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Effects of Proposed Mergers and Acquisitions Among Biotechnology Firms on Seed Prices



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Executive Summary

- This report examines the likely effects on prices in agricultural seed markets of proposed mergers and acquisitions: DuPont/Pioneer with Dow and Monsanto with Bayer.
- This industry has consolidated substantially in recent decades, and is now dominated by just six large multinational firms.
- Market contestability is a critical concept for analyzing the conditions under which these mergers would occur, and for specifying an empirical model with appropriate assumptions. Due to large sunk research costs and intellectual property protections, these markets are not contestable. There are substantial barriers to new entry into these markets, and competitive pressures will constrain price markups less than they would in contestable markets.
- Empirical evidence in recent years finds prices for seed are somewhat marked up above marginal costs. That is, these firms, in their current forms, are potentially exercising some market power.
- Given the poor contestability of these markets, we employ the Hausman method of estimating the effects of proposed mergers and acquisitions on markups and market prices of differentiated goods under the assumption of no new entry.
- We find that the proposed mergers would cause the following expected increases in seed prices: 2.3% for corn, 1.9% for soybeans, and 18.2% for cotton. We find a 25% chance that price increases would meet or exceed the following values: 2.6% for corn, 2.1% for soybeans, and 20.2% for cotton.
- Changes in market concentration that would result from the proposed mergers meet criteria such that the Department of Justice and Federal Trade Commission would consider them “likely to enhance market power” in the seed markets for corn and cotton.

1. Overview

This report analyzes price effects in the seed markets for corn, soybean, and cotton of two proposed mergers: DuPont with Dow, and Monsanto with Bayer. We review the literature regarding the changes that have occurred in agricultural input markets over the last several years, and relevant concepts from industrial organization theory. We apply a model of changes in price markups (above the marginal cost of production) caused by mergers under the assumption of no new entry to quantify expected price changes.

In the following section, we outline technological changes and rising concentration in agricultural seed and chemical industries, emerging trends in market concentration, and how the mergers and acquisitions further intensified market concentration. In the third section, we discuss the concept of market contestability, particularly as it relates to the agricultural seed and chemical industries. In the fourth section, we present the methodology that we use to analyze the price impacts of the proposed mergers. In the fifth section, we discuss the data employed and list their sources. In the sixth section, we calculate changes in Herfindahl-Hirshman Index values that would result from the proposed mergers. In the seventh section, we apply the methodology to the proposed DuPont/Pioneer-Dow merger in the corn and soybean seed markets and the proposed Monsanto-Bayer merger in the seed market for cotton.

2. Background

In the past few decades one of the most noticeable changes in U.S. agriculture has been in agricultural input markets. The unprecedented growth in yields and agricultural total factor productivity owes much to biological innovations in crop seeds, development of hybrid crops in the early part of the 20th century, with adoption of high-yielding varieties and modern biotechnology. Development of new types of pesticides and seeds have substantially improved agricultural productivity (Fernandez-Cornejo 2004; Fernandez-Cornejo and Just 2007). Agricultural input markets have evolved and family-owned and other small businesses gave way to larger enterprises that integrated in plant breeding, conditioning, production, marketing, and other functions. The evolution in the industry was coupled with increasing market concentration

in seed and chemicals supply, and the industry was further shaped by widespread mergers and acquisitions. These dramatic changes have raised significant concerns regarding market power and its influence on agriculture, in general (Fernandez-Cornejo 2004; Fernandez-Cornejo and Just 2007).

Along with industry evolution, there has been a rapid growth in private research and development, which shifted the roles of public research and development. Thus, research in agricultural input industry became predominantly private, and private firms have transformed from small scale operations to large and integrated enterprises (Fernandez-Cornejo and Schimmpfenning, 2004). Figure 1 depicts the historical trend of private and public R&D expenditures. When adjusted for inflation, private investment in R&D has increased substantially between 1960 and 1996, and R&D investments from the public sector have remained stagnant. As outlined by Fernandez-Cornejo and Schimmpfenning (2004), increased protection of intellectual property rights for crop-seed innovations through patents and certificates has accelerated private investment and stimulated R&D expenditure, even on such crops as soybeans where farmers have often saved part of the current crop for use as seed the following year.

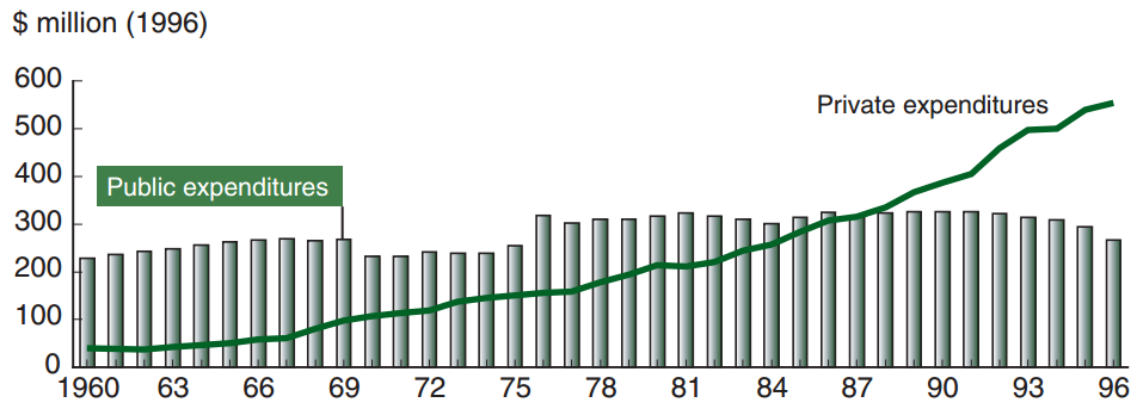


Figure 1. Private vs. public expenditures on crop variety (from Fernandez and Shimelpfenning, 2004)

The clear trends of private and public R&D expenditure, presented in Figure 1, were observed between the years from 1960 through 1996. However, relatively recent study conducted by Fuglie et al. (2012) shows that increased consolidation and concentration in the private seed industry over the past decade have slowed down the intensity of private research undertaken on crop biotechnology relative to what would have occurred without consolidation, at least for corn, cotton, and soybeans. As found by Schimelpfenning et al. (2004), patents and concentration are

substitutes, meaning more concentration is associated with fewer patents. As the input market became increasingly concentrated, and firms developed market power, they had fewer competitors to protect their intellectual property from.

