The role of seed company-supplied information in farmers' decisions

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July 26, 2002

Selected Paper, AAEA Annual Meetings, Long Beach, California, July 28-31, 2002

Abstract: Structural and technological change in American agricultural input markets has increased the influence of seed company supplied information relative to other information sources in farmers' decisions. I examine theoretically the incentives for biotechnology firms to provide reliable, useful information to potential customers.

I would like to thank the Iowa Farm Bureau for their cooperation with the focus groups and the survey; the farmers who participated in the focus groups; the seed dealers, chemical dealers, elevator operators and many helpful employees at Pioneer who thoughtfully answered my questions. I am indebted to the Goodhue family for their support during the field work.

This is a work in progress. All comments are welcome.

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1. Introduction

Structural and technological change in American agricultural input markets has increased the influence of seed company supplied information relative to other information sources in farmers' decisions. Simultaneously, large seed companies have increased their investment in delivering information to farmers. These seed industry trends suggest that these companies are competing in providing information to increase their market share, or to increase farmers' willingness to pay.

Advertising (supplying direct or indirect information to potential customers) is the primary economic example of non-price competition between firms. However, models of consumer product firms' decisions to advertise assume they cannot supply direct information to consumers. Due to this assumption, these models fail to explain why seed companies supply direct information to farmers in the form of yield trials. In light of seed companies' increased control over product information, I examine theoretically the incentives for biotechnology firms to provide reliable, useful information to potential customers. The key question is *How does firm-supplied information affect price competition?*

2. Biotechnology and the availability of product information

Biotechnology has shortened the seed product cycle, increasing the relative importance of seed company-supplied information. Advances in biotechnology facilitate the development of new germplasm, so seed companies require less time to develop a seed with better genetics. Once developed, such a seed can then be combined with different combinations of specialized traits to create multiple new products; for example, seed company X develops a higher yielding seed A which can be offered to the marketplace as seed A, combined with the gene for Bt as seed A-Bt, combined with the gene for tolerance to Roundup Ready as seed A-RR, etc. Biotechnology enables seed companies to introduce a larger number of new corn hybrids each year. For example, Pioneer's 1998 Annual Report states that "Prior to 1997, the Company typically introduced 15 to 20 new corn hybrids each year in

North America. Pioneer introduced 37 new hybrids in 1998 compared to 27 in 1997. The Company expects to introduce more than 50 new hybrids in fiscal year 1999." Since it is costly for firms to expand their seed product line, seed companies discontinue some less profitable seed varieties when they introduce new seed varieties.[1] Hence, product cycles for seed varieties are narrowing as noted by Begemann (1997) and shown by the following excerpt from Pioneer's 1998 Annual Report: "New genetics account for more than 40% of current year unit sales...Approximately 70% of the units sold in 1999 are expected to be from [corn] hybrids introduced in 1997 or later."

In turn, new product use has increased rapidly for farmers. In recent focus group discussions, Iowa farmers commented that every year they plant about 25% of their acreage to corn hybrids they have not used before, a substantial increase from 10 years ago. When the seed product cycle was longer, farmers could wait to plant the seed until they gathered information from their own test plots, friends and neighbors who had planted the seed in the past, and the Iowa State University Cooperative Extension yield trials (ISUYT).[2]

If seeds are only available commercially for two to three years, farmers have a limited option to wait for seed information generated by direct experience and third-party sources, which increases the influence of seed company supplied information in the farmer's decisions.

2.1. **Structural change and competition through information.** Several large firms have emerged from a period of active mergers, acquisitions and alliances among suppliers of agricultural inputs. Multinational chemical companies, like DuPont and Monsanto, that have have invested heavily in agricultural biotechnology, have purchased major seed companies like Pioneer and DeKalb. According to Kalaitzandonakes and Hayenga (2000), DuPont and Monsanto supply about 55% of the seed corn market. Monsanto, through its purchase of the foundation seed company

[1] A seed company faces a number of limitations to broadening the seed product line. First, it is costly to store seed from one year to the next. Second, for each seed, the company must maintain identity during harvest and transport. Finally, the parent stock is limited, and often specific parent strains are used in multiple products. Seed companies will allocate each parent strain to its highest valued uses. To eliminate inventories, leftover seed is blended and sold at a discount.

[2] In 2000, entry in the ISUYT was limited to a maximum of 9 paid entries per district and only includes seeds that are commercially available in quantities of at least 10 bushels, and a maximum of 3 check hybrids per brand. For 2001, the maximum number of entries to the ISUYT has increased to 12 per district, and firms can now enter "advanced experimentals".

Holdens, influences another 30% of the seed corn market. These two dominant firms have increased their investment in testing and distribution networks. These actions suggest that they may be competing over the provision of information.

