Journal of Agricultural and Resource Economics 36(3):448–464

The Effects of Vertical Organization on the Pricing of Differentiated Products

Guanming Shi and Jean-Paul Chavas

We investigate differentiated product pricing and the effects of vertical organization under imperfect competition. We rely on vertical measures of concentration (termed VHHI) to study how the exercise of market power varies with substitution/complementarity relationships among products and vertical structures. This approach is applied to U.S. soybean seed pricing under vertical integration versus licensing. We find evidence that vertical organization affects seed prices, with an impact ranging from 1.87% to 13.6% of the mean price. These effects vary by institutional setup. We also find that complementarity can mitigate price enhancements associated with market concentration.

Key words: biotechnology, imperfect competition, pricing, seed, soybean, vertical structures

Introduction

Many researchers have examined the role of market power exercised by firms in vertical structures,[1] but the implications of vertical control remain a subject of debate (e.g., Tirole, 1992; Whinston, 2006). One school of thought argues that greater vertical control leads to efficiency gains, while other researchers raise lingering concerns about potential adverse welfare effects of vertical control and possible efficiency losses associated with reduced competition (e.g., Whinston, 2006; Rey and Tirole, 2008).

Adding differentiated products to the analysis of vertical organization further complicates matters. Previous work has often avoided this issue by focusing on monopolies or on perfect substitutes in upstream and/or downstream markets (e.g., Hart and Tirole, 1990; Ordover, Saloner, and Salop, 1990; O'Brien and Shaffer, 1992). However, product differentiation is commonly found in vertical channels (see Hastings (2004) for the case of gasoline). This raises questions about how to analyze the effects of vertical organization on pricing differentiated products. The objective of this paper is to study the linkages between vertical structures and pricing under product differentiation by using a Cournot model of multi-product firms to examine the relationship between price margins, vertical organization, and market concentrations.

A key aspect of our analysis involves the characterization of vertical market concentrations under product differentiation. One approach has been to rely on the Herfindahl-Hirschman Index (HHI) to assess horizontal market concentration (e.g., Whinston, 2006). Our analysis extends this index by developing a vertical HHI (termed VHHI), which captures the ways market concentration and vertical organization interact to influence the exercise of market power and, consequently, the prices of differentiated products.

Guanming Shi is an Assistant Professor and Jean-Paul Chavas is a Professor in the Department of Agricultural and Applied Economics at the University of Wisconsin, Madison. The authors thank two anonymous reviewers and the Journal Editor for useful comments on an earlier draft of the paper. This research was funded in part by NRI grant #144-QS50 and a USDA Hatch grant.

Review coordinated by Gary Brester.

[1] See, for example Spengler (1950), Hart and Tirole (1990), Ordover, Saloner, and Salop (1990), O'Brien and Shaffer (1992), McAfee and Schwartz (1994), de Fontenay and Gans (2005), Lafontaine and Slade (2007), and Gans (2007).

Adapting HHI measures to the analysis of vertical organization is not new. McAfee et al. (2001) and Gans (2007) studied how HHI-type measures can be used to examine the effects of vertical mergers, but their analyses focused on the case of a single consumer good. The VHHI concentration measures used in our analysis apply to vertical organization under differentiated products.[2] The usefulness of the approach is illustrated in an econometric application to pricing in the soybean seed industry. The VHHI measures provide valuable insights into the effects of vertical integration under product differentiation.

The soybean seed market makes an excellent case study. Recent advances in biotechnology have led agricultural biotech firms to differentiate their seed products through patented genetic materials either individually (often referred as "single-trait") or in bundled form (often referred as "stacked traits"). In addition, mergers and acquisitions in the U.S. soybean seed industry in the last two decades have changed the industry's horizontal and vertical structures, and markets for soybean seeds have become increasingly concentrated. In the late 1980s, the four largest firms accounted for 40% of the soybean seed market, a substantial rise from 5.2% in 1980 (Fernandez-Cornejo). Our data show that this share further increased to 55% in 2007. These changes are associated with the growing importance of biotech firms producing patented genes in the upstream trait market, which has become highly concentrated: Over the last ten years, only two biotech companies have been involved in the soybean seed market. Finally, the vertical organization of the industry has also changed. While biotech firms producing patented genes have relied extensively on licensing their technologies to seed companies (who produce the seeds sold to farmers), they have recently increased their use of vertical coordination through integration. Our data show that vertical integration in the U.S. single-traited soybean seed market has increased from 13% in 2000 to 26% in 2007.

As noted by Graff, Rausser, and Small (2003), these structural changes have been motivated in part by complementarities of assets within and between the agricultural biotechnology and seed industries. It seems likely that seed markets have become highly concentrated because vertical and horizontal integration have created efficiency gains due to economies of scope in the production of genetic traits. However, biotech firms can also use their market power to increase seed prices, which can adversely affect economic efficiency and farmers' profits (Fulton and Giannakas, 2001; Fernandez-Cornejo). We question whether structural changes in the U.S. soybean seed market are motivated by efficiency gains or reflect attempts to increase market power.

Answering these questions requires an assessment of the effects of vertical organization under imperfect competition. In the context of the U.S. soybean seed market, this paper presents an empirical investigation of how differentiated seed products are priced in concentrated markets under two alternative vertical structures: vertical integration versus licensing.

Our analysis also examines how institutional setups can affect soybean seed pricing. Beginning in the 1970s, the U.S. soybean seed industry experienced a rapid shift from public sector to private sector breeding. Acreage shares of publicly-developed varieties decreased from over 70% in 1980 to 10% in the mid-1990s (Fernandez-Cornejo), and to 0.5% in 2007, according to our data. These changes were initiated largely by advances in breeding technology (including biotechnology) and changes in the intellectual property protection of life forms. Presently, how these institutional changes impact pricing is not well understood. Our study provides new and useful information about these effects.

Our econometric analysis of the soybean seed industry documents that, as expected, publicly-sourced seeds are priced significantly lower than privately-sourced seeds (after controlling for quality differences). We find that seeds sold through vertically-integrated structures are priced higher than those that are licensed. Our investigation also shows how complementarity can mitigate market power-related price enhancements within the privately-sourced seed market. We find that market

[2] For example, Gans (2007) proposes a single vertical concentration index for a homogeneous product. This differs from our approach, in which our proposed VHHI measures involve multiple vertical concentration indexes, allowing for product differentiation across both horizontal markets and vertical structures. See Chavas and Shi for a discussion about how our VHHI measures compare and differ from that of Gans (2007).

concentration studies that ignore vertical structures (e.g., those that utilize a traditional HHI) fail to capture the full linkages between market structure and pricing.

Model

We consider a vertical sector involving N firms producing K outputs, which can be produced under V alternative vertical structures (e.g., vertical contracts or ownership). We use $y^n = (y^n_{11}, \ldots, y^n_{k\tau}, \ldots, y^n_{KV}\}$ to denote the vector of output quantities produced by the nth firm, where $y^n_{k\tau}$ represents the kth output quantity produced by the nth firm under the τth vertical structure. We assume that the vertical structures can support product differentiation and price discrimination schemes, so products and prices can vary across vertical structures (e.g., from differences in consumer perception, quality, label and/or packaging). Within this context, price-dependent demand for the kth output under the τth vertical structure, "$k\tau$," is $p_{k\tau}(\sum_{n=1}^{N} \mathbf{y}^n)$. For each product, this allows for different demand and different pricing across vertical structures.