2.1. Market Concentration

Over the last two decades, global market concentration (the share of global industry sales earned by the largest firms) has increased in the crop seed/biotechnology and agricultural chemical industries (Fuglie et al. 2012). These industries also invest heavily in research. Currently, the largest four firms in each of these industries account for more than 50% of global market sales. Growth in global market concentration over 1994-2009 was most rapid in the crop seed industry, where the market share of the four largest firms more than doubled from 21 to 54%.

These firms increased their market dominance through expanding their sales faster than the industry average or by through mergers and acquisitions of other firms (Fuglie et al. 2012). Details about latest mergers and acquisitions are outlined later in this review. Additionally, these big firms increased their sales faster than others in the industry by offering better products or services (often an outgrowth of larger R&D investments), improving their marketing ability, and offering competitive prices (often through economies of scale). Table 1 outlines how four firm concentration has changed over time in agricultural seed and chemical industries. The enormous growth in the concentration mainly came from acquisitions of other firms.

Table 1. Market concentration for global input industries (Fuglie et al. (2012) and ETC Group(2013))

	Year	Four-firm concentration ratio
Crop seed and biotechnology	1994	21%
	2000	33%
	2009	54%
	2013	58%
Agricultural chemicals	1994	29%
	2000	41%
	2009	53%
	2013	62%

As explained by Fuglie et al. (2012), the emergence of biotechnology was a major driver of consolidation in the crop seed industry. Companies sought to acquire relevant technological capacities and serve larger markets to share the large fixed costs associated with meeting regulatory approval for new biotechnology innovations.

The agricultural chemical sector has been mainly affected by regulatory changes by the government regarding health, safety, and environmental impacts of new and existing pesticide formulations. Larger firms appear better able to address these stricter regulatory requirements (Fuglie et al. 2012).

As outlined by Fernandez-Cornejo and Schimmelpfenning (2004), the development and rapid producer acceptance of hybrid seeds and with greater protection of intellectual property rights, the amount of private capital devoted to the seed industry and the number of private firms engaged in plant breeding grew rapidly until peaking in the early 1990s. Later, seed industry consolidation became widespread, with fewer firms capable of investments in research sufficient to develop new seed varieties. This resulted in increased concentration, with the majority of seed sales controlled by four large firms. Current concentration in the seed markets for corn, soybean, and cotton are presented in Table 2. The share of U.S. seed sales controlled by the four largest firms providing seed of each crop reached 91% for cotton, 82% for corn, and 76% for soybeans in 2014-2015. One contrast to this general trend was wheat (not presented in the table), with more than 70% of the planted wheat coming from varieties developed in the public sector (Heyenga 1998).

As of 2010, seven large seed companies each had annual seed sales of over \$600 million. Five of these top seed companies are Syngenta, Bayer, Dow, Dupont, and Monsanto. These companies are also market leaders in agricultural chemicals. A sixth firm, BASF, is making significant investments in crop biotechnology research but so far reports few crop seed or trait sales, although it is a market leader in agricultural chemicals. These companies currently constitute the "Big 6" involved in crop seed, biotechnology, and chemical research (Fuglie et al. 2012).

Table 2. Seed market shares for corn, soybean, and cotton

Crop seed providers	Share in the market
Corn seed:	
Monsanto	36%
DuPont/Pioneer	35%
Dow	6%
Syngenta	6%
Four total	82%
Cotton seed:	
Bayer	39%
Monsanto	31%
Dow	15%
Americot	6%
Four total	91%
Soybean seed:	
DuPont/Pioneer	33%
Monsanto	28%
Syngenta	10%
Dow	5%
Four total	76%

Heyenga (1998) documents the adoption of herbicide-ready plant varieties. The use of insect resistant corn and cotton dramatically reduced insecticide use. He further points out that the combination of insect resistant technologies may dramatically reduce corn insecticide market volumes, reduce chemical industry profits, and result in many companies exiting the market. With regards to cotton, Heyenga (1998) argues that because cotton has a large number of pests, insect resistance to a few will not necessarily eliminate insecticide use in the crop.

Heyenga (1998) further argues that introduction of herbicide resistant seed dramatically affected the soybean and corn herbicide markets, and as mentioned before, it is having less effect in the cotton market. Monsanto's introduction to Roundup is cost-effective for a broad spectrum of weeds which it controls effectively (especially in the case of soybeans). According to the author, the number of soybean acres treated with Roundup doubled in 1998. Accordingly, most competitors had their market share drop by one-third to one-half. American Cyanamid, the

market leader, had the greatest volume reduction. Soybean herbicide prices have plummeted as a result of the Roundup Ready soybean success (Heyenga 1998). Since 1998, the use of Roundup-ready soybeans has become nearly universal.

2.2. Mergers and Acquisitions

Over the last two decades, the big companies (i.e. Monsanto, DuPont) have led the way with massive investments in biotechnology research, and with seed and biotechnology company mergers and acquisitions.

As described by Fuglie et al. (2012), historically the seed-biotechnology companies have been dependent on small and medium scale companies as major sources of innovation. The new small and medium-sized enterprises were specializing in developments of genetic traits, new research, or a combination of both. Most of these new entries occurred in the late 1970s and early 1980s, and in the late 1990s and early 2000s. However, in the last several years, exits of small and medium-sized enterprises have outweighed new entry. By 2010, there were less than 30 active small and medium-sized enterprises that were specializing in crop biotechnology. The main reason of disappearance of these companies was acquisition by larger firms (Fuglie et al. 2012). Fernandez-Cornejo and Just (2007) find a positive link between pesticide productivities and concentration. They discuss that as the productivity of pesticides and seeds has increased, the concentration of these input industries has also increased. In the 1960s, over 70 basic manufacturers of pesticides were operating in the United States, but mergers and acquisitions have combined those firms into roughly eight major multinational manufacturers. Hubbard (2009) backs up the aforementioned arguments and he points out that because of enormous amount of mergers and acquisitions that expanded agricultural biotechnology, many smaller companies could not compete with large firms that owned much of the genetic resource base in seed, and licensing genetics from these firms was costly. He finds that at least 200 independent seed companies have been lost in the thirteen years prior to 2009. Moreover, biotechnology research demands financial resources that most smaller firms do not have. Large firms investing in these technologies and earning royalties from licensing agreements quickly achieved a market advantage that led to numerous buy-outs (Hubbard, 2009). There are several factors that can explain increased merging and acquisitions in agricultural input industries.

