*AgBioForum, 12(3&4): 326-333.* 

# Pricing of Herbicide-Tolerant Soybean Seeds: A Market-Structure Approach

**Guanming Shi, Jean-Paul Chavas, and Kyle W. Stiegert**
*University of Wisconsin-Madison*

This article investigates the effects of supply-side factors on the pricing of soybean seeds in the United States. We discuss recent trends that have shaped the US soybean seed market. Using an econometric model, we also analyze the impacts on soybean seed prices of changes in market size, market concentration, and vertical organization (including vertical integration and biotech trait licensing). We simulate the effects of recent market changes on the pricing of different seed types. The analysis finds that increased within-market concentration tends to enhance seed price in that market. However, in a multi-market framework, the simulations show that the presence of complementarity in production and distribution mitigates these price enhancing effects.

***Key words:*** vertical structures, pricing, imperfect competition, seed, biotechnology.

## Introduction

Over the last century, plant breeding has generated significant genetic improvements and higher crop yields, which have greatly increased agricultural productivity. The last three decades have seen a growing role of the private sector in genetic improvements in agriculture. This was stimulated by the 1970 Plant Variety Protection Act (PVPA), which granted breeders exclusive rights to new varieties for a period of 18 years (extended to 20 years since the 1994 PVPA Amendment) and later by the extension in the 1980's of utility patents covering plants and animals (e.g., *Diamond v. Chakrabartty*, 1980; *ex-parte Allen*, 1984; *ex-parte Hibbard*, 1987). Legal protection of varieties provided incentives for private R&D investments in the US seed industry.

The change in intellectual-property (IP) protection regimes along with the emergence of biotechnology advancements in seeds eventually led to major changes in US seed markets (Alston & Venner, 2002; Butler & Marion, 1985; Falck-Zepeda & Traxler, 2000; Fox, 1990). Many small seed firms vanished, and mergers and acquisitions created a new seed industry dominated by large companies (Fernandez-Cornejo, 2004). Seeds with biotech traits, often referred to as genetically modified (GM) seeds, appeared in agricultural markets during the 1990s and were quickly adopted by US farmers. By 2008, 80% of US corn acres and 92% of US soybean acres were planted with GM seeds (US Department of Agriculture, National Agricultural Statistics Service [USDA NASS], 2008). Globally, in 2008, GM crops were grown commercially in 25 countries and planted on a total of 309 million acres (8% of all cropland; James, 2008).

This "biotechnology revolution" has been associated with structural changes in the seed industry. In this article, we examine the changes that have taken place in the US soybean seed industry. We focus our attention on their implications for pricing of both conventional soybean seeds and the herbicide-tolerant soybean seeds. We examine the effects of recent changes in market sizes and market concentrations. Because the production of biotech soybean seeds[1] involves the integration or coordination of upstream biotech firms (who own the IP rights to those new biotech traits contained in the seed) and the downstream seed companies (who produce and distribute these seeds), our research also considers vertical strategies and the subsequent impacts on pricing of seeds to farmers. Recent trends toward greater vertical integration by biotech firms into seed production and sales while charging technology fees to other seed firms has the potential to impact producer welfare in ways that are not currently well understood. Our research begins to unravel these impacts.

While seeds developed using conventional breeding methods have differing agronomic and end-use characteristics, the advent of biotechnology in agricultural introduced further product differentiation. Indeed, seeds are differentiated by genetic trait, bundling of traits, and different vertical structures in which they are produced

1. *A "biotech seed" is a seed with identifiable biotech traits (genes), which may be inserted through genetic modification or traditional breeding practice. A seed containing a bundle of more than two traits is called a "bundled" seed in this article.*

and marketed (through different labeling and packaging). In addition, the seeds can differ according to the institutional setup of providers. Over the last 20 years, the US soybean seed industry has experienced a rapid shift from public-sector breeding to private-sector breeding. The acreage share of publicly developed varieties decreased from more than 70% in 1980 to 10% in the mid-1990s (Fernandez-Cornejo, 2004), and to 0.5% in 2007 (Shi & Chavas, 2009). Our study presents new and useful information on the implications of these institutional changes for soybean seed pricing.

## The US Soybean Seed Market

Our analysis uses a large, extensive data set providing detailed information on the US soybean seed market. The data were collected by **dmr**kynetec (hereafter dmrk), St. Louis, MO. The dmrk data come from a stratified sample of US soybean farmers surveyed annually from 2000 to 2007.[2] The survey provides farm-level information on seed purchases, acreage, seed types, and seed prices. It was collected using computer-assisted telephone interviews.