First, seed companies are restructuring their distribution networks (Kalaitzandonakes 1997). Seed companies are moving away from their traditional network of farmer-dealers who sold seed in during the winter and farmed during the growing season. Now seed companies are hiring dealers to be full-time, year-round salesmen. Dealers are required to attend in-depth training meetings, and to either have degrees in fields like agronomy or be certified in areas like pest control. One newly hired salesman said that dealers are expected to be credible information sources on almost every aspect of crop production.

Second, based on conversations with employees at Pioneer (DuPont), the firm has adopted a strategy of increased testing intensity to improve effective product quality. Pioneer's goal is to identify the range of each hybrid's highest potential yield. Traditionally, individual farmers experimented to learn which products perform the best in their region. By only selling the best set of hybrids in each region, Pioneer supplies a product that substitutes for farmers' own-field experiments.

3. Relevant literature

The adoption literature has demonstrated theoretically and empirically the importance of product information in the farmer's decision to adopt a new technology or product (Feder and O'Mara 1982, Lindner 1983).

There are two theoretical literatures that examine a firm's incentives to supply product information: advertising and learning. First, the theoretical literature on advertising describes the incentives for an individual firm to provide product information to potential buyers. The informative advertising literature makes an informational distinction between two types of consumer goods: *search* goods where the quality of the good is observable before purchase, and *experience* goods where the quality of the good is only observed during consumption (Nelson 1970).

The informative advertising literature asserts that for experience goods, consumers will only use "hard" information from third party sources (Tirole 1988, Nelson 1974). Hence, even though the firm knows the quality of its products, the firms will not directly provide this quality information, nor can they pay a third party to certify it, because the consumer will not treat the information as pertinent or credible. The most credible, relevant information for the consumer is generated by consumer purchases. This theoretical approach does not explain the seed industry practice of providing farmers with seed trial results.

Second, the literature on firms learning about demand focuses on experience goods, where consumer purchases generate an information externality. In these models, firms learn about market demand for a homogeneous product, the degree of product differentiation between two products, or the value of a new product where the quality differential with respect to the incumbent product is unknown and the products are differentiated vertically, horizontally or both. In all of these models, firms indirectly generate information through their pricing strategy (Mirman, Samuelson and Schlee 1994, Harrington Jr. 1995, Bergemann and Valimaki 1996, Bergemann and Valimaki 1997, Vettas 1998, Caminal and Vives 1999). Information on consumer valuation or product quality is transmitted to uninformed consumers (potential new consumers) either through market price, behavior of informed consumers (repeat purchases), or market share. Firms can engage in pricing strategies such as *penetration pricing*, where they charge a low price, to capture new buyers and repeat purchases. In essence, the firm's pricing decision embodies both strategic price and information considerations.

In applying the consumer-based definitions of search goods and experience goods to seed corn, it is important to highlight some differences between consumers and producers. Producer utility from production inputs (i.e., expected profit if the farmer is risk neutral) is more quantifiable and observable than consumer utility from any consumer product. Because of the correlation in product performance between testing sites and individual farms, firms are able to generate information of some value to producers. Even so, due to the costliness and difficulty of observing profitably producer heterogeneity, firms cannot identify each individual producer's demand for their product (i.e., perfectly price discriminate).

Seed corn is best described as an experience good. While some seed qualities are observable before purchase (for example, number of growing days), most seed qualities are only imperfectly observed after the crop is planted and harvested, due to heterogeneous land quality, stochastic weather, and stochastic pest shocks. Both the advertising literature and the learning literature assume that firms will not directly provide information on experience goods to consumers. In the case of the American seed corn industry however, we observe firms providing information from yield trials to producers which cannot be explained by existing theory. This raises the question of why firms invest in providing information to farmers.

4. Model of the seed industry

I examine the firm's incentives to provide information directly to farmers. My approach is different from the existing adoption, learning and advertising literatures. The adoption literature focuses on the role of information in adoption and diffusion from the perspective of the farmer rather than the firm. The advertising literature informs my model to the extent that seeds are best defined as experience goods, and firms know the expected yield of the new seed, but they have to convey it to the farmers through test station yields and indirectly through other farmers. The learning literature examines the firms' incentives to provide information relevant to the adoption decision but restricts the firms to indirectly supply information through the pricing decision, rather than directly.

In order to highlight the strategic aspects of supplying seed information, I compare demand for a seed of known quality, supplied by the incumbent or old firm, to demand for a new seed where the new firm faces the decision to supply information. A firm introducing a new seed will maximize profits by choosing the product price, and the quality of the product information. Accurate product information is costly to supply. In the case of seed varieties, information is generated at firm-owned testing stations. The new firm can increase the quality of information about the seed two ways: first, by increasing the number of testing sites, and second, by increasing the number of years a seed is tested before its commercial release. For the purposes of this model, I will focus on the first case and have the firm choose the number of testing sites, each of which supply one observation about the performance of the new product. The old firm's problem is to maximize expected profits choosing product price in each period. The new firm's problem is to maximize expected profits, choosing the number of testing sites in period zero and the product price in each period after that. For simplicity, I assume that the costs of producing the product are zero. I only consider the case where the average yield of the new seed at the company's test stations is higher than the expected yield of the old seed where the farmers know from experience the seed quality.