One reason discussed in the literature is intellectual property rights (IPRs). Lesser (1998) studied the relationships between IPRs and agricultural biotechnology industry concentration. He argues that IPRs have significant impacts on firm entry, and make vertical integration in downstream industries more or less necessary, which creates financial incentives for downstream mergers and acquisitions. He concludes that IPRs have significant structural impacts in agricultural biotechnology. In addition, Heyenga (1998) discusses that chemical companies have vertically integrated into the seed and biotechnology industries. As he explains, the goal of such integration was to capture profits from biotechnology innovations which, in some cases, are also complementary to their chemical technology. In addition, these moves are an effort by the chemical companies to defend themselves against their competitors' moves. Moreover, Heyenga (1998) argues that as a result of acquisitions the increasing dominance of a few major players, and the biotechnology and chemical patent restrictions on what competitors can do, raised questions regarding the potential for too much market power in parts of the seed and chemical industries.

Other motivations for increased mergers and acquisitions are economies of scale, and scope. As explained by Fulton and Giannakas (2001), economies of scale and scope mean that larger and diversified firms have lower average costs, which gives a clear incentive for firms to get large. Moreover, those that do not get large are vulnerable to being driven out of the market by larger and more cost efficient firms. As mentioned by Fulton and Giannakas (2001), economies of scale and scope are created as a result of investment in non-rival goods, and intellectual property is an example of a non-rival good.

Howard (2009) describes the details on how agricultural chemical and seed industries consolidated and came to be controlled by just six large multinational corporations. Until recently, these big corporations were focused on mainly producing agrochemicals. He points out that new protections for hybrid seeds led to the entrance of oil, pharmaceutical, and grain trading companies. Agrochemical corporations were experiencing declining profit opportunities as a result of increased regulations and fewer markets in which to expand. Therefore, these companies decided to build on their existing relationships with farmers to enter into another, and more profitable input industry, a seed market. As explained by Matson et al. (2014), the main motivation was to grant full patent protections on soon-to-be commercialized transgenic seeds and the expectation of strong government enforcement of these monopolies. Howard (2009)

further stresses that the big companies did not focus on outcompeting already established seed firms, but by acquiring them. Each of these acquisitions not only expanded the market share, but also added to these companies' seed distribution resources. The agrochemical companies bought hundreds of independent biotechnology and seed companies, and they also merged with one another. The outcome was that the number of big multinational companies was reduced to just six, which intensified the agricultural input industry consolidation further.

Figure 2, from Howard (2009), illustrates changes that occurred in the agricultural input industry. Each firm in the figure is labeled by name and parentheses are used to indicate nine transactions that occurred before 1996. In addition, full ownership is represented with a solid line, while partial ownership is represented with a dashed line. Figure 2 indicates that while Monsanto has clearly been the most active in making acquisitions, all of the largest firms have contributed to seed industry consolidation. This figure also shows some connections between these key firms through joint ventures.

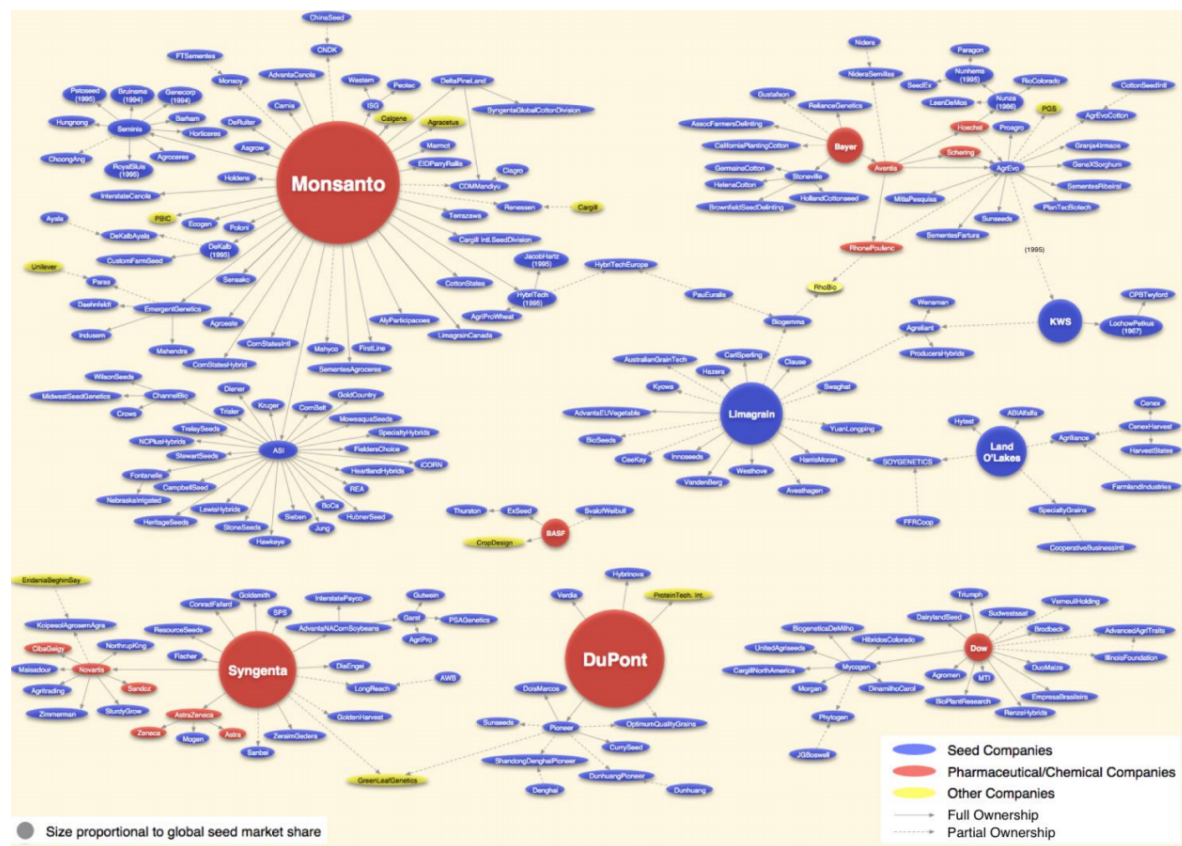


Figure 2. Seed industry structure, 1996 – 2008 (from Howard, 2009)

Although Hennessy and Hayes (2000) concluded that Monsanto was involved in a duopolistic seed market and relatively competitive chemical market, things have since changed. Figure 3 is adapted from Howard (2015) and shows cross-licensing agreements involving pharmaceutical/chemical companies for transgenic seed traits. These arrangements among the big six agrochemical-seed companies are sometimes referred to as “non-merger mergers”, because there is no change in the ownership, but they nonetheless raise serious questions regarding cartel behavior and market dominance.