Farmers typically buy seeds locally, and seeds are usually developed for different agro-climate conditions in different regions. We define the "local market" at the Crop-Reporting-Districts (CRD)[3] level. To guarantee reliable measurement of local-market statistics, our analysis focuses on those CRDs with more than 10 farms sampled every year between 2000 and 2007. The data contain 76,308 observations from 76 CRDs in 18 different states.[4] On average, around 3,000 farmers are included in the sample each year, of which between 30-50% remain in the sample for the next year.[5] Moreover, farmers purchase multiple seed varieties, on average three different seed varieties every year. Some large farms purchase up to 27 different varieties in a single year.[6]

2. *The survey is stratified to over-sample producers with large acreage.*
3. *A crop-reporting district (CRD) is defined by the US Department of Agriculture to reflect local agro-climatic conditions. In general, a CRD is larger than a county but smaller than a state.*
4. *They are AR, IL, IN, IA, KS, KY, LA, MI, MN, MS, MO, NE, NC, ND, OH, SD, TN, and WI.*
5. *Thus, the dmrk survey is not a true panel, as the farm composition of the sample changes over time.*
6. *Due to the fast turnover in the seed market, farmers may try new varieties every year, thus would purchase more than one variety of seed for their field.*

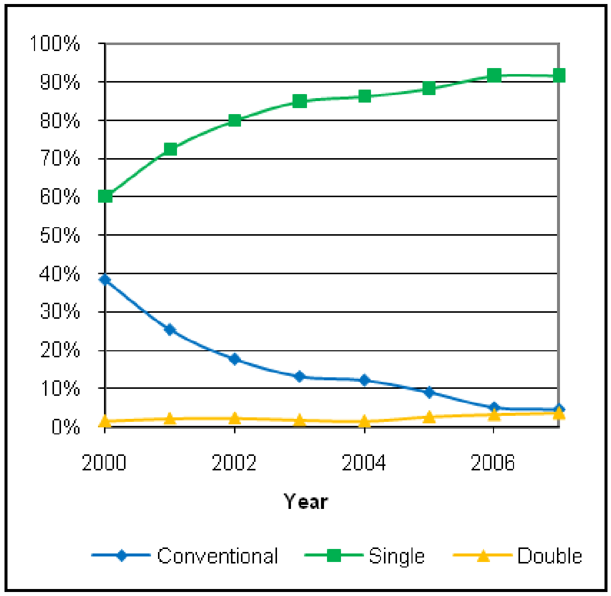


**Figure 1. Soybean seed adoption rates in the US, acreage share, 2000-2007.**

Currently the only available gene/trait technology in the biotech soybean seed market is herbicide tolerance (HT), designed to reduce yield loss from competing plants (weeds). There are two major HT traits, labeled here as HT1 and HT2. These traits are owned by different biotech companies, which also own subsidiary soybean seed companies. Some biotech seeds contain only one of these traits, while some are bundled and contain both HT1 and HT2 traits (also called "double stacking").

Constructed from our data, Figure 1 shows the evolution of soybean acreage shares, reflecting adoption rates in the United States from 2000 to 2007 for conventional seed, single-trait biotech seed (either HT1 seed or HT2 seed), and double-stacking biotech seed (HT1/HT2). The conventional seed's acreage share has decreased rapidly over the past eight years, from 38.3% in 2000 to 4.6% in 2007. The single-trait biotech seeds dominate the market, with a steady increase in acreage share from 60% in 2000 to 92% in 2007. Double-stacking seed has a small acreage share—though still increasing—from 1.5% in 2000 to 3.6% in 2007. This trend contrasts with the corn market, in which the single-trait biotech corn seed's acreage share has been decreasing since 2005, while the proportion of US corn acres planted with stacked seeds has increased from 2.1% in 2000 to 56.2% in 2007 (Shi, Chavas, & Stiegert, 2008).