For simplicity, we assume that efficient contracts exist among firms in the vertical sector. This means that upstream production and marketing decisions are efficient and made in ways consistent with the minimization of aggregate cost across all marketing channels.[3] Given these conditions, the nth firm's profit is $\pi^n = \sum_k \sum_\tau [p_{k\tau}(\sum_{i=1}^{N} \mathbf{y}^i) y^n_{k\tau}] - C^n(\mathbf{y}^n)$, where $C^n(\mathbf{y}^n)$ denotes the nth firm's cost of producing $\mathbf{y}^n$. We assume a Cournot game. Under differentiability, the decisions of the nth firm satisfies $\pi^n \geq 0$, along with the profit maximizing conditions with respect to the output quantity $y^n_{k\tau}$:

$$\text{(1a)} \qquad p_{k\tau} + \sum_m \sum_u (\partial p_{mu} / \partial y^n_{k\tau}) \cdot y^n_{mu} - \leq 0,$$

$$\text{(1b)} \qquad y^n_{k\tau} \geq 0,$$

$$\text{(1c)} \qquad \left[p_{k\tau} + \sum_m \sum_u (\partial p_{mu} / \partial y^n_{k\tau}) \cdot y^n_{mu} - (\partial C^n / \partial y^n_{k\tau}) \right] \cdot y^n_{k\tau} = 0.$$

Under a Cournot model, equations (1a) - (1c) are pricing equations capturing cross-product effects for commodities that are differentiated horizontally (m versus k) as well as vertically (τ versus u). Equation (1c) is the complementary slackness condition, which applies irrespective of whether the product "kτ" is produced ($y^n_{k\tau} > 0$), or not ($y^n_{k\tau} = 0$). As such, it remains valid regardless of how many K products the firm chooses to carry and by which vertical structure that the firm chooses to market these products. Thus, equation (1c) is broad enough to allow for interactions among firms both horizontally and vertically.

We assume that the cost function of the nth firm takes the form $C^n(\mathbf{y}^n) = FC^n + VC^n$, where $FC^n > 0$ denotes fixed costs and $VC^n = \sum_k \sum_\tau c_{k\tau} y^n_{k\tau} + 0.5 \sum_k \sum_m \sum_\tau \sum_u c_{mu,k\tau} y^n_{mu} y^n_{k\tau}$ denotes variable costs. This allows the fixed cost to vary across firms and the variable cost to vary across products and vertical structures. The presence of fixed cost can imply increasing returns to scale. In that case, marginal cost pricing would imply negative profit, and any sustainable equilibrium would necessarily be associated with departures from marginal cost pricing. Fixed costs, FC^n, can come from upstream markets (e.g., R&D costs that an upstream firm incur when developing a new technology) or downstream markets (such as the expense of establishing a vertical structure).

Cost structure can also reflect economies of scope, which can arise when outputs exhibit complementarity. Complementarity occurs when $\partial^2 VC^n / \partial y^n_{mu} \partial y^n_{k\tau} < 0$; that is. when production of output "mu" reduces the marginal cost of producing output "$k\tau$" for $m \neq k$ and $u \neq \tau$ (Baumol,

[3] The presence of efficient vertical contracts rules out vertical externalities. Previous research has discussed possible inefficiencies in vertical contracts (Spengler, 1950; Tirole, 1992). These include "double marginalization" situations, wherein a failure to deal with vertical externalities can contribute to cost increases. While these inefficiencies would affect cost (as in equations (1a) and (1c)), we neglect these effects in our analysis. Even though the study of these effects remains of interest, it is not possible for us to identify the effects of double marginalization without data on upstream prices in the soybean seed industry. Double marginalization under product differentiation is a topic for future research.

Panzar, and Willig, 1982). Economies of scope can also occur when production of joint outputs reduces fixed cost (Baumol, Panzar, and Willig, 1982). In these situations, firms can reduce aggregate costs and generate efficiency gains by selling multiple products across multiple vertical structures.

Our model can also depict the exercise of market power. Let $\partial p^n_{mu}/\partial y^n_{k\tau} = \alpha_{mu,k\tau}$, where $\alpha_{mu,k\tau} < 0$ corresponds to downward sloping demand. The marginal cost of $y^n_{k\tau}$ is $\partial VC^n/\partial y^n_{k\tau} = c_{k\tau} + \sum_m \sum_u c_{mu,k\tau} y^n_{mu}$, with $c_{mu,mu} \geq 0$ under non-decreasing marginal productivity and $c_{mu,k\tau} = c_{k\tau,mu}$ by symmetry.[4] We use $Y_{k\tau} = \sum_{i=1}^N y^i_{k\tau}$ to denote the aggregate output quantity of product "$k\tau$." Assuming that $Y_{k\tau} > 0$, then $S^n_{k\tau} = y^n_{k\tau}/Y_{k\tau} \in [0,1]$ is the nth firm's market share for product "$k\tau$." We divide equation (1c) by $Y_{k\tau}$ and sum across all firms to yield:

$$p_{k\tau} = c_{k\tau} + \sum_m \sum_u (c_{mu,k\tau} - \alpha_{mu,k\tau}) \sum_{i=1}^N S^i_{mu} S^i_{k\tau} Y_{mu}, \tag{2}$$

which can be written as:

$$p_{k\tau} = c_{k\tau} + \sum_m \sum_u (c_{mu,k\tau} - \alpha_{mu,k\tau}) H_{mu,k\tau} Y_{mu}, \tag{3}$$

where $H_{mu,k\tau} = \sum_{i=1}^N S^i_{mu} S^i_{k\tau}$. Equation (3) is a price-dependent supply function for product "$k\tau$." It includes the markup term:

$$M_{k\tau} = \sum_m \sum_u (c_{mu,k\tau} - \alpha_{mu,k\tau}) H_{mu,k\tau} Y_{mu}, \tag{4}$$

where $M_{k\tau}$ is the component of price associated with the exercise of market power. Given $H_{mu,k\tau} \in [0,1]$, then $H_{mu,k\tau} \to 0$ under perfect competition, when there are many active firms. It follows that $M_{k\tau} \to 0$ under perfect competition. At the opposite extreme, $H_{mu,k\tau} = 1$ under a monopoly, when there is a single active firm. In general, $H_{mu,k\tau}$ increases with market concentration. As such, the term $M_{k\tau}$ in equation (4) is the price markup that captures the market concentration effects of imperfect competition. In addition, M/p is related to the Lerner index L, defined as a relative measure of departure from marginal cost pricing: $L = (p - \partial C/\partial y)/p$. When marginal cost is constant, equations (3) - (4) imply that the Lerner index for product "$k\tau$" reduces to $L_{k\tau} = (M_{k\tau}/p_{k\tau})$.

Equation (4) provides useful information on the structural determinants of $M_{k\tau}$. When there is a single product ($K = 1$) and a single vertical structure ($V = 1$), $H_{11,11}$ is the classical Herfindahl-Hirschman Index (HHI). As Chavas and Shi demonstrate, market concentration can be analyzed as if there were a single market when all products are perfect substitutes, and the classical HHI becomes a simple weighted average of our VHHI measures.

Given a positive marginal cost ($c_{11,11} \geq 0$) and a negative demand slope ($\alpha_{11,11} < 0$), equations (3) - (4) indicate that an increase in the HHI, $H_{11,11}$, which simulates an increase in market power, is associated with an increase in M_{11}, and thus an increase in price, p_{11}. As a rule of thumb, the USDOJ regards HHI greater than 0.25 as an indication of a concentrated market, in which the exercise of market power may raise competitive concerns (Shapiro).