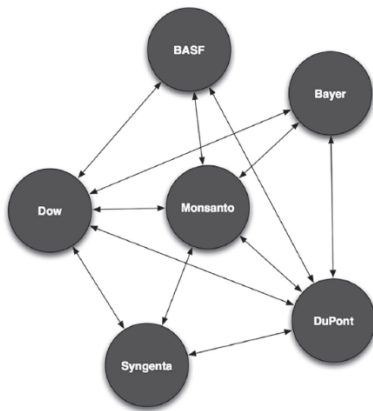


Figure 3. Big Six cross-licensing agreements for transgenic traits (from Howard, 2015)

From Figure 3, we can see that Monsanto has a central position in this network. For example, Smartstax corn includes eight different transgenic traits as a result of agreements between Monsanto and Dow. As explained by Howard (2015), the entire outcome is similar to formation of a cartel that excluded other competitors and potential entrants, implying that many remaining small firms either must to join the big six, or go out of business. This suggests a substantial barrier to new entry in the markets for transgenic seed.

3. Contestability

A market is contestable if there is freedom of entry and exit into the market, and there are little to no sunk costs. Because of the threat of new entrants, existing companies in a contestable market must behave in a reasonably competitive manner, even if they are few in number.

Concentrated markets do not necessarily imply the presence of market power (Fulton and Giannakas, 2001; Henrickson and Heffernan, 2007). 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 or near costless, there must be no sunk costs. If there were low sunk costs, then new firms would use a hit and run strategy. In other words, they would enter industry, undercut the price and exit before the existing firms have time to retaliate. However, if there are high sunk costs, firms would not be able to exit without losing significant portion of their investment. Therefore, if there are high sunk costs, hit-and-run strategies are less profitable, firms keep prices above average costs, and markets are not contestable. In this case, market power is a concern. Fulton and Giannakas (2001) outline that there exist substantial sunk costs in agricultural biotechnology, and firms charge prices above marginal costs. They stress that seed and chemical industry is not contestable and that the threat of entry cannot be relied upon to keep profits at normal levels.

3.1. Barriers to entry

Comanor (1964) and Scherer (1984) both suggest that rapidly evolving and costly agricultural biotechnology innovations tend to limit entry. King (2001) points out that investments in agricultural input markets are often risky, expensive, and long-term. Additionally, he discusses that intellectual property protection in the seed industry helps inventors exercise market power and prevents the entry of imitators and competitors. A similar argument was supported by Barton (1998) as well.

Ollinger and Fernandez-Cornejo (1998) examine sunk costs and regulation in the U. S. 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.

Harl (2000) suggested that increased concentration is leading to control by a few firms of the major processes by which genetic manipulation occurs, thereby blocking use of those technologies by other firms. He also argues that capital needed to conduct the kind of research required to maintain a product flow similar to that of the firms pressing for monopoly-like concentration levels is one of the main barriers. Another barrier, he points out, is that, existing patent and plant variety protection may mean that potential competitors are frozen out of

competition as a practical matter for the duration of the patent. The author further stresses that smaller firms are unable to maintain access to higher performing germ plasm, and most of these firms would not be able to survive economically. Howard (2009) also mentions about high expenditure costs and argues that developing transgenic traits and identifying gene sequences creates a strong barrier to entry for smaller firms.

Brennan et al. (1999) studied the impact of mergers on research and development in the U.S. biotechnology industry. The authors used USDA field trial data for private companies as a measure of innovation activities. The results of Herfindahl-Hirschman Index (HHI) and Four Firm Ratio analyses indicated that the impacts of concentration are negatively related to new firm entry. They point out that cost of obtaining permission to use patented technology or genetic material prevents smaller firms from participating in innovative research and creates significant barriers to entry. Hubbard (2009) also backed up the argument and discussed that there is a financial disincentive to seek access to patented material to expand research because of costly royalties and onerous licensing agreements with patent owners, some of which have led to lawsuits. This reality serves as a major barrier to new companies entering the plant breeding industry.

Boyd (2003) and Glenna and Cahoy (2009) discuss that agrochemical–seed firm relationships are not always cooperative and they have filed numerous lawsuits against each other. As pointed out by the authors, these lawsuits create “patent thickets,” in which broad claims overlap. Such thickets make it difficult to bring a product to market without potentially infringing on a patent, thus creating a significant barrier to entry for small firms.

Moretti (2006) points out that even though the original purpose of patents was to encourage innovation, the increased concentration and intellectual property congestion had an opposite effect. He argues that multinational agrochemical companies have growing control over essential proprietary technologies, and created a barrier to entry for new start-ups.

3.2. Recent Evidence Regarding the Effects of Market Structure on Agricultural Input Prices

If a market was contestable, existing firms would behave in a more or less competitive manner. Thus, if the market is highly profitable, this may suggest that industry is less contestable. According to Yahoo Finance, the aforementioned six multinational companies reported multimillion dollar profits in the years of 2013-2015.

Fuglie et al. (2012) discusses that market power resulting from the structural changes in agricultural input industries make farmers pay higher prices for purchased inputs. Additionally, with stronger legal protection over their intellectual property and fewer firms offering competition, firms charge higher prices for their new innovations. The authors emphasize that over the last two decades, the prices of farm inputs have been rising faster than the prices U.S. farmers receive for their crops and livestock. Although the authors mention that multiple factors could have contributed to changing prices, it is difficult to isolate the effects of market power and other factors affecting high prices.

Shand (2012) also discusses that from 1994-2010, seed prices in the U.S. increased more than any other farm input, more than doubling relative to the price farmer's received for their harvested crops. The author outlines that this increase is due to the increase in value-added characteristics developed by private seed and biotech companies through R&D programs. Hubbard (2015) stressed that with a diminished ability to save seeds and fewer options in the market, the price of seeds has increased as much as 30% annually in recent years, significantly higher than the rate of inflation. In addition, Howard (2015) emphasizes that transgenic seeds frequently require the purchase of proprietary inputs such as glyphosate herbicides, and this precedent is even being extended to non-transgenic seeds. These impacts have served to increase the profits and market capitalization of dominant firms, and they have also reduced options for farmers. This argument was discussed back in 1993 when Just and Heuth (1993) projected that chemical companies would develop biological innovations that increase dependence on the chemicals that they sell.

Howard (2015) projects that given how agrochemical firms increasingly shifted their focus to seed, they will continue seed company acquisitions and farmers will experience additional price increases in the future. The author also suspects that this will also accelerate the synergistic effects of consolidation and increasing intellectual property protections. As the firms that now dominate the global seed industry increase their size and expand intellectual property protections, the disadvantages for their smaller competitors will become even worse. As mentioned earlier, the expense of developing transgenic traits and identifying gene sequences, would create a strong barrier to entry for smaller firms.

