seed market, and by Shi, Stiegert and Chavas (2010) in the U.S. cottonseed market. This evidence is consistent with the presence of complementarity and economies of scope in the production of seeds with bundled traits. In general, sub-additive seed pricing is good for farmers who want to have access to multiple traits, since it reduces their access cost to these traits.

Using less aggregated data of the corn market, Shi, Chavas and Stiegert (2010b) and Stiegert, Shi, and Chavas (2010) uncovered a more varied price discrimination pattern. The former paper studied pricing at the biotechnology firm level, while the latter broke out the Corn Belt into two regions: the core and the fringe. In both studies, sub-additive pricing is most commonly observed. However, there was also limited evidence of super-additive pricing, where the price of stacked seeds is sold at a premium compared to component pricing. Super-additive pricing may be associated with firms taking advantage of market power to extract economic gains from farmers. In Stiegert, Shi, and Chavas (2010), its occurrence appears closely tied to the herbicide-tolerance trait and only in the core region. In Shi, Chavas and Stiegert (2010b), super-additive pricing is found to be specific to the behavior of a single firm. Although limited in scope, the presence of super-additive pricing implies that different pricing patterns may emerge in ways that depend on specific market settings.

Conduct and Pricing in the U.S. Seed Industry

Seed prices may also depend on the increasing level of industrial concentration. Biotechnology firms can benefit from complementarities and economies of scope that enhance the efficiency of R&D activities related to genetic improvements across traits and/or crops. On the other hand, high concentration raises concerns about the exercise of market power, which could have adverse effects on the efficiency of R&D activities, the rate of technological progress in agriculture, and the rate of adoption of biotechnology.

To confront the issue of market concentration, we develop and employ a multi-product variant of the traditional Herfindahl-Hirschman index (HHI) as a measure of market concentration. These indices are called generalized HHI or GHHI. The GHHI recognizes traditional own-market concentration and extends the analysis to consider cross-market concentrations involving markets for different seed types. The cross-market GHHI is shown to have a positive relationship with price when the products are substitutes, but a negative relationship with price when products are complements. For example, complementarities can arise if a more integrated system of production of GM seeds by a few large firms contributes to reducing the cost of development. If these complementarities are large, they can reduce or reverse the price-enhancing effect of market power. An econometric analysis of seed prices can provide useful information on how market concentration can affect seed prices. For corn, Shi, Chavas and Stiegert (2010a) and Stiegert, Shi, and Chavas (2010) found evidence of departures from marginal cost pricing, reflecting that market power does influence seed prices paid by farmers. For cotton, Shi, Stiegert and Chavas (2010) found that increases in own-market concentration do contribute to higher seed prices. But they also documented that, through complementarities, cross-concentration tends to be associated with lower seed prices. This shows that increased market concentrations do not always increase prices. It also stresses the need to analyze the implications of imperfect competition in a multi-market context.

Vertical Ownership and Pricing

Does vertical organization affect pricing in the U.S. seed sector? Shi and Chavas (2010) and Shi, Stiegert and Chavas (2010) study this issue for soybean and cotton, respectively. The analysis distinguishes between two types of vertical organizations: licensing and vertical integration.

The evolving vertical structure in the U.S. cottonseed industry is of special interest. While the licensing of biotechnology seeds remains dominant, biotechnology firms have increased their use of vertical control through integration. The market for integrated cottonseed has grown beginning in 2005 when Monsanto repurchased a previous spinoff (Stoneville) and expanded on its vertical integration afterwards. Bayer CropScience, a large agricultural biotechnology company, entered the cottonseed market in 1999 through the acquisition of FiberMax varieties from Aventis Crop Science, and has exhibited a major growth in sales since 2002 (Shi, 2009). And similar trends exist in the soybean seed markets. In single-trait soybean seed markets, vertical integration has increased from 13% of the market in 2000 to 26% in 2007.

This documents a general trend toward vertical integration in the U.S. seed sector. Are these changes motivated by efficiency gains that might reduce the prices paid by farmers? Or are they reflecting attempts to increase market power that raises the price? Shi and Chavas (2010) and Shi, Stiegert and Chavas (2010) found evidence that seed prices do vary with the vertical organization of the sector. For both soybean and cotton, they document that seed prices under vertical integration tend to be higher than under licensing. This indicates that vertical integration by biotechnology firms may increase the exercise of market power and the firms' ability to extract economic benefits from seed dealers and farmers. Such finding is consistent with biotechnology companies' reluctance to allow licensees to stack the licensed trait with other companies' trait, as exemplified by the antitrust settlement in the above mentioned Monsanto-DPL case. Biotech firms can recover the R&D expenditure more effectively through direct sale under vertical integration than through licensing fee revenue. Indeed, cheaper alternatives from the licensees may impose some competitive pressure to the integrated firms' product.

Final Thoughts

Biotechnology advances have been catalysts for innovations in agriculture, and they have been associated with a growth of private R&D investments, the patenting of GM traits, and increased concentration in seed markets. The rapid adoption of GM seeds in the United States gives an indication that biotechnology has contributed to strong agricultural productivity gains. So far, seed prices have been low enough to maintain farm profitability and induce farmers to adopt GM seeds.

Mergers have led to increased concentration in seed markets, and they are part of trend toward greater vertical integration in the biotechnology seed sector. The rapid emergence of only a few firms that hold most patents on GM traits is a public policy concern. These changes raise questions about the organizational efficiency of the U.S. and global seed industries, which is important as seeds are crucial factors affecting the ability of agriculture to feed a growing world population. Will concentrated markets lead to higher seed prices, fewer choices for farmers and closure of independent seed companies? What market structure would maintain the incentive for private investments in seed development? While history has shown that the privatization of the seed industry can be consistent with rapid technological progress in agriculture, maintaining a balance between providing incentives for agricultural innovations and sustaining farm profitability remains a challenge. Our most consistent finding through all studies is a preponderance of sub-additive pricing in stacked seeds. We have also found that increased concentration in the seed industry has contributed to higher seed prices. However, through multimarket complementarity effects, increased concentration can also be associated with efficiency gains and lower seed prices. Future research should be directed toward a better understanding of these topics to provide policymakers with information on how to protect and expand innovations while maintaining a good distribution of associated benefits between innovators, farmers and consumers.

For More Information

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