EXAMINING PRICE PATHS OF A PORTFOLIO OF AGRO-BIOTECHNOLOGY SEEDS: The Effects of Competition and Farmers’ Response

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Introduction

The pressures of a changing business environment have resulted in new rules for strategic price decisions in the food and agribusiness sector. The proliferation of biotechnology methods results in an increasing rate of innovation and new product introduction. New products, once introduced, are rapidly replaced by competitive innovation, making obsolete the existing products and requiring the introduction of new or modified ones (Cooper, 1993). While not predicted with certainty, one of the indirect effects is to shorten the product life cycle of the biotechnology-derived products. Thus, it is of critical importance to develop and maintain a proper pricing strategy over time. Furthermore, many firms introducing biotechnology-derived products do so as an extension of an existing product line in order to serve new market niches.

However, competitors are not willing to stand by idly as their markets are invaded. Monroe (1990) observes: “Technological progress has reduced the average life of the products. Thus, a new product does not have much time to become profitable, and any pricing mistakes made during the introduction will diminish potential profitability (p.8)”. The pricing strategy may be altered by competitors’ responses in non-price marketing efforts. Therefore, pricing new and existing products has become more critical than ever.

This paper aims to analytically evaluate the time paths of pricing a portfolio of seeds, which simultaneously address the goal of encouraging adoption and maximizing a firm’s returns within a competitive environment while considering shorter life cycles. Specifically, this paper provides analytical answers to the following two research questions:

1. How does a seed firm prefer to price a competing set of seeds? Does the optimal pricing time path for a single product change when a portfolio of competing products is considered?

2. How does competitive uncertainty in the form of farmer’s response and non-price marketing effort affect the resulting pricing time paths of the competing products?
**Problem Setting**

In the agriculture sector, product improvement is often associated with the emergence of biotechnology techniques. Katz (1996) describes biotechnology as a series of tools that are useful in providing foods sources that fit current needs. Biotechnology offers the opportunity for marketing channel participants to be focused on customer demands by providing a large set of improved and differentiated products targeting specific and well-identified food market niches. Within the present research, biotechnology is a broad term, which encompasses a wide spectrum of techniques from identifying and selecting for naturally occurring genetic traits (e.g. gene markers) through direct manipulation of the genome (genetically modified organisms or GMOs). No specific biotechnology technique is inferred.

As customers’ needs are continuously changing, input producers as well as output producers adapt their production systems to that change in order to develop and improve their products accordingly. Participants compete on the basis of customer’s satisfaction; they are continuously searching for the best marketing tools for competitive advantage. Thus, competition among them shortens the life cycle of new products, but by an uncertain amount. By the same token, it is commonly believed that biotechnology-derived products, once introduced, do not have as long of a market life cycle as in years past.

Given the competitive environment, the uncertainty of product life cycle, and the investment in biotechnology, a producer of biotechnology-derived products is faced with the simultaneous goals of 1) recovering substantial investment, 2) facilitating the adoption of new (biotech) products and 3) optimizing returns from the product portfolio supplied to the market. Therefore, synchronized pricing of new and existing products has become more critical than ever. Errors by suppliers in pricing new products may result in failure to provide sufficient returns above development costs, either through failure to obtain an adequate margin or through failure to obtain adequate volume.

For theoretical and analytical purposes, the investigation focuses on the seed industry for the following three reasons. First, the rapid change in the seed industry is associated with changes in the
market. Second, the measurement of the success of a seed has shifted from yield per acre to dollars earned per acre because of quality differentials (Engelke, 1997) and associated price of the output. Third, the seed industry is characterized by an oligopolistic supply situation where participants compete not by reducing seed prices, but by expending more money in sales promotion and scientific research (Ducos, 1987). Also, with the introduction of the biotechnology-derived seeds, seed firms face competition from other producers of farm inputs whose inputs are substitutes for biotechnology-derived seed characteristics.  

The seed portfolio consists of an existing corn seed and two biotechnology-derived corn seeds (a cost-lowering input-trait and a value enhanced output-trait) whose characteristics are valued by target-users within the same market. Input-trait and output-trait corn seeds are derived from the use of biotechnology techniques. With input-trait corn seed, the set of inputs necessary to grow the plant is altered. However, with output-trait seed, the chemical composition of the output is different from regular corn.

With the introduction of biotechnology-derived corn seeds, farmers have the opportunity to grow all the seeds for the same and/or specific market. Farmers grow input-trait corn seeds to satisfy participants’ needs in the market served by the regular corn seeds but at lower cost. At the same time, farmers grow the output-trait corn seed for a specific customer (e.g.: poultry feed) in the corn market. Poultry participants may specify directly or indirectly to the farmer the type of seed they want in order to get the desired qualities. This situation implies a willingness to provide some incentives, either through price or other financial means, to farmers in order to motivate their participation. This paper ignores recent developments in US marketing channels resulting from the European trade environment concerning genetically modified products.