As mentioned above, the Big Six firms presented on Figure 3, engage in a web of cross-licensing agreements to share the technologies, particularly for transgenic crops with stacked

traits. The effect is similar to the formation of a cartel to exclude other potential competitors. Therefore, small existing firms will have two main options: to consider strategic alliances (with larger firms) or exit strategies.

In summary, large sunk research costs and intellectual property protections create substantial barriers to new entry in these markets, and they are therefore not contestable. Prices for seed and some other agricultural inputs have consequently increased in recent years.

4. Hausman Methodology

In this section, we briefly review some available methods for analyzing the price effects of proposed mergers, and then describe the Hausman method that we employ in some detail. This method is appropriate for markets with differentiated goods and the assumption of no new entry. We additionally briefly describe the microeconomic theory we use to calibrate, using available econometric evidence, the own and cross-price elasticities of demand that we require.

Several methods have been proposed in the literature to study competitive analysis with differentiated products. Werden and Froeb (1994) used a logit model, and assumed Nash equilibrium in prices and constant marginal costs to study the impact of mergers in differentiated products industries. The authors studied simulations of hypothetical mergers of U.S. long distance carriers. They propose that simulations such as these provide a firmer foundation for antitrust policy than traditional structural indications. However, this approach has been criticized by Hausman (2010). In particular, this method assumes that market shares are indicative of consumer's second choices only if the "independence of irrelevant alternatives" (IIA) property holds for consumer demand. For example, the choice of a given consumer between Monsanto corn seed and Dow corn seed does not depend on whether Du Pont/Pioneer's corn seed is also available. Hausman (2010) further stresses that standard logit models should not be used in merger simulation models because at both the aggregate and individual levels they impose the IIA property. Moreover, assuming that marginal costs are constant, it may not be a realistic assumption. Merger firms may experience efficiency gains, in which case marginal costs may change when compared to the status quo.

The other approach that has been recently employed is "upward pricing pressure" (UPP) technique. This approach was initially proposed by Shapiro (1996) and it is now included in the

2010 Merger Guidelines. This approach heavily depends on a term called the “diversion ratio,” which is closely related to the cross-price elasticity of demand. The diversion ratio is explained as the fraction of unit sales lost by the first product due to an increase in its price that would be diverted to the second product. This approach is a significant improvement when compared to its predecessor, 1992 Merger Guidelines, as the UPP does not require market definition or the calculation of market shares or HHIs. However, this approach, as well, has been heavily criticized by Hausman (2010) for two reasons. First, the UPP is limited to the situation of single product for each merging firm, while in reality many merging firms producing differentiated products produce more than a single product each. Second, and more importantly, the analysis is based on the effect of merger on only one product at a time and does not consider the impact on both products. In other words, price of one product is held constant when the UPP is calculated for the other product. However, in reality, both prices will most likely change simultaneously. In addition, this approach calculates the upward pricing pressure estimate, and not the expected change in prices, which is the focus of unilateral effects analysis to begin with.

Given the limitations of the methods mentioned above, we follow Hasuman et al. (1994), Hasuman and Leonard (1997), and Hausman (2010), and use for our analysis the Nash-Bertrand assumption under conditions where entry is expected not to occur even if prices are raised after a merger. Suppose that firm 1 produces a single product in a market with n products and chooses price to maximize profit

$$\pi = (p_1 - mc_1)Q_1(p_1, \dots, p_n) \quad (1)$$

where p_1 is an output price and mc_1 is a marginal cost. The first order condition, under a Nash equilibrium, is given by:

$$\frac{\partial \pi}{\partial p_1} = Q_1(p_1, \dots, p_n) + (p_1 - mc_1) \frac{\partial Q_1}{\partial p_1} = 0 \quad (2)$$

In equilibrium, the firm sets price based on:

$$\frac{p_1 - mc_1}{p_1} = -\frac{1}{e_{11}} \quad (3)$$

where e_{11} is the firm's own price elasticity.

Suppose that brand 1 merges with brand 2. The merged firm will take into account that if it raises the price of either brand, some of the lost demand will go to the other brand it controls, assuming the products are substitutes. Thus, the price constraining effect of brand 2 on brand 1 will be eliminated if they are no longer independent brands. The merger will remove the competitive constraint, and may lead to higher prices. The size of effect will depend upon the size of the own and cross price elasticities of demand for the brands of the 2 merging firms. On the other hand, the merger could lead to production efficiencies (reductions in marginal costs), which would lead to lower prices. The size of the price reduction is directly related to the size of marginal cost reduction. Whether a merger has overall positive or negative impact on the prices depends on whether the former effect is larger than the latter (Hausman and Leonard, 1997). With brands 1 and 2 merging, the merged firm maximizes its profit as follows:

$$\pi = (p_1 - mc_1)Q_1(p_1, \dots, p_n) + (p_2 - mc_2)Q_2(p_1, \dots, p_n) \quad (4)$$

The first order conditions solve for 2 partial derivatives with respect to p_1 and p_2 . These conditions are expressed as:

$$\begin{cases} s_1 + s_1 * e_{11} * \frac{p_1 - mc_1}{p_1} + s_2 * e_{21} * \frac{p_2 - mc_2}{p_2} = 0 \\ s_2 + s_2 * e_{22} * \frac{p_2 - mc_2}{p_2} + s_1 * e_{12} * \frac{p_1 - mc_1}{p_1} = 0 \end{cases} \quad (5)$$

where e terms are elasticities, s terms denote revenue shares, and mc terms are post-merger marginal costs.

Solving the first equation for brand 1's price-cost markup in terms of brand 2's price cost markup yields:

$$\frac{p_1 - mc_1}{p_1} = \frac{e_{21} \frac{s_2}{e_{22}} - s_1}{s_1 * e_{11} - s_1 \frac{e_{12} * e_{21}}{e_{22}}} \quad (6)$$

Two things emerge from equation (6). First, the higher the pre-merge revenue share of brand 1, the lower expected price increase for brand 1. Second, the higher the share of brand 2, the higher the expected price increase for brand 1. Intuitively this means that, a product with a large amount of sales that merges with a product with small amount of sales, the expected outcome is that price change on the high sales product will be relatively small, while the expected effect on the small sales product is expected to be relatively large.