Equations (2) - (4) extend the HHI under vertical structures (when $V > 1$) and a multi-product scenario (when $K > 1$). We define the $H_{mu,k\tau}$ as vertical Herfindahl-Hirschman indexes or VHHI measuring vertical market concentrations. From equations (3) - (4), the VHHI provides a basis to evaluate the effects of vertical organization and market power on pricing. To illustrate, consider the special case where $u \neq \tau$, $m = k$, where products are differentiated across vertical channels due to consumer perception and/or quality differences. From equation (3), a rise in the VHHI $H_{ku,k\tau}$

[4] This specification assumes that the cost parameters, c_{kt} and $c_{mu,k\tau}$, are constant across firms, although they can vary across products and across vertical structures. In the seed context, it is generally believed that marginal cost of producing biotech seeds and conventional seeds are similar across firms, and the major differences in cost are from research and development, and intellectual property monitoring and enforcement, which are generally categorized as fixed costs that are typically firm specific (Traxler and Godoy-Avila, 2004; Basu and Qaim, 2007).

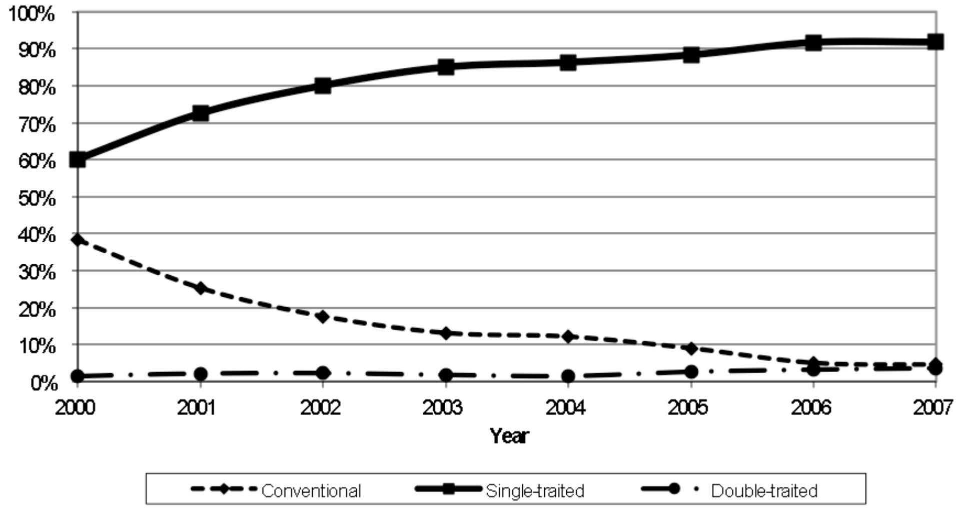

Figure 1. Acreage Share of Different Soybean Seeds in the U.S., 2000 - 2007

would be associated with an increase (a decrease) in price $p_{k\tau}$ if $[c_{ku,k\tau} - \alpha_{ku,k\tau}] > 0 \quad (< 0)$. Given that $\alpha_{ku,k\tau} = \partial p_{ku}/\partial y_{k\tau}$, we follow Hicks (1939) and note that $\alpha_{ku,k\tau}] < 0 \quad (> 0)$ when product k exhibits substitution (complementarity) on the demand side across vertical structures u and τ. This occurs in situations where an increase in quantity of product "$k\tau$" tends to decrease (increase) the perceived marginal value of product "ku." Similarly, $c_{ku,k\tau} = \partial^2 VC/\partial y_{ku}\partial y_{k\tau} > 0 \quad (< 0)$ when products "$k\tau$" and "ku" are substitutes (complements) on the supply side. This corresponds to situations where an increase in output quantity $y_{k\tau}$ tends to increase (decrease) the marginal cost of producing y_{ku}. The complementary case (where $c_{ku,k\tau} < 0$) can generate economies of scope where multi-output production reduces costs. In general, the term $[c_{ku,k\tau} - \alpha_{ku,k\tau}]$ is positive when "$k\tau$" and "ku" behave as substitutes and negative when "$k\tau$" and "ku" behave as complements, on both the supply and demand sides. Thus, a rise in $H_{ku,k\tau}$ would contribute to an increase (decrease) in $M_{k\tau}$ and in price $p_{k\tau}$ when "$k\tau$" and "ku" are substitutes (complements). Identifying the role of substitution/complementarity in the exercise of market power is not new (e.g., Tirole, 1992; Venkatesh and Kamakura, 2003; Whinston, 2006; Rey and Tirole, 2008). However, our VHHI measures provide simple and explicit linkages between substitution/complementarity and prices.

This leads us to ask whether there are conditions under which vertical structures would have no effect on prices. Such situations can occur if products are perfect substitutes (on both the demand and supply sides) across vertical structures. Then, the law of one price applies and $p_{k\tau} = p_k$ for the kth product across all vertical structures. Perfect substitution on the supply side corresponds to situations where the cost function takes the form $C^n(\boldsymbol{y}^n) = C^n(\sum_\tau y^n_{1\tau}, \ldots, \sum_\tau y^n_{K\tau})$, which implies that $c_{k\tau} = c_k$ and $c_{mu,k\tau} = c_{mk}$. Similarly, perfect substitution on the demand side occurs where $\partial p_{mu}/\partial y_{k\tau} \equiv \alpha_{mu,k\tau} = \alpha_{mk}$. These restrictions generate the following testable hypotheses H$_0$: $c_{mu,k\tau} - \alpha_{mu,k\tau} = c_{m\tau,ku} - \alpha_{m\tau,ku} = c_{mu,ku} - \alpha_{mu,ku} = c_{m\tau,k\tau} - \alpha_{m\tau,k\tau}$, under which vertical organization has no effect on prices.

Data

Our analysis relies on an extensive data set collected by dmrkynetec (hereafter dmrk)[5] that provides detailed farm-level seed purchase information about the U.S. soybean seed market. The survey was stratified to over-sample producers with large acreages, and was collected using computer assisted telephone interviews. Farmers typically buy their seeds locally, and seeds suitable for planting at local market differ from region to region. We define the "local market" at the Crop Reporting District (CRD) level, as defined by the U.S. Department of Agriculture according to agro-climatic conditions. We consider only those transactions that occurred in CRDs where more than ten farms are sampled in every year. Our data set contains a total of 75,560 farm-level purchase observations, from eighteen states over a span of eight years (2000-2007). These are not panel data; the farm sample changes from year to year.

The soybean seed industry currently markets herbicide tolerance (HT) traits. These patented genetic traits are inserted into seeds by biotech firms to make these seeds resistant to certain herbicides. This may make weed control less costly and more effective, and this can boost yields by reducing weed competition for sun light and nutrients. We use the labels $HT1$ and $HT2$ to delineate the two major HT traits, one being tolerant to a glyphosate herbicide, and the other being tolerant to a non-glyphosate herbicide. Due to confidentiality agreement with dmrk, we cannot reveal the names of traits that are specific to a company. Different biotech companies own these HT traits, and they also own subsidiary seed companies.[6] Some soybean seeds contain either $HT1$ or $HT2$ trait; others include a bundle of both $HT1$ and $HT2$ traits, a scenario called "double stacking."

Figure 1 illustrates how soybean acreage shares have evolved over time for different types of soybean seeds in the United States between 2000 and 2007. The acreage share of conventionally-bred seeds has decreased rapidly, from 38.3% of the market in 2000 to 4.6% in 2007. Single-traited biotech seeds dominate the market, accounting for over 90% of acreage share since 2006. "Double stack" seeds have captured a small but slowly growing market share.