The timing of the model is described in Table 1. In period 0, the new firm chooses the number of testing sites. In period 1, the test station information is available to farmers to make their adoption decision, and both firms compete in prices. In period 2, farmers gain additional information about the new seed from the yield outcome of the first period adopters. Again, the firms compete in prices.

Table 1: Timing of the model

Period	New firm's decisions	Old firm's decisions	Seed- specific information in farmers' prior
0	Choose number of test sites	None	None
1	Choose period 1 price	Choose period 1 price	Test station information
2	Choose period 2 price	Choose period 2 price	Test station information and average yield of period 1 adopters

In order to examine how firm-supplied information affects price competition, I compare the outcomes of a two period model (period 0 and period 1 described above), and a three period model. In the two period context, the seed company invests in supplying test station information directly to the farmer to maximize profits. In the three period context, the firm can supply information through two instruments, test station information and period 1 price which affects the number of period 1 adopters. The three period context will reveal if the profit maximizing strategy continues to be investing in test station information, and will highlight the efficacy of test station information to generate demand relative to price.

4.1. **Demand for seed and farmers' beliefs:** Regardless of the period, demand for each seed depends on the farmers' expected profit maximization decision. I assume the farmers are risk neutral, that each farmer demands one unit of seed, and he will purchase the seed that he believes yields the highest expected profit. In order to focus on the seed purchase decision, I abstract from all other production costs and assume that all production costs, except for the seed, are invariant to the seed decision.[3] Both seeds produce a homogeneous crop with the same output price, which is exogenous and normalized to 1.

Each farmer's decision can be written as:

$$maxE[\pi_{j,t}] = max\{\bar{Y} - w_t, \quad [\alpha_j(m_t - \bar{Y}) + \bar{Y}] - r_t\}$$

where $\bar{Y}$ is the expected yield of the seed of known quality, w_t is the price of the seed of known quality, r_t is the price of the new seed, and $\alpha_j(m_t - \bar{Y}) + \bar{Y}$ is the expected yield of the new seed, given the available information. For the new seed, the farmer's expectations depend on his prior belief about the expected yield of the new seed given the available information (m_t, described in the next subsection), and his belief about the applicability of that information to his farm (α_j).

[3] Alexander and Goodhue (*forthcoming*) and Alexander, Fernandez-Cornejo and Goodhue (2001) examine the role of input costs and risk in the farmer's adoption decision.

In focus groups, Iowa farmers treated information from seed companies differently than information from other farmers and the ISUYT[4]. Some farmers believe seed companies and dealers only report the best outcomes; other farmers trust their seed company or dealer completely. Hence, the farmers are heterogeneous in their beliefs about the value of information supplied by the seed company. I assume for expositional convenience that farmers are uniformly distributed in their beliefs about the value of seed company information and each farmer weights the seed company-supplied information about the yield advantage of the new seed by $\alpha_j \in [0,1]$. If $\alpha_j = 1$, the farmer assumes the seed company-supplied information is accurate and relevant to his decision. If $\alpha_j = 0$, the farmer completely ignores the firm's information.

There are at least three explanations for the heterogeneity in farmer's beliefs about the value of seed company test data with respect to his own farm. First, farmers are heterogeneous in their tendency to trust the seed company, as described above. A farmer who trusts the seed company would believe that α is large, and have more confidence in the seed company information than a farmer who believes α is small. Second, farmers are heterogeneous in their farming ability. A high ability farmer, who consistently produces high yields, would have more confidence that his own yield outcomes will be close to test station yield outcomes, and hence, believe α is large (Feder, Just and Zilberman 1985). Finally, farmers have heterogeneous land quality and growing conditions. A farmer who believes that his growing conditions closely resemble the conditions of the test stations would believe that the test station outcomes are a better predictor of the seed's performance on his land compared to a farmer whose growing conditions are dissimilar to the test stations.

Demand is defined by the farmer who is indifferent between purchasing the seed of known quality, and the new seed. Farmers who have more confidence in the information available at t than the indifferent farmer ($\alpha_{t,j} > \alpha_t$) will purchase the new seed. Farmers who discount the available

[4] (*"Role of Marketing in Agricultural Biotechnology", Focus Group Transcript 1, Mason City, Iowa* 1999, *"Role of Marketing in Agricultural Biotechnology", Focus Group Transcript 2, Mason City, Iowa* 1999, *"Role of Marketing in Agricultural Biotechnology", Focus Group Transcript 3, Albia, Iowa* 2000)

information more than the indifferent farmer will purchase the old seed. Since each farmer only purchases one unit of seed, α_t represents the share of farmers that purchased the old seed in period t, and $1 - \alpha_t$ represents the share of farmers who adopt the new seed in period t.