The remaining $n - 2$ firms, not involved in the merger, still maximize their profits as they were maximizing before the merger situation:

$$\frac{p_i - mc_i}{p_i} = -\frac{1}{e_{ii}}$$

for $i = 3, \dots, n$ (7)

To generalize 2 merging firms into m merging firms, the newly combined firm will set its prices optimally, yielding the first order conditions for each product as follows:

$$\left[\frac{p_j}{\sum_{k=1}^m p_k q_k} \right] \frac{\partial \pi}{\partial p_j} = s_j + \sum_{k=1}^m \left[\frac{p_k - mc_k}{p_k} s_k \right] e_{kj} = 0$$

for $j = 1, \dots, m$ (8)

To avoid having to solve for nonlinear equations, Hausman et al. (1994) proposed linearization to approximate the post-merger prices.

$$S + E'w = 0 \quad (9)$$

where s is the vector of revenue shares, E is the matrix of own and cross price elasticities, and w is the vector of price-cost markups multiplied by the share.

$$\begin{bmatrix} s_1 \\ \vdots \\ s_m \end{bmatrix} + \begin{bmatrix} e_{11} & \cdots & e_{m1} \\ \vdots & \ddots & \vdots \\ e_{1m} & \cdots & e_{mm} \end{bmatrix} \begin{bmatrix} s_1 * \frac{p_1 - mc_1}{p_1} \\ \vdots \\ s_m * \frac{p_m - mc_m}{p_m} \end{bmatrix} = \begin{bmatrix} 0 \\ \vdots \\ 0 \end{bmatrix} \quad (10)$$

The individual markup equations are solved through inversion of the matrix of elasticities:

$$\begin{bmatrix} \frac{p_1 - mc_1}{p_1} \\ \vdots \\ \frac{p_m - mc_m}{p_m} \end{bmatrix} = -1 * \begin{bmatrix} e_{11} & \cdots & e_{m1} \\ \vdots & \ddots & \vdots \\ e_{1m} & \cdots & e_{mm} \end{bmatrix}^{-1} \begin{bmatrix} s_1 \\ \vdots \\ s_m \end{bmatrix} o \begin{bmatrix} 1 \\ s_1 \\ \vdots \\ 1 \\ s_m \end{bmatrix} \quad (11)$$

where o stands for Hadamard product of two matrices (element-wise multiplication).

Following Hausman et al. (1994), the percentage change in price following the merger can be expressed as follows:

$$\frac{p_j^M - p_j}{p_j} = \frac{\frac{mc_j^M}{mc_j}}{\frac{e_{jj}}{1 + e_{jj}} (1 - \theta_j^M)} - 1 \quad (12)$$

where θ_j^M is a post-merger price-cost markup, mc_j is a pre-merger marginal cost, mc_j^M is a post-merger marginal cost, and e_{jj} is an own price elasticity. Decreased marginal cost can lead to lower post-merger prices if θ_j^M does not increase too much.

If the merging firm does not have changes in marginal costs, then equation (12) becomes:

$$\frac{p_j^M - p_j}{p_j} = \frac{1}{\frac{e_{jj}}{1 + e_{jj}} (1 - \theta_j^M)} - 1 \quad (13)$$

The percentage change in price of each merging product will depend on the size of θ_j^M which is calculated from equation (11).

4.1 Cross-price Elasticities

As described in the following section, we have estimates of own-price elasticities of demand (or Lerner indices) seed markets. However, we do not have estimates of cross-price elasticities of demand (across firms) that are needed to apply the Hausman methodology. We additionally recognize that the own-price elasticities are not known with certainty, and indeed we have a range of such estimates.

To address these problems, we derive theoretic own- and cross-price elasticities of demand, as a function of seed market shares and a single unknown behavioral parameter. Specifically, we solve the cost minimization problem for a representative seed consumer, assuming an abstract, composite seed input is produced using constant elasticity of substitution (CES) technology. Under this arrangement, we have Hicksian own-price elasticities of demand of

$$e_{ii} = \sigma \left[w_i^{1-\sigma} \alpha_i \left(\sum_k \alpha_k w_k^{1-\sigma} \right)^{-1} - 1 \right] \quad (14)$$

where the w are market prices of seed from individual suppliers, the α parameters describe the intensity of each input, and the σ is the elasticity of substitution. The elasticity of demand for input i with respect to the price of input j is given by

$$e_{ij} = \sigma w_j^{1-\sigma} \alpha_j \left(\sum_k \alpha_k w_k^{1-\sigma} \right)^{-1} \quad (15)$$

Given a value for σ , input cost shares s_i for each input from an observed equilibrium, and assuming all input prices are one¹, the α parameters are calibrated as

¹ Allowing arbitrary quantity units for seed facilitates the assumption that all prices are one. This approach is typical in Computable General Equilibrium modeling.

$$\alpha_i = s_i \left(\sum_k s_k^{1/\sigma} \right)^{-\sigma} \quad (16)$$

4.2 Simulations

We conduct a simulation exercise, with each trial consisting of the following series of steps:

1. We draw a random value for the σ parameter from a distribution that generates a resulting range of own-price elasticities consistent with econometric evidence described in the data section below.
2. We use the value for σ from step 1, observed market shares described in the data section below, and equations 14 through 16 to calculate commensurate own- and cross-price elasticities.
3. We use the elasticities for the merging firms from step 2 in equation 13 to calculate a percentage change in seed prices due to the merger.²

We then characterize the distribution of possible post-merger price increases using values across all trials.

5. Data

To employ our chosen methodology and analyze the proposed DuPont/Pioneer-Dow and Monsanto-Bayer mergers, we require industry market shares and own-price elasticities of demand. The details of obtaining the data for each component are discussed in the subsequent sections.

² Note that using equation 13 rather than equation 12 implies that marginal costs do not change as a result of the merger. The primary marginal cost associated with seed production, transgenic or otherwise, is simply the cultivation cost, which will scale approximately linearly with quantity produced. Mergers in this industry may well produce reductions in fixed costs (e.g., trait development), but are not likely to substantially reduce the marginal costs of seed production.

5.1. Industry market shares

Industry market shares were obtained from two different sources. Industry shares for the corn and soybean seed industries were obtained from Begemann (2015), and share estimates for seed for upland cotton were obtained from USDA's AMS 2015 report. These data are presented in Table 3. Monsanto currently holds 35.5% of the market for corn seed, while DuPont has 34.5% and Dow has 6%. In soybean seed, Monsanto has a 28% share, while DuPont has 33.2% and Dow has 5.2%. In seeds for cotton, Monsanto, Dow, and Bayer enjoy the largest shares: 31.2%, 15.3%, and 38.5% market shares, respectively.