Table 1 shows the number of seed companies distributing different type of soybean seeds from 2000 to 2007. The total number of companies active in the soybean

**Table 1. Number of soybean seed companies operating in different markets, 2000-2007.**

| Year | Total | Conventional | HT1 | HT2 | Double stacking HT1 & HT2 | Total acreage (million acres) |
|---|---|---|---|---|---|---|
| **2000** | 211 | 172 | 176 | 66 | 4 | 63.5 |
| **2001** | 196 | 137 | 178 | 51 | 8 | 64.4 |
| **2002** | 198 | 131 | 178 | 40 | 12 | 62.3 |
| **2003** | 182 | 102 | 163 | 28 | 13 | 62.7 |
| **2004** | 187 | 99 | 179 | 25 | 13 | 62.9 |
| **2005** | 180 | 89 | 169 | 27 | 24 | 60.7 |
| **2006** | 178 | 57 | 173 | 24 | 27 | 62.7 |
| **2007** | 172 | 54 | 167 | 15 | 30 | 53.2 |

seed market declined from 211 in 2000 to 172 in 2007. The decrease comes mostly from the conventional seed market (from 172 in 2000 to 54 in 2007) and HT2 seed market (from 66 in 2000 to 15 in 2007), while the number of companies selling HT1 seed remains stable over the years (between 160 and 180), and more companies now carry double-stacking seeds (from 4 in 2000 to 30 in 2007).

The biotech companies who developed the HT trait also have affiliated seed companies, either through vertical integration or merger. According to patent law, if a non-affiliated seed company wants to produce a seed with patented trait(s), it needs to obtain a license from the patent owner, the related biotech company. This licensing requirement does not apply to the case where the seed companies are affiliated with the biotech company. Typically both affiliated and non-affiliated seed companies produce and market the relevant HT seeds. We consider two vertical structures, *vertical integration* (where the seed company is owned by a biotech firm) and *un-integrated* or *licensing* (where seeds are sold to farmers by a non-affiliated seed company under a license agreement with a biotech firm).

Noting that single-trait seeds dominate the US soybean seed market, Figure 2 illustrates the evolving acreage share of vertical integration versus un-integrated for single-trait seed from 2000 to 2007. It shows that the proportion of the vertically integrated seed has increased from 13% of the market in 2000 to 26% in 2007.

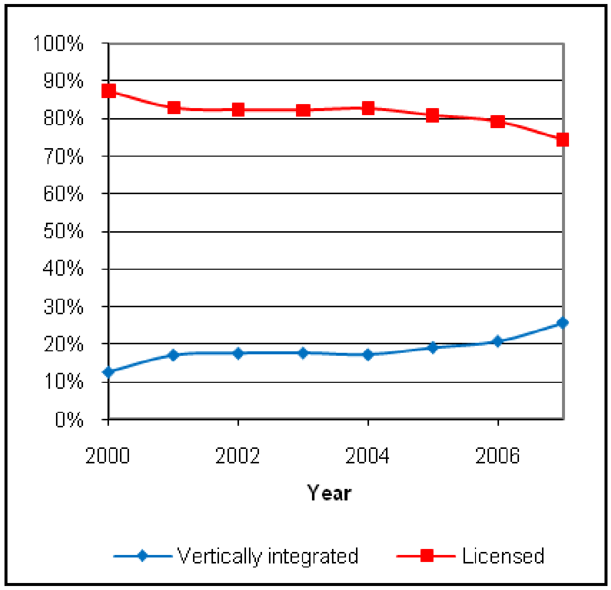


**Figure 2. Vertical integrated vs. licensed single trait soybean seeds, acreage share 2000-2007.**

## The Pricing of Soybean Seeds

Product pricing and strategy under imperfect competition have been studied extensively in the industrial organization literature. The US seed industry has become increasingly concentrated after a series of mergers and acquisitions since the 1990s (e.g., Shi, 2009). Although the number of firms marketing soybean seeds has been declining (see Table 1), the aggregate number may be sufficient to assure that prices are driven by a reasonably competitive process. However, the summary statistics in Table 1 are at the national level, which may not describe well the competitive process in local markets. As our analysis of the data reveals, the level of firm concentration is very high in many regions and the seeds that perform well in various agro-climactic regions are far narrower than the aggregate numbers suggest. Shi and Chavas (2009) reported that the average Herfindahl-Hirschmann index (HHI) for 76 CRDs from 2000 to 2007 for conventional soybean seed is 0.412, about twice the Department of Justice's threshold for "significant market power," 0.18.[7]

Figure 3 presents the average prices for conventional, single-trait type, and stacked seeds from 2000 to 2007. All three seed types exhibit a similar trend in