The poultry industry is the set of potential customers for the output-trait corn seed in this study because of the importance of corn in the broiler diet (Han et al., 1987; Adams et al., 1994;  

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1 The term “biotechnology-derived seed” is used to identify plant genetic material whose characteristics have been altered through the use of biotechnology techniques.
Wright and Morgan, 1996; Duldley-Cash, 1997). This research considers a conventional corn seed, Bt corn seed, and high-oil corn seed. The use of Bt corn seed and high-oil corn, for example, allows farmers and poultry participants to reduce other input costs by applying less pesticides chemicals for the former and less supplemental fat ingredients in broiler diets for the latter. However, pesticide producers as well as supplemental fat producers may retaliate through price reduction in order to make these seeds less valuable. In this case, the competition that faces the seed firm comes from within the seed industry as well as from other producers of farm inputs whose inputs are substitutes for biotechnology-derived seed characteristics. Thus, it is important to analytically examine the sensitivity of the preferred pricing time paths with respect to market changes, potential competitive reactions, and shortened product life cycle.

**Literature Review**

There exist extensive theoretical and empirical works on pricing models within generalized competitive and/or noncompetitive markets. Several of them emphasize the single-pricing pricing case where a single product is supplied in the market. While the situation fits the assumptions of different models, it might not be appropriate in the case where more than one product is supplied by one firm in the same market. When a firm produces several goods, the problem faced is to set a portfolio pricing strategy that maximizes the firm’s profits.

Urban (1969) analyzes an *a priori* product line model for finding the best marketing mix for each product. Brand interdependency is tested through direct and cross-price elasticity and sensitivity of three marketing variables (price, promotion and place). Through cross-price elasticity, he finds evidence of complementarity interactions between brands despite their substitution functions. Mussa and Rosen’s (1978) analysis on product line pricing shows that a monopolist provides products of different quality to capture consumer surplus. Little and Shapiro (1980) theoretically show that cross-

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2 Within this research, regular corn seed, input-trait corn seed, and output-trait corn seed refer to conventional corn seed, Bt corn seed, and high-oil corn seed, respectively.
elasticities, elasticities, margins, and demand determine the optimal price. Oren et al. (1984) analyze product line pricing for a firm within a competitive setting assuming no reaction from rivals when a firm sets its prices. Moorthy and Png (1992) examine the product line-pricing problem with the assumption that a monopolist introduces the products sequentially instead of simultaneously. Kadiyali et al. (1996) extend the product line-pricing problem within a duopolistic setting where a firm prices its products taking in account its rival’s reaction. Their empirical test on firms selling laundry detergent proves that a leader-follower strategy is an option when pricing different products.

These different studies related to product line pricing consider a simple market structure to analyze the pricing problem faced by a firm supplying many products. These studies consider some variables of the marketing mix. With the introduction of biotechnology-derived seeds, a seed firm faces farmers’ acceptance and competitive reaction from within the industry and outside the industry as explained earlier. This study extends the product portfolio problem within a competitive setting by modeling a three-step competition variable. The first competitive variable incorporates the different benefits provided by each type of seed. The second competitive variable incorporates a marketing mix ratio, which depicts the relative value of the non-price competition strategies (place and promotion). The third competitive variable evaluates the reaction of the other farm input producers whose market is likely affected by seed producers. The representative seed firm simultaneously supplies both existing and improved seed varieties, which target the same well-defined market segments.

With the continuous market changes, pricing strategies as modeled here stress the importance of value or benefits that the product provides to customers. Price is associated with the notion of perceived value\(^3\). Morris and Morris (1990) depict perceived value in terms of low price as well as benefits received such as improved quality or unique quality traits. Hence, a higher perceived value presupposes a willingness to buy the product; otherwise customers search for alternative brands (Martins, 1993).

\(^3\) For more detail see Thomas Nagle (1997) and Michael Marn (1997).
Variable costs of production for the three seed varieties are assumed to be equal. Given the changing characteristic of the seed market that is reflected by farmers’ and grain users’ attitudes toward different seed varieties and the resulting objective of maximizing the firm’s revenues, this study intends to provide seed producers with useful insights on specific factors influencing the pricing strategy of a portfolio of competing seeds for a given planning horizon. Dynamic programming (DP) is an appealing method because seed producers will be able to identify the time paths of these influencing factors and the resulting time path of preferred price from the beginning to the end of the planning horizon.

**Adoption Behavior of the Decision Maker**

Farmers as well as grain’s users search for profit as well efficiency in their production operations when adopting a specific seed variety. Their attitude toward a seed’s attributes will differ with respect to seed varieties.

For regular corn seed, the purchase decision is based on its yield performance given the fact that each farmer is a price taker in the farm input and output markets. A positive change in corn yield implies an increase in farm revenue assuming unchanged other variables (other related farm inputs). However, yield improvement depends on the environmental conditions under which the corn is grown. Besides the yield improvement, the purchase of the regular corn seed is also related to corn price. A change in the price of corn may affect a farmer’s purchase decisions. Corn price impacts the size of acreage allocated to grow corn. Farmers’ response is incorporated through “output price elasticity”, which measures the change in acreage with respect to corn price change. The direct impacts of yield improvement are not incorporated in the model.