$$\bar{Y} - w_t = [\alpha_t(m_t - \bar{Y}) + \bar{Y}] - r_t, \quad \text{or}$$

$$\alpha_t = \frac{r_t - w_t}{m_t - \bar{Y}}$$

4.2. **Producer beliefs about the yield of the new seed:** I explicitly describe how farmers form expectations about the yield of the new seed using the standard Bayesian updating rule. (See, for example Cyert and DeGroot (1970), Cyert and DeGroot (1974), and Townsend (1978). Fischer, Arnold and Gibbs (1996) used it in a modified form.) I assume the yield of the new seed is normally distributed with unknown mean (δ) and specified precision (ν^2), which is the inverse of the variance, or $\frac{1}{\sigma^2}$. Information from either seed company yield trials or farmers adopting the new seed is treated as a random sample from this distribution. The farmer's initial beliefs are normally distributed with mean m. Once the farmer receives information from either seed trials or period one users, the farmer updates his beliefs about the point estimate of the mean, m.

In period 1, when the seed company is the only source of information, then μ is the mean of the prior beliefs about the yield of the new seed, s is the number of testing stations, $\bar{x}_0$ is the average yield from the testing stations, and h is the precision of the test station information. I normalize the precision of information by setting the precision of the period 0 prior to 1. The mean of the farmers' period 1 prior is

$$m_1 = \frac{\mu + sh_0\bar{x_0}}{1 + sh_0}$$

.

If the seed company does not publicize the results of the yield trials, then the mean of the farmer's prior on the expected yield of the new hybrid would be equal to the expected yield of the known hybrid ($\bar{Y}$).

Farmer beliefs in the second period will depend on outcomes of the two first period, the number of adopters, and the average yield realized by the adopters. The share of adopters of the new seed in the first period $(1 - \alpha_1)$ determines the amount of information generated for the second period. If $\alpha_1 = 0$, then all the farmers adopt the new seed in period 1. If $\alpha_1 = 1$, then none of the farmers adopt the new seed in period 1.

In period 2, farmers incorporate the new information generated by the farmers who adopted the new seed in period 1. The share of farmers who adopted the new seed in period 1 is $(1 - \alpha_1)$, the average yield of the new seed in period 1 is $\bar{x_1}$, and the precision of information generated by the period 1 adopters is h. The mean of the farmers' period 2 prior is

$$m_2 = \frac{\mu + sh_0\bar{x_0} + (1 - \alpha_1)h_1\bar{x_1}}{1 + sh_0 + (1 - \alpha_1)h_1}$$

.

4.3. **The two period model:** I begin by solving a two period model, where the firm offering the new seed chooses the optimal number of testing sites in period 0, and taking the number of testing sites as given, the two firms compete in prices on the seed market in period 1. The two period model focuses on the new firm's incentives to supply *direct* information to potential consumers.

I solve for the new firm's optimal decisions using backward induction, since the period 0 decision regarding the number of testing sites influences the period 1 price competition. I present the solution to the model following the logic of backward induction, presenting the period 1 problem, followed by period 0, where the firm offering the new seed chooses the number of testing sites to maximize its profits.

4.3.1. *Period 1:* Both firms maximize profits choosing period 1 prices, taking the information and beliefs as given. The new firm's profit maximization strategy is as follows:

$$\underset{r_1}{max} \quad (1-\alpha_1)r_1(1-\frac{(r_1-w_1)}{(m_1-\bar{Y})})r_1$$

The firm's best response to the price offered by the incumbent firm is $r_1(w_1) = \frac{w_1+m_1-\bar{Y}}{2}$.

The incumbent firm offering the product of known quality will also maximize profits in each period choosing seed price.

$$\underset{w_1}{max} \quad \alpha_1 w_1(\frac{(r_1-w_1)}{(m_1-\bar{Y})})w_1$$

The incumbent firm's best response to the price offered by the new firm is $w_1(r_1) = \frac{r_1}{2}$.

Given each firm's best response function, the period 1 outcome is

$$r_1 = \frac{2[m_1 - \bar{Y}]}{3}$$
$$w_1 = \frac{[m_1 - \bar{Y}]}{3}$$
$$\alpha_1 = 1/3$$
$$\Pi_1^{new} = \frac{4[m_1 - \bar{Y}]}{9}$$
$$\Pi_1^{old} = \frac{[m_1 - \bar{Y}]}{9}$$

.