Biotech seeds are distributed by seed companies affiliated with the biotech companies that own a particular trait and by seed companies that are unaffiliated. U.S. patent law states that if a non-affiliated seed company wants to produce a seed that contains a patented trait, it is required to obtain a license from the patent owner. Affiliated seed companies are exempt from this requirement. Therefore, we consider two vertical structures, $\{v, \ell\}$, where v corresponds to vertical integration (whether a seed company is affiliated with a related biotech firm) and ℓ corresponds to licensing (whether an unaffiliated seed company licenses a trait from a biotech firm). As noted earlier, the proportion of vertically-integrated seed increased from 13% of the single-traited market in 2000 to 26% in 2007. Among those farmers who adopted some biotech seeds in 2007, 57% purchased them only through the licensed channel, 16% bought seeds only through the integrated channel, and 27% bought their seeds from both sources.

Table 1 reports summary statistics for key variables used in the analysis. Seeds are usually sold at a list price, less a discount available at the point of sale. Our study utilizes the after-discount "net price" that farmers pay (in $ per 50lb bag). The net price is measured for each seed purchase taking place at the farm-level. Some farmers obtain seeds for free, which may be due to special transaction deals, and we drop those observations in our analysis. The average purchase price is $23.05/bag.

Farm size varies substantially, with a mean at 619 acres. To capture seed quality differences across seed types, we use data on soybean yield for biotech seeds and conventional seeds. The

[5] dmrkynetec changed its name to GfK Kynetec in May 2009. Its web address is www.gfk.com, and the seed data set is a product called TraitTrak.

[6] Biotech companies also own the agrochemical production units that produce the corresponding herbicides with the HT traits. Thus, the integrated firms can earn profit from selling a system of trait-seed-herbicide. In this article, we do not investigate the role of herbicide pricing (and its associated crop production cost effects) for two reasons. First, we do not have access to detailed information on herbicide prices and usage. Second, the herbicide market is fairly homogeneous across space (e.g., Wisconsin farmers can easily buy a herbicide from a California vendor), indicating that local market effects are more likely to be reflected in the variation of seed prices than herbicide prices.

Table 1. Summary Statistics

Variable	N	Mean	Std Dev	Min	Max
Net Price ($/Bag)	75532	23.05	5.03	5	35
Farm Size (Acre)	75532	619	656	4	24000
Yield difference between publicly-sourced conventional seeds and biotech seeds[a]	904	−3.84	2.24	−6.87	−1.17
Yield difference between and private conventional seeds and biotech seeds	74628	0.34	1.23	−5.35	9.53
Conventional Seed Market Concentration, $H_{0\ell,0\ell}$	564	0.41	0.28	0.06	1
Cross-Market Concentration (Conventional and Licensed $HT1$), $H_{0\ell,1\ell}$	520	0.11	0.09	$6.0E-05$	0.61
Cross-Market Concentration (Conventional and Integrated $HT1$), $H_{0\ell,1v}$	308	0.18	0.18	0.001	1
Licensed $HT1$ seed market concentration, $H_{1\ell,1\ell}$	608	0.20	0.09	0.07	0.81
Integrated $HT1$ seed market concentration, $H_{1v,1v}$	601	1	0	1	1

Notes: For market concentration measurements, Hs, we report only the summary statistics for non-zeros at the CRD level. Therefore, the number of observations is, at most, 76 x 8 = 608. Two VHHI are not reported in the table: $H_{1\ell,1v} = H_{1v,1\ell} = 0$, because in the soybean industry, we do not observe companies that are both vertically-integrated and licensed in the same seed type market. This is not a general case; in the cotton seed market, these measures are non-zero. Moreover, $H_{0\ell,1\ell} = H_{1\ell,0\ell}$ and $H_{0\ell,1v} = H_{1v,0\ell}$ by symmetry in construction.
[a] Yield data (bushels/acre) are taken from field tests conducted by University of Wisconsin Agricultural Experiment stations from 2000 to 2007. Field tests are for both publicly-sourced and privately-sourced conventional soybean seeds, as well as biotech seeds.

yield data come from field experiments conducted by the University of Wisconsin Agricultural Experiment Stations from 2000 to 2007. We also use the yield data to capture quality differences between publicly-sourced conventional seeds and privately-sourced conventional seeds. Yield differences between seed types are a proxy measure for quality differences. The data show that publicly-sourced seeds have an average lower yield than biotech seeds and private conventional seeds.

We use subscript "0" to indicate the conventional seed market and subscript "1" to indicate the single-traited $HT1$ market. Since the production of conventional seeds does not involve the upstream biotech market, we characterize the vertical structure in the conventional market as non-integrated and denote the conventional seed by the subscript "0ℓ." The mean value of conventional seed HHI, $H_{0\ell,0\ell}$, is 0.41, which is much higher than the USDOJ's recent new threshold of 0.25 for identifying "significant market power" (Shapiro). Biotech $HT1$ seeds in the licensing channel exhibit greater competition with a mean value of $H_{1\ell,1\ell}$, at 0.20.

We also observe significant changes in the VHHI across regions and over time. Figure 2 shows the time trend in the average constructed VHHI. Market concentration in the conventional seed market ($H_{0\ell,0\ell}$) increased substantially from 0.23 in 2000 to 0.62 in 2007. Cross-market concentration between the conventional seed ("0ℓ") and integrated $HT1$ seed ("$1v$") markets, $H_{0\ell,1v}$, also rose especially after 2005: from 0.13 in 2000 to 0.19 in 2005 and then to 0.40 in 2007. These trends reflect the fact that the soybean seed market has undergone dramatic structural changes over the last decade. Our analysis of the determinants of seed prices both over time and across space provides useful information about the effects of these changes.

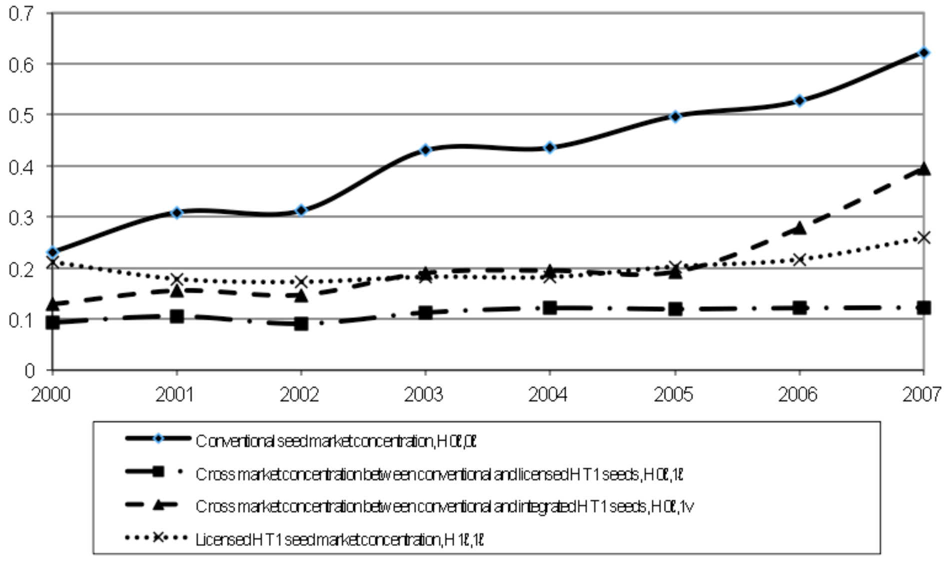

Figure 2. Mean VHHI over Time, 2000-2007

Econometric Specification

Our investigation involves the evaluation of factors affecting farm-level seed prices. Some of these factors are farm-specific, while others reflect market-level characteristics. Our econometric analysis captures both sets of factors and documents their effects on seed prices. We pay particular attention to the impact of market characteristics related to horizontal and vertical market concentrations.