Table 3. Seed Market Shares

	Corn	Soybeans	Cotton
Monsanto	35.5%	28.0%	31.2%
DuPont Pioneer	34.5%	33.2%	0.0%
Dow	6.0%	5.2%	15.3%
Syngenta	5.7%	9.8%	0.0%
Bayer	0.0%	0.0%	38.5%
Americot	0.0%	0.0%	6.4%
AgReliant	7.0%	3.1%	0.0%
Public saved	0.0%	2.4%	0.0%
Others	11.3%	18.3%	8.6%
Total	100.0%	100.0%	100.0%

Corn and soybeans shares are as of 2014, and upland cotton shares are as of 2015.

5.2. Own-price Elasticities of Demand and Market Power

There are some recent quantitative empirical studies measuring market power in the U.S. seed industry. A few recent studies have examined the pricing decisions of seed firms based on new empirical industrial organization (NEIO) models of the firm's profit function. Shi et al. (2008) 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 authors incorporated 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. The authors found that,

when statistically significant, the Lerner indexes were always positive, ranging from 2.25% for conventional seeds to 21.14% for herbicide tolerance trait. The effect of market power on price is found to be moderate in the conventional seed market, but larger in the herbicide tolerance trait market (HT1). Also, the Lerner index was significant and fairly large in the bundled-seed markets involving HT1, equal to 14.39 for Bt-European Corn Borer (BT-ECB) and HT1, 17.62 for Bt-Rootworm (Bt-RW) and HT1, and 15.32 for Bt-ECB, BT-RW, and BT-HT1. Statistically significant results found by Shi et al. (2008) are summarized in table 4. Implied own-price elasticities of demand are recovered from the Lerner index formula using equation 3.

Table 4. Estimated Lerner indexes from Shi, et al. (2008) for the corn seed market

Seed type	Lerner Index (100 * L)	Implied Elasticity
Conventional	2.25	-44.44
HT1	21.14	-4.73
Bt-ECB and HT1	14.39	-6.95
Bt-RW and HT1	17.62	-5.68
Bt-ECB, Bt-RW, and HT1	15.32	-6.53

Kalaitzandonakes et al. (2010) studied empirical measures of price mark-ups attributable to market power in the U.S. seed industry between 1997 and 2008. This is a period characterized by the vertical integration of leading multinational biotechnology firms. Their results suggest that, in the case of the U.S. corn and soybean seed industry concentration, moderate market power and dynamic market efficiency coincided over the period of the analysis. The authors found that upper bound in the corn and soybean seed mark-up (Lerner index) to be approximately 14.6% and 17.5%, respectively. Their findings are within the range of values found by Shi et al. (2008). The results are summarized in table 5. Implied own-price elasticities of demand are recovered using equation 3.

Table 5. Estimated Lerner indexes in the corn and soybean seed markets From Kalaitzandonakes et al. (2010)

Seed type	Lerner Index (100 * L)	Implied Elasticity
Corn, overall price-cost mark-up for all varieties	14.6	-6.85
Soybean, overall price-cost mark-up for all varieties	17.5	-5.71

Zhang (2014) constructed a multiple discrete choice model with random coefficients that allows participants to purchase multiple items with continuous quantities. The author imposed a flexible correlation structure among products' observable characteristics, and panel effects on individual consumers' seed variety choices. She investigated the U.S. farmers' adoption of different corn seed varieties from 2000 to 2007. Her results indicated that farmers value the biotechnology advances over time, and their preferences are shifted away from conventional and single-trait seeds to newly-introduced multiple trait seeds. She categorized all firms into two groups: integrated biotech/seed firms with both seed and biotech sectors of patented GM traits, and independent seed companies operating only in the seed sector. There are four integrated biotech firms in the data: Monsanto, Syngenta, Dow, and DuPont/Pioneer. The author found that farmers have highly elastic demand for all seed types. The own price elasticities of genetically modified seeds were, on average, greater than conventional seeds. Moreover, the results of cross-price elasticities (across traits, not firms) indicated that farmers are less likely to switch back to conventional seeds as the prices of genetically modified seeds increase, confirming that conventional and genetically modified seeds are not close substitutes.

Table 6. Own price and cross price elasticity estimates for differentiated corn seed types by Zhang (2014)

Quantities\Prices	Conventional seeds	ECB-RW-HT1-HT2	ECB-RW-HT2	ECB-HT1-HT2	ECB-HT1	ECB-HT2	ECB	HT2
Conventional seeds	-11.53	0.216	0.125	0.242	0.284	0.359	0.396	0.292
ECB-RW-HT1-HT2	0.345	-14.793	0.853	0.724	0.701	0.493	0.622	0.55
ECB-RW-HT2	0.37	2.295	-9.416	0.929	0.451	0.461	0.498	0.644
ECB-HT1-HT2	0.389	0.977	0.414	-12.478	0.766	0.573	0.58	0.771
ECB-HT1	0.312	0.518	0.139	0.494	-12.38	0.474	0.474	0.347
ECB-HT2	0.741	0.847	0.302	0.775	1.025	-12.002	1.267	1.017
ECB	0.182	0.24	0.098	0.2	0.327	0.307	-14.04	0.224
HT2	0.488	0.554	0.286	0.657	0.547	0.653	0.696	-12.99

ECB-European Corn Borer, HT1-herbicide tolerance type 1, HT2-herbicide tolerance type 2, RW-resistance to rootworm.

6. Herfindahl-Hirshman Index (HHI)

While market concentration is not a key focus of our analysis, we nonetheless calculate changes in this index, as the U.S. Department of Justice (DOJ) and Federal Trade Commission (FTC) have explicit guidelines related to this measure. The HHI is the sum of squared market share percentages. It therefore falls in the range (0, 10,000], with 10,000 representing a pure monopoly market.

Under DOJ/FTC’s Horizontal Merger Guidelines, a market is considered “moderately concentrated” if the HHI is between 1,500 and 2,500, and “highly concentrated” if the HHI is above 2,500 (U.S. Department of Justice, 2016). For an industry that is highly concentrated, any action that increases the HHI by 200 or more points is considered “likely to enhance market power.”

Based on the data in Table 3, we see that DuPont/Pioneer and Dow have similar market shares in both the corn and soybean seed markets: 34.5% and 6%, respectively in corn, and 33.2% and 5.2%, respectively, in soybeans. The merger would give Dow-DuPont about 41% of the market for corn seeds and 38% of the market for soybean seeds. In the seed market for cotton, Monsanto and Bayer hold 31.2% and 38.5% market shares, respectively, and the proposed merger would consequently give Monsanto-Bayer about 70% of this market.