Π_t^{new} is the profit of the new firm, and Π_t^{old} is the profit of the incumbent firm. The incumbent firm retains one-third of the market share, and the new firm captures two-thirds of the market. The prices charged by both firms, and the profits of both firms are strictly increasing in the farmers' beliefs about the expected yield of the new seed, m_1. As m_1 increases, the perception of vertical differentiation between the new seed and the incumbent seed increases. The increased profits are consistent with the general result that product differentiation relaxes price competition, and allows competing firms to achieve higher profits. The new firms' decision in period 0 determines m_1 which is a function of the number of testing sites. Due to the assumption that the test station yields of a newly introduced seed will be above the expected yield of the current industry leaders ($\bar{x}_0 > \mu$), m_1 is strictly increasing in s. Therefore, the incumbent firm will receive higher profits when the new firm chooses to increase the number of testing sites in period 0. The new firm also receives higher period 1 revenues when it increases the number of testing sites, however, it incurs higher costs in period 0.

4.3.2. *Period 0:* The new firm chooses the optimal number of testing sites to maximize the sum of period 0 and period 1 profits. In period 0, the new firm incurs the costs of the testing sites and receives no revenues. I assume a fixed cost per test site, c, so there is a constant marginal cost to supplying direct information. The new firm's profit maximization problem is

$$\max_{s} \quad \frac{4[m_1(s) - \bar{Y}]}{9} - cs\frac{4[\frac{\mu + sh_0\bar{x}_0}{1+sh_0} - \bar{Y}]}{9} - cs$$

The optimal number of testing sites is

$$s^* = \frac{2}{3}\sqrt{\frac{\bar{x}_0 - \mu}{ch_0}} - \frac{1}{h_0}.$$

The optimal number of testing sites depends on the farmers' period 0 prior, the average yield at the test stations, the precision of the test station information, and the cost per test station. As the mean of the farmers' period 0 prior on the new seed (μ) increases, the optimal number of testing sites decreases. As the mean of the test site yields ($\bar{x}_0$) increases, the optimal number of testing sites increases. As the cost of each testing site (c) increases, the optimal number of testing sites decreases. As precision of test station information (h_0) increases, the optimal number of testing sites depends on the magnitude of the precision of the information. If the precision of test station information is low relative to the yield gain divided by the cost of a test station ($\frac{1}{h_0} > \frac{[\bar{x}_0 - \mu]}{9c}$), then as the precision increases, so does the optimal number of testing sites. Alternatively, if the precision of test station information is high relative to the yield gain divided by the cost of a test station ($\frac{1}{h_0} < \frac{[\bar{x}_0 - \mu]}{9c}$), then as precision increases, the optimal number of testing sites decreases.

When precision is high, farmers have higher confidence in the test station information, and the marginal test station has little influence on farmer beliefs. The marginal test station has a greater influence on farmer beliefs when the precision of the test station information is low.

4.4. **Three period model:** I extend the model to 3 periods to allow the new firm to both *directly* and *indirectly* supply information to potential customers. The seed company now has two instruments that affect the supply of information in subsequent periods, price and test station information, to maximize the present value of expected profits over multiple periods. The seed company's initial pricing and information decision will determine the number of farmers who plant the new seed in the first period, and thus the amount of information that will be generated for the second period.

In period 0 the new firm chooses number of testing sites, and in period 1 and period 2 the firms compete in prices. The outcome of the period 1 price competition will determine the number of period 1 adopters of the new seed. The average yield achieved by the period 1 adopters will affect farmer beliefs about the yield of the new seed in period 2. In this manner, the firms can *indirectly* supply information about the yield of the new seed that is available before the farmers make their period 2 production decisions.

In analyzing the three period model, I'll first solve the model analytically for the case where both firms ignore the information link between period 1 and period 2. Then, I'll present the results of numerical simulations to examine how firm behavior changes when at least one of the firms influences period 1 adoption in order to influence period 2 beliefs. Finally, I will discuss the profitability of exploiting the information feedback of period 1 adoption relative to the case where both firms ignore the feedback.

4.5. **The three period model with no feedback:** First, I examine the three period model where the players choose **not** to influence period 1 adoption in order to influence farmers' period 2 beliefs about the expected yield of the new seed. Again, I present the solution to the model following the logic of backward induction, presenting the period 2 price competition, followed by period 1 price competition, and lastly, followed by period 0 where the firm offering the new seed chooses the number of testing sites to maximize its profits.

Period 2: For period 2, both firms maximize profits choosing period 2 prices, taking the information and beliefs as given. For now, there is no discounting.

The new firm's profit maximization strategy is as follows:

$$\max_{r_2} \quad (1-\alpha_2)r_2$$

The firm's best response to the price offered by the incumbent firm is $r_2(w_2) = \frac{w_2+m_2-\bar{Y}}{2}$.

The incumbent firm offering the product of known quality will also maximize profits in each period choosing seed price.

$$\max_{w_2} \quad \alpha_2 w_2$$

The incumbent firm's best response to the price offered by the new firm is $w_2(r_2) = \frac{r_2}{2}$.