Equation (3) is the basis for our analysis of U.S. soybean seed prices. As derived, equation (3) expresses the determinants of pricing for differentiated products under alternative vertical structures in situations of imperfect competition. Our attention is focused on two vertical structures, ℓ and v, and on four seed types, each of which contains genetic traits that are available individually or stacked: conventional (type 0), single-traited $HT1$ (type 1), single-traited $HT2$ (type 2), and $HT1$ and $HT2$ stack (type 3).

Our analysis allows for fixed and variable costs to vary across vertical structures. A vertically-integrated firm can recover R&D fixed costs directly through seed sales; however, it may also face higher integration costs. Under a licensing scenario, a seed company pays a licensing fee to a biotech firm to help it recover its R&D investment. In general, the two vertical structures can vary in terms of efficiency and in the exercise of market power. The multi-product nature of the market can affect the assessment of both efficiency and exercise of market power. Complementarity across vertically differentiated products can contribute to economies of scope but also reduce firms' ability to exercise market power. Alternatively, substitutability across vertical structures could help enhance the exercise of market power.

We begin with a standard hedonic pricing model wherein the price of a good varies with its characteristics (following Rosen, 1974). Consider a hedonic equation that represents the determinants of price p for seed type k sold in the τth vertical structure:

$$p_{k\tau} = \beta_{k\tau} + \delta_{k\tau} + \boldsymbol{\phi}\boldsymbol{X} + \varepsilon_{k\tau}, \tag{5a}$$

where $\beta_{k\tau}$ is allowed to vary to capture market concentration effects (see below), $\delta_{k\tau}$ is a term capturing the characteristic effects of seed "kτ," $\boldsymbol{X}$ is a vector of relevant covariates, and $\varepsilon_{k\tau}$ is an error term with mean zero and finite variance. Specification (5a) allows prices to vary across seed types and vertical structures.

Following equations (3) - (4), we introduce market concentration effects in equation (5a) by specifying:

$$\beta_{k\tau} = \beta_0 + \sum_m \sum_u \beta_{mu,k\tau} H_{mu,k\tau} Y_{mu}, \tag{5b}$$

where $\beta_{mu,k\tau} \equiv [c_{mu,k\tau} - \alpha_{mu,k\tau}]$ and $H_{mu,k\tau} \equiv \sum_{i=1}^{N} S^i_{mu} S^i_{k\tau}$ is the VHHI, S^i_{mu} being the ith firm's share in the market for seed "mu." We calculate all VHHI terms at the CRD level, assuming it to be relevant to the local market. Similar to equations (3) - (4) and because $H_{mu,k\tau} \to 0$ under competitive conditions, we can capture the exercise of market power in equations (5a) - (5b) through the markup term:

$$M_{k\tau} = \sum_m \sum_u \beta_{mu,k\tau} H_{mu,k\tau} Y_{mu,k\tau}, \tag{6}$$

where $M_{k\tau} = 0$ under perfect competition. Equation (6) measures the effects of imperfect competition under various vertical structures.

Our empirical analysis relies on equations (5a) - (5b). They are price-dependent supply functions for products differentiated both horizontally (k) and vertically (τ). They capture market concentration effects (via $H_{mu,k\tau}$) across horizontal markets (m and k) and vertical structures (u and τ).[7] Building on equations (5a) - (5b), the price equation for conventional seeds (type 0) is:

$$p_{0\ell} = \beta_0 + \sum_{m=o}^{3} (\beta_{m\ell,0\ell} H_{m\ell,0\ell} Y_{m\ell} + \beta_{mv,0\ell} H_{mv,0\ell} Y_{mv}) + \delta_{0\ell} + \boldsymbol{\psi X} + \varepsilon_{0\ell}. \tag{7}$$

For $HT1$ seed (type 1), the price equations for licensed and integrated seeds are:[8]

$$p_{1\ell} = \beta_0 + \sum_{m=o}^{3} (\beta_{m\ell,1\ell} H_{m\ell,1\ell} Y_{m\ell} + \beta_{mv,1\ell} H_{mv,1\ell} Y_{mv}) + \delta_{1\ell} + \boldsymbol{\psi X} + \varepsilon_{1\ell}, \tag{8}$$

$$p_{1v} = \beta_0 + \sum_{m=o}^{3} (\beta_{m\ell,1v} H_{m\ell,1v} Y_{m\ell} + \beta_{mv,1v} H_{mv,1v} Y_{mv}) + \delta_{1v} + \boldsymbol{\psi X} + \varepsilon_{1v}. \tag{9}$$

The $\boldsymbol{X}$ covariates in equation (5a) include lagged yield differences, location, year dummies, individual farms' total soybean acreages, and binary terms capturing alternative purchase sources. Lagged yield differences are proxy variables for quality differences across seed types. We use one-year lagged values: yields obtained the previous year are part of the relevant information set as marketing/purchase decisions of seeds are made before planting time. Yield differences are measured as the difference in average yield between seed types (including publicly-sourced conventional seeds, private conventional seeds and biotech seeds). We define the location variables as state dummy variables, which reflect spatial heterogeneity in cropping systems, weather patterns

[7] Alternative models of imperfect competition for differentiated products include Nevo (2001) and Berry, Levinsohn, and Pakes (2004). These models focus more explicitly on the determinants of market shares under imperfect competition. As in our approach, they also face endogeneity issues between prices and market concentrations. Our handling of endogeneity issues is discussed below in more detail.

[8] Similar equations can be written for $HT2$ (type 2) and stack seeds (type 3). However, our sample includes an insufficient number of observations for these seed types, and this prevents us from obtaining reliable measures of the VHHI. Therefore, for these two seed types, we only explore how prices vary across characteristics and vertical structures. For type 3, we label the seed as vertically-integrated if it is produced and marketed by one of the biotech companies.

and yield potentials. We also include year dummies in order to capture inflation, increasing demand for seeds, advances in genetic technologies, and other structural changes over time. We use the farm acreage variable to catch possible price discrimination that may be related to bulk purchases. We use purchase source to describe possible price discrimination schemes that affect the prices that farmers pay for their seeds. Finally, to capture possible life cycle effects of each product, we include entry and exit dummies for a specific type of seed: *Entry* = 1 if it is in its first year on the market, and *Exit* = 1 if it is in its last year on the market.

Since the 1980s the soybean industry has transitioned away from using publicly-bred seed in favor of privately-bred varieties. Our model is based on profit-maximizing behavior that may not apply to public breeders. We expect pricing in the public sector to differ from that of the private sector. On this basis, we have introduced a dummy variable that captures institutional structure: *Pub* = 1 represents the public sector and *Pub* = 0 signifies the private sector. In equation (5b) we include the dummy variable *Pub* as both an intercept shifter and a slope shifter.

Econometric Estimation

One econometric issue in the specification (5a) - (5b) is the endogeneity of the VHHI. We expect that market concentration, H; quantity sold, Y; and seed price will be jointly determined, given that each is dependent upon a firm's market strategies. The fact that we do not observe some of the determinants of these strategies implies that terms H and Y are likely correlated with the error term in equation (5a). If so, least-squares estimation would yield biased and inconsistent parameter estimates. We can resolve this issue by using an instrumental variable (IV) method to estimate equations (5a) - (5b).