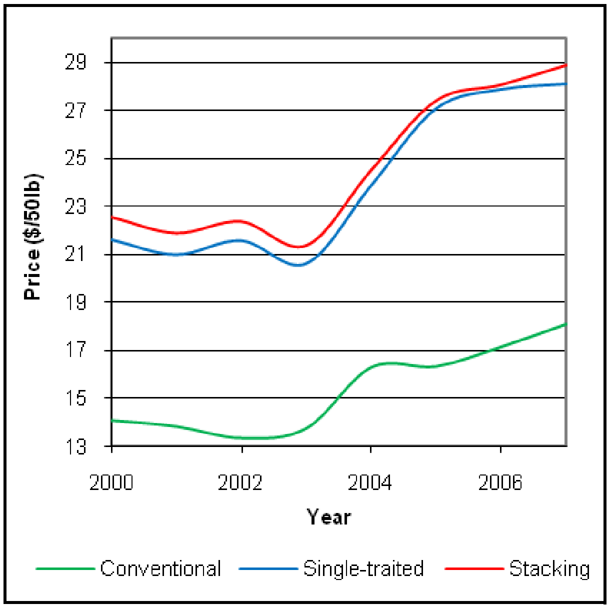


**Figure 3. Price (nominal) trend of US soybean seeds, 2000-2007.**

price: stable or slightly decreasing from 2000 to 2003, and then increasing steadily since then. Unsurprisingly, the average conventional seed price is lower than the biotech seed prices. Stacked seeds are sold at a small premium over single-trait seeds.

Using the dmrk data, an econometric analysis of the pricing of soybean seeds was developed. Following Shi and Chavas (2009), it involved specifying and estimating a price equation where soybean seed price was regressed on seed type, location, year dummy variables, farm size, and other economic variables. The effects of market size and market concentration were also analyzed, the latter being measured by a generalization of the HHI.

The standard HHI is defined as HHI=$\sum_{i=1}^{n} s_i^2 \in [0, 1]$, where $s_i \in [0, 1]$ is the $i^{\text{th}}$ firm's market share ($i = 1, \ldots, n$). It has been commonly used in applied industrial organization (e.g., Whinston, 2006). Shi and Chavas (2009) developed the generalized HHIs, reflecting both vertical and horizontal aspects of market concentration. Termed VHHI (for Vertical HHI), these concentration indexes are defined as $\text{VHHI}_{mk,u\tau} = \sum_{i=1}^{n} s_{mu}^i s_{k\tau}^i$, where $s_{mu}^i$ is the market share of the $i^{\text{th}}$ firm for the $m^{\text{th}}$ product in the $u^{\text{th}}$ vertical structure. The VHHIs are close to zero under competition (in the presence of a large number of firms) and increase in magnitude under imperfect competition. In the special case where $m = k$ and $u = \tau$, then VHHI reduces to the standard HHI, where HHI attains its upper bound of 1 under monopoly.

Following Shi and Chavas (2009), the impacts of the VHHIs' measures on prices are specified as follows:

$$p_{k\tau} = \beta_0 + \sum_{m\in\mathbf{K}} \sum_{u\in\mathbf{V}} \beta_{mk,u\tau} VHHI_{mk,u\tau} Y_{mu} T_k D_\tau + \delta_{k\tau} + \boldsymbol{\varphi}\mathbf{X} + \varepsilon_{k\tau}, \quad (1)$$

where $p_{k\tau}$ is the net price ($/50lb) of the $k^{\text{th}}$ seed under the $\tau^{\text{th}}$ vertical structure; $Y_{mu}$ is the total amount of $m^{\text{th}}$ type of seed under the $u^{\text{th}}$ vertical structure in the local market; $T$ and $D$ are dummy variables for seed type and vertical structure type; $\mathbf{X}$ is a vector of other relevant covariates including purchase source, farm size, state location and time trend; and $\varepsilon_{K\tau}$ is an error term with mean zero and finite variance. When positive (negative), the coefficient $\beta_{mk,u\tau}$ reflects substitution (complementarity) relationships between $Y_{mu}$ and $Y_{k\tau}$, $k \neq m$, $u \neq \tau$ (see Shi & Chavas, 2009). This price equation shows that market concentration (as measured by the VHHI) interacts with market size (as measured by the $Y$s) in their effects on prices.

Since the VHHIs are likely to be endogenous, the model was estimated by two-stage least squares. The model has a high explanatory power (uncentered R-square = 0.99). Many parameters are statistically significant, and the model documents how changing market structure is associated with the price of soybean seeds. Table 2 reports selected regression results related to market concentration and vertical structure (the full results are reported in Shi & Chavas, 2009). The first column describes which VHHI term interacting with the cross-market size $Y$ is used, and the second column describes which sub market is being evaluated.