Given each firm's best response function, the period 2 outcome is

$$r_2 = \frac{2[m_2 - \bar{Y}]}{3}$$
$$w_2 = \frac{[m_2 - \bar{Y}]}{3}$$
$$\alpha_2 = 1/3$$
$$\Pi_2^{new} = \frac{4[m_2 - \bar{Y}]}{9}$$
$$\Pi_2^{old} = \frac{[m_2 - \bar{Y}]}{9}.$$

As in the two period model, the prices charged by both firms, and the profits of both firms are strictly increasing in the mean of the farmers' period 2 prior m_2. As m_2 increases, the perception of vertical differentiation between the new seed and the incumbent seed increases. The increased profits are consistent with the general result that product differentiation relaxes price competition, and allows competing firms to achieve higher profits. The firms' decisions in earlier periods determine m_2 which is a function of both the share of period 1 adopters, and the number of testing sites.

Period 1: Both firms choose not to influence period 1 adoption and farmer's beliefs in period 2. The outcome is the same as for period 2, except that prices and profits depend on m_1 instead of m_2. The outcome of both firms ignoring the information link between period 1 adoption and period 2 beliefs is the following:

$$r_1 = \frac{2[m_1 - \bar{Y}]}{3}$$

$$w_1 = \frac{[m_1 - \bar{Y}]}{3}$$

$$\alpha_1 = 1/3$$

$$\Pi_1^{new} = \frac{4[m_1 - \bar{Y}]}{9}$$

$$\Pi_1^{old} = \frac{[m_1 - \bar{Y}]}{9}$$

Period 0: In period 0, the firm offering the new seed chooses the optimal number of testing sites to maximize the sum of profits from period 1 and 2, taking into account the cost of the testing sites $C(s) = cs$.

$$\underset{s}{max} \quad \Pi_1^{new}(m_1(s)) + \Pi_2^{new}(m_2(s)) - cs$$

When both firms choose not to act on the information, I can differentiate total profits with respect to the optimal number of testing sites in order to obtain an expression that defines s^*. In this case the optimal number of testing sites is an implicit function of the farmers' prior μ, average test station yields $\bar{x_0}$, average yields of period 1 adopters $\bar{x_1}$, the precison of test station information h_0 and adopter information h_1, and the marginal cost of the testing sites c.

$$\frac{h_0(\bar{x_0} - \mu)}{[1 + s^* h_0]^2} + \frac{h_0[(\bar{x_0} - \mu) + h_1(1 - \alpha_1)(\bar{x_0} - \bar{x_1})]}{[1 + s^* h_0 + h_1(1 - \alpha_1)]^2} - \frac{9c}{4} = 0$$

Table 2 presents the comparative statics on the optimal number of testing sites.[5] As the mean of the farmers' prior on the new seed (μ) increases, the optimal number of testing sites decreases. As the mean of the test site yields ($\bar{x_0}$) increases, the optimal number of testing sites increases. As the mean yield of the period 1 adopters ($\bar{x_1}$) increases, the optimal number of testing sites increases. As the cost of each testing site (c) increases, the optimal number of testing sites decreases. As the precision of the test station information (h_0) increases, the optimal number of testing sites also increases. As the precision of the information from the period 1 adopters (h_1) increases, the optimal number of testing sites decreases if the farmers have higher confidence in the test station information relative to their confidence in the information generated by the first period adopters.

Table 2: Comparative statics on the optimal number of testing sites in the three period model when there is no feedback

$\frac{\partial s^*}{\partial \mu}$	-
$\frac{\partial s^*}{\partial \bar{x_0}}$	+
$\frac{\partial s^*}{\partial \bar{x_1}}$	-
$\frac{\partial s^*}{\partial h_0}$	+
$\frac{\partial s^*}{\partial h_1}$	- if $sh_0 > h_1(1-\alpha_1)$
$\frac{\partial s^*}{\partial c}$	-

4.6. **Three period model with feedback:** When the firms act on the information link between period 1 adoption and period 2, they have a different best response function in period 1. The period 2 outcome is the same as previously described.

The firm offering the new seed chooses its period one price in order to influence information through period 1 adoption.

$$\max_{r_1} \quad (1-\alpha_1(r_1))r_1 + \frac{4[m_2(\alpha_1(r_1)) - \bar{Y}]}{9}$$

[5] The comparative statics hold if the average yield of the period 1 adopters is less than the average of the test station yields, or only slightly above the test station yields ($\bar{x}_1 < \bar{x}_0 + \frac{\bar{x}_0-\mu}{h_1(1-\alpha_1)}$). If the average yield of the period 1 adopters is substantially above the test station average yields ($\bar{x}_1 > \bar{x}_0 + \frac{\bar{x}_0-\mu}{h_1(1-\alpha_1)}[\frac{[1+sh_0+h_1(1-\alpha_1)]^3}{[1+sh_0]^3} + 1]$, then the comparative static results are reversed.