We first test for possible endogeneity of the H's and Y's using a C statistic calculated as the difference of two Sargan statistics (Hayashi, 2000, p. 232). Under the null hypothesis of exogeneity for H and Y, the C statistic is distributed as Chi-square with degrees of freedom equal to the number of variables tested. The test is robust to violations of the assumption of conditional homoscedasticity (Hayashi, 2000). In our case, the C statistic is 32.36, with a p-value of less than 0.0001, which offers strong statistical evidence against the null hypothesis of exogeneity.

The presence of endogeneity motivates the use of an IV estimator; this raises the issue of selecting appropriate instruments, which need to satisfy two conditions. First, they should be orthogonal to the error term in equation (5a). Second, they should be relevant variables that can identify the appropriate parameters (i.e., they should not be "weak instruments").

Due to lags in the seed production process, seed companies make production decisions at least a year in advance of marketing decisions. Therefore, lag values are part of the information set that seed companies have available to them at the time they make their production decisions. Although our data set is not a panel at the farm-level, we do have panel data on CRD-level concentration measure (H) and on each seed type's market size (Y); the lagged values of H and Y should be good candidates for instruments. On that basis, equations (5a) - (5c) were estimated by two-stage-least-squares (2SLS) using the one-year lagged value of Y and the interaction between the one-year lagged value of each H and the one-year lagged value of Y as instruments.

In addition to *a priori* reasoning, this choice of instruments is supported by a series of statistical tests. The Hansen over-identification test was not statistically significant, with a p-value of 0.23, which indicates that our instruments satisfy the required orthogonality conditions. To test for "weak instruments," we use the Bound, Jaeger, and Baker (1995) measures and the Shea (1997) partial R^2 statistic. Test results using methods from Staiger and Stock (1997) do not provide evidence that our instruments are weak. The Kleibergen-Paap weak instrument test (Kleibergen and Paap, 2006) yields a test statistic of 28.29. Using the critical values presented in Stock and Yogo (2005), this indicates again that our instruments are not weak.

Finally, we evaluated the properties of the error term in equation (5a). Typically, each farm purchases several different seed varieties (the sample mean is three varieties per farm per year).

Some of the unobserved factors affecting seed prices may be farm-specific and vary across farms. Therefore, the error term in equation (5a) may exhibit heteroscedasticity. Using a Pagan-Hall test (Pagan and Hall, 1983), we find strong evidence against homoscedasticity, with a Chi-square statistic of 183.84 and a p-value of less than 0.0001. On that basis, we use heteroscedastic-robust standard errors in the estimation of equations (5a) - (5b). We also cluster the standard errors at the farm level. Indeed, we expect the error terms in equation (5a) to be correlated across observations associated with a given farm in the presence of farm-specific unobserved factors.

Results

Table 2 reports the econometric results of our 2SLS IV estimation of equations (5a) and (5b) with heteroscedastic-robust standard errors under clustering. The ordinary least squares (OLS) estimation results are also reported for comparison. The OLS estimates of the parameters differ substantially from those of the 2SLS results (reflecting the presence of endogeneity). Given that IV estimation corrects for endogeneity bias, our discussion below focuses on the 2SLS estimates.

The Effects of Various Seed Types

Table 2 indicates that publicly-bred seeds (most of them conventional seeds) are priced significantly lower than those that are privately-bred, at a discount of \$1.98 per bag. This is consistent with observations from field test results that private seeds generally outperform publicly-sourced seeds. This may also suggest that private and publicly-sourced seed companies rely on different pricing rules. Results show that all biotech seeds receive a price premium over private conventional seeds; This price premium, which varies with the vertical structure, ranges from \$2.21 to \$7.78, which likely reflects the fact that HT technology helps reduce input costs related to herbicide and management. By comparing δ_{iv} with $\delta_{i\ell}$ in table 2, we find that seeds sold under vertical integration are priced consistently higher than those produced and marketed under licensing agreements for all three types of biotech seeds.

Market Concentration and Vertical Structures

Our model utilizes the VHHI to capture market share information about each seed type in different vertical structures. Earlier, we argued that the impacts of VHHI $H_{mu,k\tau}$ depend on substitutability/complementarity relationships between seed "*mu*" and seed "$k\tau$." If the two seeds are substitutes (complements), we expect that an increase in the VHHI will be associated with a rise (decrease) in prices.

For the three VHHI that relate to conventional seed prices ($H_{0\ell,0\ell}$, $H_{1\ell,0\ell}$, $H_{1v,0\ell}$), the interaction between the public dummy and the VHHI separates out public and private sector effects. Table 2 offers strong statistical evidence that the public and private sectors follow different pricing rules. For the private sector, the coefficient of the traditional HHI ($\beta_{0\ell,0\ell}$) is positive and statistically significant; however, this positive effect disappears for the public sector. The cross-market VHHI coefficient between licensed $HT1$ and conventional seeds ($\beta_{1\ell,0\ell}$) is negative for the private sector and positive for the public sector, suggesting that the two products are complements (in supply and/or in demand) in the private sector. If complementarity exists on the demand side, it should similarly affect seed pricing in the public sector. However, the coefficient, $\beta_{1\ell,0\ell}\_pub$, is positive for publicly-sourced conventional seed, and this offsets the complementarity effects between licensed $HT1$ and conventional seeds. We therefore infer that the complementarity between these two seeds likely comes from the supply side, wherein the private and public sectors differ appreciably. The VHHI coefficients for the private and public sectors that cross the integrated $HT1$ and conventional seeds ($\beta_{1v,0\ell}\_pub$ and $\beta_{1v,0\ell}$) are not statistically significant.

For the two cross-market VHHI coefficients that affect $HT1$ biotech seed, the coefficient of $H_{0\ell,1\ell}$ (estimated as $\beta_{0\ell,1\ell}$ associated with the pricing of licensed $HT1$ seed) is negative and statistically

Table 2. OLS and IV (2SLS) Regression with Robust Standard Errors (N=64,522)