The first four rows of estimates measure the own-HHI impacts on each relevant market. The level of concentration in conventional seed has a positive and significant impact on the conventional-seed price. This corresponds with the traditional story that higher levels of concentration allow firms greater pricing latitude which usually infers higher prices. Importantly, it

7. *Although the national HHI is only 0.106, not all soybean seeds perform well in all regions. Therefore, regional HHIs provide a better characterization of the degree of competitiveness in seed markets.*

**Table 2. IV (2SLS) regression with robust standard errors.[a]**

| Dependent variable: Net price ($/50lb) | | Coefficient | Robust z statistics |
|---|---|---|---|
| **Own-VHHI effects:** | **Submarket** | | |
| $VHHI_{11,\ell\ell}Y_{1\ell}$ | $T_1D_\ell$: conventional seed | 0.163** | 2.58 |
| $VHHI_{11,\ell\ell}Y_{1\ell}$ | $T_1D_\ell\_pub$: public-sourced conventional seed | -0.156* | -1.89 |
| $VHHI_{22,\ell\ell}Y_{2\ell}$ | $T_2D_\ell$: HT1 under licensing | 0.000 | 0.02 |
| $VHHI_{22,vv}Y_{2v\ v}$ | $T_2D_v$: HT1 under vertical integration | -0.021*** | -2.62 |
| **Cross-VHHI Effects:** | | | |
| $VHHI_{21,\ell\ell}Y_{2\ell}$ | $T_1D_\ell$: conventional seed | -0.261*** | -3.85 |
| $VHHI_{21,v\ell}Y_{2v}$ | $T_1D_\ell$: conventional seed | 0.009 | 0.10 |
| $VHHI_{21,\ell\ell}Y_{2\ell}$ | $T_1D_\ell\_pub$: public-sourced conventional seed | 0.330*** | 3.22 |
| $VHHI_{21,v\ell}Y_{2v}$ | $T_1D_\ell\_pub$: public-sourced conventional seed | -0.029 | -0.21 |
| $VHHI_{12,\ell\ell}Y_{1\ell}$ | $T_2D_\ell$: HT1 under licensing | -0.145*** | -3.01 |
| $VHHI_{12,\ell v}Y_{1\ell}$ | $T_2D_v$: HT1 under vertical integration | 0.075 | 1.58 |
| **Centered $R^2$ = 0.74; Uncentered $R^2$ = 0.99** | | | |
| **Number of observations=64,550** | | | |

*[a] Statistical significance is noted by * at the 10% level, ** at the 5% level, and ** at the 1% level.*

**Table 3. Soybean seed market in Illinois.[a]**

| | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 |
|---|---|---|---|---|---|---|---|---|
| **Conventional seed (million lbs)** | 31.7 | 24.9 | 17.5 | 14.2 | 11.4 | 9.2 | 4.6 | 2.7 |
| **HT single-trait seed (million lbs)** | 42.5 | 52.9 | 55.1 | 59.1 | 53.5 | 57.5 | 61.1 | 51.0 |
| **Stacked seed (million lbs)** | 1.4 | 2.7 | 2.0 | 0.8 | 0.6 | 1.4 | 2.1 | 0.8 |
| **Total volume (million lbs)** | **75.6** | **80.5** | **74.6** | **74.1** | **65.5** | **68.1** | **67.9** | **54.5** |
| $VHHI_{11,\ell\ell}$ | 0.13 | 0.16 | 0.19 | 0.20 | 0.21 | 0.23 | 0.40 | 0.50 |
| $VHHI_{12\ell\ell}$ | 0.09 | 0.11 | 0.11 | 0.12 | 0.12 | 0.12 | 0.12 | 0.15 |
| $VHHI_{12\ell v}$ | 0.13 | 0.13 | 0.11 | 0.14 | 0.16 | 0.13 | 0.15 | 0.16 |
| $VHHI_{22,\ell\ell}$ | 0.16 | 0.14 | 0.14 | 0.17 | 0.17 | 0.16 | 0.16 | 0.20 |