The firm's best response function, defined by the first order condition, to the price offered by the incumbent firm is

$$m_1 - \bar{Y} - 2r_1(w_1) + w_1 + \frac{4hd}{9[1 + sh_0 + (1 - \alpha_1^*(r_1, w_1))h_1]^2} = 0$$

$$\text{where} \quad d = [\mu - \bar{x_1} + sh_0(\bar{x_0} - \bar{x_1})]$$

The incumbent firm chooses period one price in order to influence information through period 1 adoption.

$$\max_{w_1} \quad \alpha_1(w_1)w_1 + \frac{[m_2(\alpha_1) - \bar{Y}]}{9}$$

The incumbent firm's best response to the price offered by the new firm is

$$r_1 - 2w_1(r_1) - \frac{h_0 d}{9[1 + sh_0 + (1 - \alpha_1^*(r_1, w_1))h_1]^2} = 0$$

.

If there is no additional information generated by the first period adopters, i.e. the average yield obtained by the first period adopters is equal to the farmers' prior for the first period, $\bar{x_1} = \frac{\mu + sh_0\bar{x_0}}{1+sh_0}$, then $d = 0$. When $d = 0$, the firms' best response functions are the same as when the firm chooses not to influence period 1 adoption. There are no gains to influencing period 1 adoption when the period 1 adopters do not generate additional information.

Each firm's best response to the other firm depends on whether the information generated by the first period adopters (d) signals that the new seed offers a small or large yield advantage over the incumbent seed. A period 1 average yield above the farmers' period 1 prior, i.e. $\bar{x_1} > \frac{\mu + sh_0\bar{x_0}}{1+sh_0} \Rightarrow d < 0$, signals a large yield advantage to the new seed. With a signal of a large yield advantage, the farmers revise their prior, i.e. $\bar{x_1} < \frac{\mu + sh_0\bar{x_0}}{1+sh_0} \Rightarrow d > 0$, signals a small yield advantage. With a signal of a small yield advantage, the farmers revise their beliefs on the yield of the new seed downward for period 2, $m_2 < m_1$, and period 2 profits for both firms are smaller than period 1 profits.

I use numerical simulations to examine how the three period model with feedback differs from the three period model without feedback. Table 4 reports the numbers I used for the simulations. Note that I've implicitly normalized the number of observations for each type of information by the number of farmers. Each test station and each adopter generates one data point. The maximum number of testing stations (s), normalized by the number of farmers is no more than 1.

Table 4: Values used in simulations

Variable	
μ	150 bu/acre
$\bar{x_0}$	160 bu/acre
$\bar{x_1}, d$ positive	151 bu/acre
$\bar{x_1}, d$ both positive and negative	153 bu/acre
$\bar{x_1}, d$ negative	157 bu/acre
h_0, h_1	.9
s	$\in [0, 1]$
Cost of test sites	-3s

Using these numbers, I compare the feedback case to the case where firms did not consider the information feedback effect. Regardless of the sign of d, when the firms act on the information to influence period 1 adoption and the second period prior, the outcome to the pricing game is such that the period 2 prior (m_2)is greater than or equal to what it would be in the case where the firms do not influence adoption. Recall that the period 2 profits for both firms are strictly increasing in m_2 due to the increased perception of vertical differentiation.

If the information generated by first period adopters signals a large yield advantage, $d < 0$, then both firms will charge lower prices in the first period, and more farmers will adopt the new seed relative to the case where the firms choose not to act on the information. If the information generated by first period adopters signals a small yield advantage, $d > 0$, then both firms will charge higher prices, and fewer farmers will adopt the new seed in the first period relative to the case where farmers choose not to act on the information.

5. Profit maximizing behavior

Of course, each firm will choose whether or not to influence period 1 adoption, in order to maximize total profits. All figures compare either the new firm's net total profits or period 1 adoption of the new seed under 3 different optimization scenarios: 1) info, where both firms act on the information, 2) optimal, where for d negative the new firm ignores the information and the old firm acts on the information, while for d positive, the old firm ignores the information and the new firm acts on the information and 3) no feedback, where neither firm acts on the information.

In Figures 1, 2, and 3, for all values of d, scenario 2 where only one firm acts on the information, yields the highest profits for both firms. When d is negative, signaling the new seed has a large yield advantage, both firms have higher profits than when d is positive.

When the information generated by first period adopters signals a small yield advantage ($d > 0$), the firm offering the incumbent seed maximizes profits by choosing not act on the information. The new firm chooses to act on the information, and charge a higher period 1 price and capturing a smaller share of the market relative to the case where the new firm ignores the information. Since period 2 profits will be lower than period 1 profits due to the signal, both firms act defensively to take more profits in period 1 when the farmers' perception of vertical differentiation is greatest.

When the information generated by first period adopters signals the new seed has a large yield advantage ($d < 0$), the firm offering the new seed maximizes profits by choosing not to act on the information. Essentially, the firm offering the new seed recognizes that it has a product that "can sell itself". The marginal gain in period 2 profits from increasing period 1 adoption in order to strengthen the positive signal is less than the marginal cost in period 1 profits from the intensified price competition. The firm offering the incumbent seed chooses to act defensively on the information, and charges a higher period 1 price, has a lower market share, and higher period 1 profits relative to the case where the firm does not act on the information.