	OLS		2SLS	
Dependent Variable: Net Price ($/Bag)	**Coefficient**	**t-statistics**	**Coefficient**	**Robust Z Statistics**
Effects of Seed Characteristics: Benchmark Is Private Conventional Seed				
$\sigma_{0\ell}$_pub (Publicly-Sourced Conventional Seed)	-1.66^{**}	-2.44	-1.98^{***}	-2.82
$\sigma_{1\ell}$ (HT1 Under Licensing)	7.73^{***}	49.67	7.40^{***}	30.83
σ_{1v} (HT1 Under Vertical Integration)	8.07^{***}	49.02	7.78^{***}	30.01
$\sigma_{2\ell}$ (HT2 Under Licensing)	0.47^{**}	2.01	0.05	0.16
σ_{2v} (HT2 Under Vertical Integration)	2.62^{***}	7.11	2.21^{***}	5.33
$\sigma_{3\ell}$ (Stack Under Licensing)	7.95^{***}	36.86	7.47^{***}	26.20
σ_{3v} (Stack Under Vertical Integration)	8.23^{***}	49.08	7.78^{***}	31.01
Market Concentration and Vertical Structures				
$\beta_{0\ell,0\ell}$ (on price of conventional seed)	0.09^{***}	3.04	0.15^{**}	2.42
$\beta_{0\ell,0\ell}$_pub (on price of publicly-sourced conventional seed)	-0.18^{***}	-2.77	-0.24^{***}	-2.88
$\beta_{1\ell,0\ell}$ (on price of conventional seed)	-0.04^{**}	-2.04	-0.25^{***}	-3.97
$\beta_{1\ell,0\ell}$_pub (on price of publicly-sourced conventional seed)	0.19^{**}	2.31	0.39^{***}	3.89
$\beta_{1v,0\ell}$ (on price of conventional seed)	-0.05	-1.60	0.02	0.22
$\beta_{1v,0\ell}$_pub (on price of publicly-sourced conventional seed)	-0.14	-1.20	-0.21	-1.57
$\beta_{0\ell,1\ell}$ (on price of HT1 under licensing)	-0.12^{***}	-5.19	-0.13^{***}	-2.87
$\beta_{1\ell,1\ell}$ (on price of HT1 under licensing)	0.02^{***}	2.82	-3.38E-04	-0.02
$\beta_{0\ell,1v}$ (on price of HT1 under vertical integration)	-0.02	-0.74	0.08^{*}	1.68
$\beta_{1v,1v}$ (on price of HT1 under vertical integration)	-3.89E-04	-0.08	-0.02^{***}	-2.68
Other Variables				
Lagged yield difference on publicly-sourced conventional seed	0.43^{***}	4.51	0.45^{***}	4.66
Lagged yield difference on private conv. Seed	0.33^{***}	3.79	0.38^{***}	4.24
Lagged yield difference on biotech seed	0.37^{***}	4.31	0.36^{***}	4.33
Exit	-0.31^{***}	-8.24	-0.32^{***}	-8.47
Entry	0.02	0.77	0.03	0.93
Year 2002	0.57^{***}	7.81	0.61^{***}	7.62
Year 2003	-0.60^{***}	-4.83	-0.52^{***}	-3.94
Year 2004	2.95^{***}	21.71	3.04^{***}	21.25
Year 2005	5.68^{***}	55.71	5.78^{***}	47.65
Year 2006	3.83^{***}	6.95	3.94^{***}	7.06
Year 2007	7.97^{***}	21.56	8.09^{***}	21.38
Total Soybean Acreage by Individual Farm (1000 Acre)	-0.27^{***}	-5.03	-0.27^{***}	-5.00
Constant	15.49^{***}	49.19	15.84^{***}	44.25

Notes: Single, double, and triple asterisks (*, **, ***) represent significance at the 10%, 5%, and 1% level. The R^2 is 0.74 for the OLS estimation. For the 2SLS estimation, the centered R^2 is 0.74, and un-centered R^2 is 0.99. To save space, we do not report results for the location and purchase source effects, which are discussed in the text.

significant. This is consistent with the effect of VHHI $H_{1\ell,0\ell}$ (estimated as $\beta_{1\ell,0\ell}$) on the pricing of conventional seed. It suggests that conventional and licensed $HT1$ seeds exhibit strong and symmetric complementarity. Given that complementarity contributes to economies of scope, this result offers indirect evidence to support our assertion that seed companies experience economies of scope in their production and marketing of conventional and licensed $HT1$ seeds. We also note that the cross-market VHHI coefficient of integrated $HT1$ and conventional seeds ($\beta_{0\ell,1v}$) is positive and statistically significant. This result may reflect transaction costs present in vertical integration (such as costs associated with negotiation and re-organization), and these may offset some of the efficiency gains that firms garner from economies of scope.

The own-market VHHI, $H_{1\ell,1\ell}$ and $H_{1v,1v}$, are indices that measure own-market concentration in the licensed and integrated (respectively) $HT1$ seed markets. The associated coefficient for the licensed $HT1$ seed market is not statistically significant. The coefficient of term $H_{1v,1v}$ is negative and statistically significant, contrary to *a priori* expectation. However, we note that throughout our study period this market remains monopolistic, thus $H_{1v,1v} = 1$. Therefore, our estimation of coefficient $\beta_{1v,1v}$ relies entirely on observed variations in market size of integrated $HT1$ seed, Y_{1v}, which has been expanding over time. The negative coefficient estimate may reflect the fact that this market expansion has contributed to lower prices.

We then explore whether vertical organization affects prices by examining whether market concentrations relate to seed prices in similar ways under alternative vertical structures. Above, we developed the testable hypotheses H$_0$: $c_{mu,k\tau} - \alpha_{mu,k\tau} = c_{m\tau,ku} - \alpha_{m\tau,ku} = c_{mu,ku} - \alpha_{mu,ku} = c_{m\tau,k\tau} - \alpha_{m\tau,k\tau}$, when vertical organization has no effect on prices (under perfect substitution across vertical structures). This generates the following testable hypotheses for our empirical estimates:

1. $H_0 : \beta_{1\ell,0\ell} = \beta_{1v,0\ell}$,
2. $H_0 : \beta_{0\ell,1\ell} = \beta_{0\ell,1v}$,
3. $H_0 : \beta_{1\ell,1\ell} = \beta_{1v,1v}$,

where the β's are the coefficients of the corresponding VHHI.[9]

Test results reject the null hypothesis for hypotheses (I) and (II) at the 5% level of significance, but fail to reject the null hypothesis for (III). This shows statistical evidence that vertical structures in the $HT1$ seed market affect the pricing of conventional seeds (hypothesis I). Moreover, we also find evidence that vertical structures affect the pricing of licensed $HT1$ and vertically-integrated $HT1$ seeds (hypothesis II). By rejecting the hypothesis of perfect substitution across vertical structures, these results document that vertically-sold seeds are differentiated. Factors contributing to this vertical product differentiation likely include brand loyalty, differences in marketing services, and previous seed experience. The results also reveal that vertical organization influences how firms exercise market power and price goods.

Other Factors

As discussed above, lagged yield differences capture quality differences across seed types. All coefficients of lagged yield differences are positive and statistically significant, showing that quality differences play a significant role in the pricing of soybean seeds.

Table 2 also illustrates variations in prices over time. The year dummies show a strong rising trend beginning in 2004. In 2007, the price per bag of seed was \$8.09 higher than it was in 2001.

[9] Demand for seed reflects farmers' desire to maximize their profits; thus, we can express the willingness to pay for a specific type of seed as marginal profit. The demand slope is therefore the second derivative of farmers' profit. Using Young's theorem, this implies the following symmetry restrictions: $\partial p_{mu}/\partial y_{k\tau} = \partial p_{k\tau}/\partial y_{mu}$. Given that $\partial p_{mu}/\partial y_{k\tau} = \alpha_{mu,k\tau}, c_{mu,k\tau} = c_{k\tau,mu}$, and $\beta_{mu,k\tau} = [c_{mu,k\tau} - \alpha_{mu,k\tau}]$, this generates the following hypotheses for the relevant cross markets:

(I) $H_0 : \beta_{1\ell,0\ell} = \beta_{0\ell,1\ell}$,

(II) $H_0 : \beta_{0\ell,1v} = \beta_{1v,0\ell}$.

Using a Wald test, we failed to reject these null hypotheses (whose p-values are 0.22 and 0.47, respectively). While the results we present below do not impose these null hypotheses, note that our main findings were not affected by imposing the above symmetry restrictions.