*[a] The subscripts for VHHIs denotes the following way: 1 for conventional seed, 2 for HT1 seed, v for vertical integration, and ℓ for licensing.* $VHHI_{mk,u\tau} = \sum_{i=1}^{n} s^i_{mu} s^i_{k\tau}$ *, where* $s^i_{mu}$ *is the market share of the* $i^{th}$ *firm for the* $m^{th}$ *seed in the* $u^{th}$ *vertical structure.*

appears that publicly developed seed offers a lower-priced alternative conventional seed in regions that are highly concentrated. Moving to rows 3 and 4 in Table 2, we observe that higher levels of concentration in the HT market has not increased the seed prices under the vertical licensing arrangement, but it does mean higher prices for seeds priced in the vertically integrated market. This shows that vertical structures have significant effects on seed pricing that interfaces with traditional notions of market power. The last six rows of estimates provide additional and more complex information about seed pricing. Each row measures the impact of the cross VHHI between the HT seed market and the market for conventional seed on pricing in each submarket. Here we note a symmetric complementary effect between the conventional and the HT seed sold under a license (both coefficients of $VHHI_{21,\ell\ell}Y_{2\ell}$ and $VHHI_{12,\ell\ell}Y_{1\ell}$ are negative and significant).

The econometric results discussed above provide a limited view of the seed market. Of special interest are how recent changes in actual market conditions are associated with the pricing of alternative soybean seeds. Below, we present selected simulation results evaluating these effects. For simplicity, we focus our attention on the state of Illinois because it is the largest soybean-producing state. Table 3 presents the evolution of market size (measured in million pounds of seed being sold for each seed type) and market concentration (measured by VHHIs) for Illinois between 2000 and 2007. Total soybean seed sales remained stable between 2000 and 2003, and then declined to a lower—but also stable—range from 2004 to 2006. Total sales dropped by more than

Table 4. Simulated effects of changes in market sizes, Illinois, 2000-2006 (Scenario 1).

| | Mean price ($/50lbs) | | | | |
|---|---|---|---|---|---|
| | 2000 | 2006 | Price difference | t-statistics | p-value |
| Conventional seed (private) | 17.23 | 15.80 | -1.43 | -2.65 | 0.01 |
| Conventional seed (public) | 12.20 | 12.42 | 0.22 | 0.43 | 0.67 |
| HT1 seed (vertically integrated) | 24.02 | 24.29 | 0.27 | 0.70 | 0.49 |
| HT1 seed (licensed) | 23.11 | 24.06 | 0.95 | 2.89 | 0.00 |

Table 5a. Simulated effects of changes in $HHI_1$ only, Illinois, 2000-2006 (Scenario 2a).

| | Mean price ($/50lbs) | | | | |
|---|---|---|---|---|---|
| | 2000 | 2006 | Price difference | t-statistics | p-value |
| Conventional seed (private) | 16.06 | 16.64 | 0.58 | 2.06 | 0.04 |
| Conventional seed (public) | 12.37 | 12.30 | -0.08 | -0.28 | 0.78 |

Table 5b. Simulated effects of changes in market concentrations, Illinois, 2000-2006 (Scenario 2b).

| | Mean price ($/50lbs) | | | | |
|---|---|---|---|---|---|
| | 2000 | 2006 | Price difference | t-statistics | p-value |
| Conventional seed (private) | 16.24 | 16.62 | 0.38 | 1.42 | 0.16 |
| Conventional seed (public) | 12.34 | 12.30 | -0.04 | -0.13 | 0.90 |
| HT1 seed (integrated) | 24.22 | 24.18 | -0.04 | -0.65 | 0.52 |
| HT1 seed (licensed) | 23.80 | 23.70 | -0.10 | -3.00 | 0.00 |

18% in 2007, reflecting in part the effects of US ethanol policy (inducing farmers to switch away from soybean toward corn). In terms of market concentration, the conventional seed market experienced rising concentration, especially since 2006. The licensed HT1 seed market also experienced some increase in concentration, but on a much lower scale. The two VHHIs show a slight increase over these years, suggesting that there are more firms who would operate across markets, producing and marketing both conventional seed and HT1 seed (either licensed or vertically integrated). This appears to reflect three important changes: evolving market conditions reflecting a rapid adoption of patented seeds, some merger activities between biotech firms and conventional seed companies, and some move toward greater vertical integration by the biotech companies and less licensing of biotech seeds by traditional seed companies.

Tables 4, 5, and 6 contain the findings from three simulation exercises. Since market concentration (as measured by the VHHIs) and market size (as measured by the *Y*s) interact with each other in the price equation, we proceed to evaluate these effects first separately, then jointly. Extrapolating from the estimated coefficients of the price equation reported evaluated for Illinois, we simulate the effects of

- Scenario 1: Changes in market size holding VHHIs constant,
- Scenario 2: Changes in market concentrations as measured by VHHIs' holding the market size constant, and
- Scenario 3: Joint changes of market size and market concentration.