When both firms act on the information, they influence adoption to a greater degree and achieve lower profits relative to the case where only one firm acts on the information. Namely, period 1 adoption of the new seed deviates further from the no feedback level of $(\frac{2}{3})$ when both act on the information relative to just one firm. In Figure 4, when d is negative, there is a higher level of period 1 adoption of the new seed when both firms act than just one. As shown in Figure 5, when d is positive, there is a lower level of period 1 adoption when both firms act than just one. Influencing adoption is costly because it intensifies the price competition between the firms, resulting in lower profits when both firms act on the information relative to just one firm.

As d increases in magnitude, this indicates that the information generated by period 1 adopters is more informative, i.e. that the difference between the period 1 prior and the period 1 outcome is increasing. For a small d, the new firm's profits, and period 1 adoption are close to the case of no feedback. As d increases in magnitude, the firms' gains from exploiting the information feedback increase.

The new firm faces a choice of how much to invest in test station information relative to how much to influence first period adoption. The simulations suggest that the information generated by the period 1 adopters is a substitute for the information generated by the testing sites. Figures 4 and 5 show that, in the models with feedback, as the number of testing sites increases, the resulting level of period 1 adoption decreases. The optimal number of testing sites will depend on how favorable the test station information is relative to the information supplied by the first period adopters. I examined how the profits for the new firm changed as the number of testing sites increased, for different average yields obtained by the new adopters. In Figure 1, when the average yield of the new adopters was 157 bushels per acre, then the optimal number of testing sites is about 0.5. When the average yield of the new adopters falls to 153 in Figure 2, the optimal number of testing sites increases to about 0.6. Finally, when the average yield of the new adopters falls to 151 in Figure 3, the optimal number of testing sites is between 0.6 and 0.7. Consistent with the comparative statics for the three period model with no feedback, as the information supplied by the period 1 adopters becomes more favorable, the optimal number of testing sites decreases ($\frac{\partial s^*}{\partial \bar{x_1}} < 0$).

6. Concluding Remarks

I examine the incentives for seed companies to supply information to potential customers, and the role of this information in price competition. In particular, I focus on the relative efficacy of two instruments: test station yields, and price. I find that the efficacy of these two instruments depends on the magnitude of the additional information supplied by period 1 adopters, and which provides more favorable information. First, the extent to which the firms benefit from exploiting the information feedback from period 1 adoption depends directly on the amount of information they supply. If the farmers' period 1 prior correctly predicts period 1 yields, then period 1 adopters do not supply additional information and there are no gains to influencing adoption. As the magnitude of the information supplied by the period 1 adopters increases, so do the gains from exploiting the information feedback. Second, since the information generated by the test stations and the period 1 adopters are substitutes, then the instrument with the more favorable signal will have a greater impact on profits.

Both firms benefit when the price competition is less intense. The firms can minimize the price competition in two ways. First, both firms gain higher profits when only one firm exploits the information feedback from period 1 adopters. Second, as the farmers' perception of the value of the new seed increases, so does the perception of vertical differentiation which reduces the intensity of price competition.

Analyzing the signal from period 1 adopters, provides insight to the new firm's decision of introducing new seeds, and how much test information to supply for the new seeds. When the signal from the period 1 adopters reinforces the test station information ($d < 0$), both firms profit. The new firm profits the most when the introduced seed has performed well in seed trials, and farmers also realize a substantial yield gain. In this case, the new firm's profit maximizing strategy will be to supply test station information, but not to offer low introductory prices to influence period 1 adoption. In contrast to the learning literature, when the firms have to option to directly supply information to consumers, penetration pricing is not the optimal strategy.

However, if the new firm expects a negative signal from period 1 adopters ($d > 0$), then the new firm's profit maximizing strategy will be to supply test station information, and charge higher prices in period 1 and reduce the level of adoption to minimize the availability of negative information in the second period. The new firm realizes substantially lower profits when the new seed flops, which implies that it has an incentive to introduce seeds that will perform as promised.

Based on conversations with Pioneer employees, my model's profit maximizing behavior of supplying seeds with a large yield advantage, and with accurate information, is consistent with Pioneer policy. First, Pioneer only introduces new seeds that have, after extensive testing, met its yield advantage threshold. Second, Pioneer considers the first year of release to be a final testing phase, and only releases a new seed in limited quantities. Not only does a new seed need to perform well at company test stations, it has to perform well for Pioneer customers. By gathering information on the performance of a new seed on farmer's fields, as well as at company test stations, ensures that the company-supplied information provides a more accurate signal to farmers. In fact, one Pioneer representative remarked that his yield book, which is complied from his customer's test plots, provides the most useful information for selling seed.

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