Our estimates also indicate that soybean seeds sold in Corn Belt states are discounted more than those sold in other states. The source of purchase is found to have some effect on prices. Many farmers purchase seeds from "farmer dealers" (42%), and their prices seems to serve as an indicator of current market prices; farmers spend only \$0.12 less per bag if buying from "company or representatives" (24%) and about \$0.26 more per bag if buying from "co-ops" (10%). However, farmers will save \$1.55 per bag if they purchase from "non-dealer neighbor farms," and will pay \$2.23 less per bag if they purchase in the previous season. Additionally, the size of soybean acreage matters: In each state, large farms pay less for seeds, which may be a result of bulk discount.[10]

Implications

For illustration purposes, we focus our analysis on Illinois in 2004. Illinois is one of the largest soybean-producing states in the United States, and it has the largest number of farms in our sample. We choose the year 2004 as it is in the middle of the sample period and set the relevant variables at sample means.[11]

Based on our econometric estimates, table 3 reports estimated prices for different seed types and different vertical structures. The mean conventional seed price is \$16.03 per bag. As expected, biotech traits add price premiums over conventional varieties. Additionally, stack seeds exhibit a premium over single-traited seeds in both vertical structures. Table 3 also reports price differences across vertical structures, illustrating that seed prices under vertical integration are higher than those under licensing arrangements. Per bag, price differences amount to \$0.50 for $HT1$ and \$2.18 for $HT2$ seeds. The effect of vertical organization on pricing ranges from 1.87% to 13.6% of mean seed price, indicating that the trend toward vertical integration may push farmers to pay higher seed prices.

Next, we evaluate the markup term, M, in equations (4) and (6) to characterize the strength of imperfect competition. We evaluate three scenarios. Scenario one considers a case wherein concentration changes only in the conventional market. In Illinois, $H_{0\ell,0\ell}$ shifts from zero to its sample mean (0.25), holding other H constant. In scenario two, market concentration changes in the licensed $HT1$ seed market. In Illinois, we adjust $H_{1\ell,1\ell}$ from zero to the sample mean at 0.16 (again holding other H constant). The third scenario considers the joint effects of the first two scenarios. We alter market concentrations in both markets, and all corresponding HHI and VHHI change accordingly. Based on our econometric estimates, table 4 reports the estimated changes in M under each scenario and the corresponding relative markup percentages (100 M/p) to reflect the market concentration effects.

For the conventional seed market under scenario one, the estimated markup component is positive and statistically significant: $M = \$0.56$ per bag. The corresponding relative markup measure (100 M/p) is 3.39, indicating that market power contributes to 3.39% of the conventional seed price. Under scenario two, the M component for licensed $HT1$ seed is not statistically different from zero (as the parameter estimate of $H_{1\ell,1\ell}$ is not statistically significant). Under scenario three, which evaluates the joint effects simulated in the first two scenarios, the market power components, M, are negative and significant for both conventional and licensed $HT1$ markets. In contrast with the first two scenarios, concentrated markets contribute to significant reductions in prices.

This difference is due to complementarity effects in cross-markets concentrations, providing empirical evidence that cross-market effects are important factors associated with seed prices. Results reported in scenario three reflect that estimated complementarity effects reduce price enhancements associated with market power. These complementarity effects are important for two

[10] Our data suggest that the average discount amount is around \$2.92, likely due to time of purchase, bulk purchase, and other discount factors. In addition, the exit dummy is negative and statistically significant. Prior to the year of exit, seed price tends to be discounted by \$0.22 per bag. Finally, the entry dummy has a positive but insignificant coefficient, suggesting that firms do not price new seeds differently than they do other seeds.

[11] We set the purchase source as "Farmer who is a dealer or agent." All simulated prices are bootstrapped.

Table 3. Estimated Prices for Different Seed Types and Vertical Structures, $/Bag

Seed Type	Licensed (l) Expected Seed Price	Licensed (l) Difference in Price vs. Conventional	Vertically-integrated (v) Expected Seed Price	Vertically-integrated (v) Difference in Price vs. Conventional	Difference Between Vertical Structures ($p_v - p_\ell$)
Conventional	16.03	N/A	N/A	N/A	N/A
$HT1$ Biotech	23.68	7.65***	24.18	8.15***	0.50***
		(0.11)		(0.13)	(0.07)
		[47.72]		[50.84]	[3.12]
$HT2$ Biotech	16.55	0.54**	18.75	2.72***	2.18***
		(0.21)		(0.35)	(0.38)
		[3.37]		[16.97]	[13.60]
$HT1$ & $HT2$ Stack	24.00	7.97***	24.30	8.27***	0.30*
		(0.20)		(0.13)	(0.17)
		[49.72]		[51.59]	[1.87]

Notes: Numbers in parentheses are standard errors. Numbers in brackets are percentage differences. Single, double, and triple asterisks (*, **, ***) represent significance at the 10%, 5%, and 1% level.

Table 4. Estimated Market Power Component

		Market Power Component					
	Mean Seed Price	**Scenario S1**		**Scenario S2**		**Scenario S3**	
Seed Type	($/bag)	M ($/bag)	100 M/p	M ($/bag)	100 M/p	M ($/bag)	100 M/p
Conventional	16.54	0.56**	3.39	N/A	N/A	-0.56**	-3.39
Licensed $HT1$	23.92	N/A	N/A	-4.08E-03	-0.02	-0.24***	-1.45

Notes: Single, double, and triple asterisks (*, **, ***) represent significance at the 10%, 5%, and 1% level.

reasons. First, when associated with the supply side, they support economies of scope and can generate efficiency gains from firm consolidations/mergers. Second, they contribute to reducing the price enhancement effects of increased concentrations. Complementarity reflects cross-market effects, which underscores the need to address market power issues in a multi-market framework both horizontally and vertically. In particular, scenario three does not show the price enhancing-effects of market power observed in scenario one for conventional seeds, illustrating that cross-market power effects dominate the own-market power effect.

Conclusion

In this study we present a Cournot model of pricing for differentiated products under imperfect competition and alternative forms of vertical control. We develop a general approach to evaluating the exercise of market power in vertical structures by using vertical HHI (termed VHHI) that capture interactions between market concentration, vertical organization, and the pricing of differentiated products.

The usefulness of the analysis is illustrated in an econometric application involving the estimation of a pricing model where the VHHI capture the effects of imperfect competition across both horizontal and vertical markets. Applied to the U.S. soybean seed market, the econometric analysis presents evidence that vertical organization has an impact on seed prices, with an effect ranging from 1.87% to 13.6% of the mean price. Market concentration analyses that neglect vertical structures by using traditional HHI would fail to capture the linkages between market structure and pricing. We reject the hypothesis of perfect substitution across vertical structures, thus documenting that vertically-sold seeds are differentiated. Vertical product differentiation is likely due to factors such as brand loyalty, differences in marketing services, and previous seed experience. We also document how both horizontal and vertical market concentrations affect soybean seed pricing; these effects vary with the institutional setup. We also uncover evidence that complementarity and economies of scope can reduce the price-enhancement associated with market concentration. Since complementarity reflects cross-markets effects, this highlights the need to address market power issues in a multi-market framework.

Our approach provides useful information on the linkages between market structure, vertical organization, and pricing. Further research could extend our analysis in several ways. First, by assuming efficient contracting among firms, we neglected issues related to possible double marginalization in a vertical sector. Additional research is needed to explore these issues. Second, our econometric analysis focused on the soybean seed industry. There is a need to explore empirically how market power affects horizontal and vertical markets in other industries. Third, the model developed in this paper could be applied to other settings. It could be used in the analysis of vertical organization in other markets where imperfect competition issues may be relevant. Finally, our model could be used to evaluate empirically the linkages between pricing and changes in horizontal and vertical structures. This could prove particularly useful in the analysis of mergers and antitrust policy.

[Received January 2011; final revision received July 2011.]

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