We calculate HHI values before and after the proposed mergers, which are presented in Table 7. For the seed markets for corn and cotton, the HHI is above 2,500 before the mergers, with soybeans falling somewhat short of 2,500. In all markets, the proposed mergers would increase HHIs by more than 300 points. The HHI change in the market for seed for cotton increases particularly dramatically, with an increase of about 2,400 points. The seed markets for corn and cotton both meet the DOJ/FTC criteria under which market power is likely to be enhanced.

Table 7. Herfindahl-Hirshman Index Values Before and After Proposed Mergers

	Corn	Soybeans	Cotton
Before	2,696	2,360	2,804
After	3,110	2,705	5,205

7. Hausman Results

In this section we calculate expected impacts on seed prices of two proposed mergers, DuPont/Pioneer-Dow and Monsanto-Bayer, for corn, soybean, and cotton. As discussed in the literature, implied own-price elasticities derived from the Lerner indexes by Kalaitzandonakes et al. (2010) and Shi et al. (2008), and empirically estimated own-price elasticities found by Zhang (2014) were in the range of -12% and -5%. Following CES production function framework discussed above, we chose the σ parameter values that would generate the own-price elasticities of demand in the range of -12% and -5%. For simulating the σ parameter, we specify a GRKS distribution. The GRKS is a parametric, piece-wise linear probability distribution function similar to the triangular distribution, that has been used extensively in applied simulation studies (Richardson et al. 2007a, 2007b; Palma et al., 2011; Monge et al., 2014). The distribution is fully characterized by minimum, expected, and maximum values. However, the assumed minimum and maximum values in the GRKS represent the 2.5% and 97.5% quantiles, respectively, whereas for the triangular distribution, they represent the lower and upper bounds of the domain. Hence, in contrast to the triangular distribution, the GRKS allows the random variable to take on values slightly below and slightly above the assumed minimum and maximum, respectively, with low probabilities of occurrence.

6.1. *DuPont/Pioneer-Dow Merger in Corn and Soybean Markets*

We calculated the impacts of the proposed merger between DuPont/Pioneer and Dow in corn and soybean industries. We did not study the impacts of the proposed Monsanto-Bayer merger in the corn and soybean seed markets given that Bayer does not participate in corn and soybean seed markets.

We calculated the change in price for the merging seed products using the methodology described in section 4. The estimated results from the simulation are summarized in table 7. Assuming no changes in the marginal costs, we find that the estimated price increases in both markets would be modest. In corn, average price increases are estimated to be 1.6% and 6.28%. Interquartile range values indicate that there is a 75% chance that the DuPont-Dow merger price increases would be less than or equal to 1.78% and 7.15%.

In soybeans, the results are almost identical. Assuming no changes in the marginal costs, the estimated price increases would be quite small. The average price increases are estimated to be 1.3% and 5.8%. Interquartile range values show that there is a 75% chance that the DuPont-Dow merger price increases would be less than or equal to 1.5% and 6.5%. The market-share weighted expected price increased 2.3% for corn seed and 1.9% for soybean seed.

6.2. Monsanto-Bayer Merger in Seed Market for Cotton

We did not analyze the effects on the seed market for cotton of the proposed DuPont-Dow merger given that DuPont has a 0% share in this market. We calculated the change in prices for the merger and the estimated results are summarized in table 8. Assuming no changes in marginal costs, we find that the estimated price increases would be quite large. The average price increases by Monsanto and Bayer are estimated to be 19.2% and 17.4%, respectively. Interquartile range values indicate that there is a 75% chance that the Monsanto and Bayer would increase their prices by more than 14.5% and 13.1%, respectively. The market-share weighted expected increase in market price for seed for cotton is 18.2%.

Table 8. Estimated Seed Price Increases for Merging Biotech Companies in Corn, Soybeans, and Cotton Industries

	Corn		Soybeans		Cotton	
	DuPont/Pioneer	Dow	DuPont/Pioneer	Dow	Monsanto	Bayer
Average	1.57%	6.28%	1.29%	5.82%	19.23%	17.41%
St. Dev	0.44%	1.76%	0.43%	1.93%	9.06%	8.20%
25% quantile	1.25%	5.00%	1.02%	4.58%	14.51%	13.14%
75% quantile	1.78%	7.15%	1.45%	6.54%	21.29%	19.28%

8. Conclusions

Over the past few decades, development of new types of pesticides and seeds have substantially improved agricultural productivity. Agricultural input markets have evolved and family owned and small businesses gave way to larger enterprises that integrated plant breeding, conditioning, production, marketing, and other functions. This evolution in the industry was coupled with

increasing market concentration in seed and chemical supply and the industry was further shaped by widespread mergers and acquisitions. The agrochemical companies bought hundreds of independent biotechnology and seed companies, and merged with one another. This has resulted in an industry that is comprised primarily of six large multinational firms.

Agricultural input markets are not likely to be contestable. Increased concentration by few firms over the major processes by which genetic manipulation occurs, enables them to control the technologies to block use by other firms. In addition, there are substantial sunk costs, including intellectual property cross-licensing and R&D expenditures, which are a substantial barrier to new entry in these markets. The market power resulting from the structural changes in agricultural input industries make farmers pay higher prices for purchased inputs. Seed prices in the U.S. have increased by larger percentages than other farm inputs in recent years.

The proposed DuPont/Pioneer-Dow merger would increase market concentration by about 414 HHI points, from 2696 to 3110, in the corn seed market. In the soybean seed market, the merger would increase the concentration by 345 HHI points, from 2360 to 2705. These values imply that the DOJ/FTC Horizontal Merger Guidelines would consider the DuPont/Pioneer-Dow merger likely to enhance market power in the corn seed market. Expected seed price increases in both markets are projected to be modest. In corn, the market-share weighted expected price increase is 2.3%. Interquartile range values indicate that there is a 25% chance that the DuPont-Dow merger average price increases for corn seed would be greater than or equal to 2.6%. In soybeans, the results are similar; assuming no changes in marginal costs, the market-share weighted expected price increases is 1.9%, and interquartile range values indicate that there is a 25% chance that the DuPont-Dow merger average soybean seed price increase would be greater than or equal to 2.1%.

The Monsanto-Bayer merger is projected to substantially increase seed prices for cotton. The merger would give Monsanto-Bayer about 70% of the market. The merger would increase market concentration by about 2400 HHI points, from 2804 to 5205. This high starting HHI value and the dramatic increase easily qualifies the proposed Monsanto-Bayer merger as likely to enhance market power in the seed market for cotton under DOJ/FTC merger guidelines. The market-share weighted expected price increase is 18.2%. Interquartile range values indicate that there is a 25% chance that Monsanto and Bayer would increase their seed prices for cotton by more than 20.2%

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