In each case, we bootstrapped[8] the simulated prices to obtain associated standard errors and focused our attention on changes taking place between 2000 and 2006.[9]

Table 4 reports the simulation results for Scenario 1. The results show that *ceteris paribus* changes in market size between 2000 and 2006 had significant effects on soybean seed prices. Table 3 indicates that the price of private conventional seed would decline by $1.43 (significant at 1% level) and that the price of licensed HT seed would increase by $0.95 (significant at 1% level). The price changes for both vertically integrated HT seed

8. *Bootstrapping was done by repeated simulations based on resampling from the distribution of the estimated coefficients in the price equation.*

9. *We focus on 2006 since the total market size changed substantially in 2007.*

**Table 6. Simulated joint effects of changes in market size and concentration, Illinois, 2000-2006 (Scenario 3).**

| | Mean price ($/50lbs) | | | | |
|---|---|---|---|---|---|
| | 2000 | 2006 | Price difference | t-statistics | p-value |
| **Conventional seed (private)** | 16.79 | 15.88 | -0.91 | -3.27 | 0.00 |
| **Conventional seed (public)** | 12.25 | 12.41 | 0.16 | 0.48 | 0.63 |
| **HT1 seed (integrated)** | 24.05 | 24.29 | 0.24 | 0.68 | 0.50 |
| **HT1 seed (licensed)** | 23.30 | 24.05 | 0.75 | 2.85 | 0.00 |

and publicly bred conventional seed were not statistically significant.

The simulation results for Scenario 2 are reported in Tables 5a and 5b. Table 5a reports *ceteris paribus* effects of changing only $HHI_1$, the market concentration measure for the conventional seed market, from its 2000 level to its 2006 level. In this case, all other within- and cross-market-concentration measures are held constant (at their mean level).

Table 5a shows that increased market concentration in the conventional seed market contributes to a $0.58 increase in the price of privately produced conventional seeds, an effect that is significant at the 5% level. As expected, it documents how a higher concentration in the conventional seed market contributes to higher price. The effect on the price of publicly produced conventional seeds is not statistically significant. This is consistent with the general belief that the public institutions follow different pricing rules compared to private firms.[10]

Table 5b simulates the effects of observed changes in both HHI and the VHHIs between 2000 and 2006. It shows no statistically significant changes in prices of most seeds due to market concentration effects. The only exception is the impact on licensed HT1 seed, where price decreased by $0.10 (significant at 1% level).

Comparing the simulation results in Table 5a (Scenario 2a) to those in Table 5b (Scenario 2b) is instructive. It shows that the cross-market concentration effects play a critical role in how changes in market concentration affect prices. While Table 5a shows that higher within-market concentration increases price in that market, Table 5b indicates that such a result may not apply in a multi-market context. Indeed, Table 5b illustrates that cross-market concentration effects can reduce the price-enhancing effects of higher concentrations. This is due to complementarity effects in the production and distribution of different seed types. As argued by Shi and Chavas (2009), such complementarity effects work against the own-market price-enhancing effects of higher concentration. Table 5b shows that, when strong enough, these complementarity effects can eliminate the price-enhancing effects of increased market power. This documents how the adverse effects of concentrated markets on pricing can be significantly altered in a multi-market context in the presence of complementarities in the production and marketing of different products.

Finally, Table 6 presents the simulated results obtained from joint changes in market size and market concentration for Illinois between 2000 and 2006. They show that the price of the private conventional seed decreases by $0.91 (significant at 1% level), and the licensed HT seeds have a price increase of $0.75 (significant at 1% level). Other seeds do not show statistically significant price changes.

Of all these simulation scenarios, the private conventional seed and the licensed HT1 seed seem to be ones whose prices are most sensitive to changes in market conditions. As discussed earlier, the pricing of public-sourced conventional seeds appear to follow different patterns (compared to privately produced seeds). Such pricing does not appear to respond to changes in market conditions. And the pricing of vertically integrated seeds is found to behave differently from licensed seeds. While they both show the same sign in price response, the vertically integrated seed price does not exhibit statistically significant price changes under any of our scenarios. This may be due to the fact that the cross-market concentration in the vertically integrated seed market in Illinois has not changed much from 2000 to 2006 (see Table 3).

Comparing Tables 4 and 5, note that the market-size effects seem to be larger than the market-concentration effects. This suggests that the dynamic market conditions play an important role. Strategic pricing may be driven in part by market-size considerations and the related benefits from pricing seeds that induce farmers to rapidly adopt newly developed seeds.

10. *Table 5a does not report the simulated prices for the HT1 seeds (integrated or licensed) because changes in concentration within the conventional seed market do not affect other markets, implying a zero price effect for the HT1 seeds.*

## Conclusion

This article investigates the pricing of soybean seeds in the United States. It documents the role of differentiated seeds, vertical organization, and strategic pricing under changing within- and across-market concentrations. The analysis is based on an econometric model of soybean seed pricing where the effects of market power and vertical structures are captured by VHHI measures of market concentrations. Simulations of the estimated model give important insights regarding supply-side factors affecting soybean seed pricing.

Our analysis documents that increased market concentration tends to increase price in the same market. But, it also presents evidence that multi-market considerations affect how market power influences pricing. We find that the presence of complementarity in production and distribution mitigates the price-enhancing effects of increased market concentration in the soybean seed markets. This stresses the need to address market power issues in a multi-market framework.

One of the emerging and important trends for this industry is that of increasing vertical integration by the biotech industry into the seed sector (see Figure 2 and related discussion). Such a trend means that biotech firms are operating with greater control over the industry. If this translates into lower seed prices, this could help stimulate rapid adoption of new technology among soybean farmers. But greater integration could also foreclose the stand-alone seed firms that have previously relied on licensing of patented biotech traits. Additional research is needed to examine the potential welfare consequences of increased vertical integration. The research in this study also shows that pricing of public-sourced seeds differs from the pricing of privately produced seeds. Future research is needed to explore the role of public institutions and their interactions with private firms in the functioning of US seed markets.

## References

Alston, J.M., & Venner, R.J. (2002). The effects of the U.S. plant variety protection act on wheat genetic improvement. *Research Policy*, *31*, 527-42.

Butler, L.J., & Marion, B.W. (1985, September). *The impacts of patent protection on the U.S. seed industry and public plant breeding* (North Central Region Research Publication 304, North Central Project 117, Monograph 16). Madison: Research Division, College of Agricultural and Life Sciences, University of Wisconsin.

Falck-Zepeda, J., & Traxler, G. (2000). The role of federal, state, and private institutions in seed technology generation. In K.O. Fuglie, & D.E. Schimmelpfennig (Eds.), *Public-private collaboration in agricultural research: New institutional arrangements and economic implications*. Ames, IA: Iowa State University Press.

Fernandez-Cornejo, J. (2004). *The seed industry in U.S. agriculture: An exploration of data and information on crop seed markets, regulation, industry structure, and research and development* (Agriculture Information Bulletin Number 786). Washington, DC: Resource Economics Division, Economic Research Service, US Department of Agriculture (USDA).

Fox, P. (1990). *Biotechnology and the seed industry.* London: PJB Publications.

James, C. (2008). *Global status of commercialized biotech/GM crops: 2008* (ISAAA Brief No. 39). Ithaca, NY: International Service for the Acquisition of Agri-Biotech Applications (ISAAA). Available on the World Wide Web: http://www.isaaa.org/Resources/Publications/briefs/39/default.html.

Shi, G. (2009). Bundling and licensing of genes in agricultural biotechnology. *American Journal of Agricultural Economics*, *91*(1), 264-274.

Shi, G., & Chavas, J.P. (2009, April). *On pricing and vertical organization of differentiated products* (Staff Paper No. 535). Madison: Department of Agricultural and Applied Economics, University of Wisconsin.

Shi, G., Chavas, J.P, & Stiegert, K. (2008, November). *An analysis of bundle pricing: The case of the corn seed market* (Staff Paper No. 529). Madison: Department of Agricultural and Applied Economics, University of Wisconsin.

USDA, National Agricultural Statistics Service (NASS). (2008). Acreage. Washington, DC: Author. Available on the World Wide Web: http://usda.mannlib.cornell.edu/usda/nass/Acre//2000s/2008/Acre-06-30-2008.pdf.

Whinston, M.D. (2006). *Lectures on antitrust economics*. Cambridge, MA: MIT Press.

## Author's Notes

This research was funded in part by NRI grant #144-QS50, USDA Hatch grant, and UW WARF graduate research grant.