The input-trait corn seed targets the same corn market but it presents the unique additional advantage of reducing input cost at the farm level. In this case, the farmer’s adoption decision depends on the expected net revenue from using the input-trait corn seed. If the expected return (net profit) from using the input-trait corn seed exceeds the expected return (net profit) from using the
regular corn seed, the adoption of the input-trait seed is possible. Assuming that other farm input

costs remain unchanged, the change in the farmer’s returns can occur through either a change in the
corn price, a reduction of other input cost (pesticide costs), or a positive change in seed performance
(reduced risk of losing crops). If a farmer believes that the input-trait is able to withstand some
environment conditions that provoke yield loss, the adoption of the input-trait corn seed is possible.
Thus, a farmer adopts the seed if he/she expects a better yield distribution. Let $g_R$ be the corn yield
per acre from using regular corn seed and $g_I$ corn yield from using input-trait corn seed. The
conditions of adoption are
\[
g_I > g_R \quad \text{and} \quad w_I s_I + w_p p_I \leq w_R s_R + w_p p_R
\]
\[
g_I \geq g_R \quad \text{and} \quad w_I s_I + w_p p_I \leq w_R s_R + w_p p_R
\]
where:
\[
w_I \quad : \text{is the price of input-trait corn seed},
\]
\[
w_R \quad : \text{is the price of regular corn seed},
\]
\[
s_I \quad : \text{indicates the quantity of input-trait corn seed for a given unit of land},
\]
\[
s_R \quad : \text{indicates the quantity of regular corn seed for a given unit of land},
\]
\[
w_p \quad : \text{is the price of pesticide, whose trait is incorporated into the seed},
\]
\[
p_I \quad : \text{indicates the amount of pesticide applied when input-trait corn seed is used},
\]
\[
p_R \quad : \text{indicates the amount of pesticide applied when regular corn seed is used}.
\]
This research is concerned with the first moment conditions.

Assuming the same corn price, the cost saving is the factor motivating the adoption/purchase
of the input-trait seed. Farmer’s attitude for the cost saving associated with the input-trait corn seed is
incorporated through a substitution effect variable.
The use of output-trait corn seed (high-oil corn seed) presents many benefits depending on the users’ needs. Farmers grow high-oil corn to meet the specific needs of poultry growers. One of the benefits is the cost savings associated with the use of output-trait corn seed such as replacing expensive ration ingredients and increasing ration energy while adding less supplemental fats in most cases because of high nutrient density provided by corn grain. At the farm level, these benefits are translated in terms of financial incentives for potential farmers’ participation, specifically in terms of premiums. The producer premiums are based on the oil content. Premiums paid range between $0.05 and $0.25 under harvest delivery contract and between $0.10 and $0.30 under a buyer’s call contract (U.S. Grains Council, 1999). These incentives may come from poultry growers or seed firms, depending on the type of coordination. Poultry growers decide the high oil corn need based on the potential cost saving. The amount of substitution between high oil, regular corn, and supplemental fats that occurs drives contracted incentives or premiums. This research assumes a simple coordination, which consists of contractual agreements between farmers and poultry growers, and no involvement of the seed firm. We use an acreage (high oil acreage) response to the premium as an adopting variable for the output-trait corn seed.

Seed firms expect to sell product every growing season. The demand of each seed variety at time t consists of new customers and repeats (number of acres allocated to a specific seed variety). The purchasing decision is based on the benefits that each seed variety provides to the users. Within the competitive setting and with a profit maximization objective, the benefits of a specific seed variety should outweigh the benefits provided by alternative seeds in order to be adopted. It is important to note that the target of output-trait corn seed is not directly the farmer but poultry growers. Any changes in the economics of poultry production might influence farmers’ decisions to grow the output-trait corn seed. If high-oil corn (from output-trait corn seeds) provides a higher input cost saving to poultry growers, they might be willing to increase their demand and at the same time the increase of incentives (premium) to farmers.
The Model

To address the research objectives, we use a dynamic programming approach. One of the benefits of the DP model is its ability to identify an optimal pricing strategy under a range of conditions through parametric variations of state variables. The DP model is based on Bellman’s Principle of Optimality, which consists of decomposing one-T period optimization problem into T connected, one-period optimization problems (Taylor and Duffy, 1994). The research model is based on the following assumptions:

1. The seed firm and the farmer are profit-maximizers.
2. Farmers respond to output-trait premiums and inputs costs by adjusting acres allocated to each corn variety.
3. Adoption is related to the benefits provided by each corn seed variety.
4. Seed firm relies on farmer’s learning curve.
5. Biotechnology-derived corn seeds (input-trait and output-trait) and hybrid corn seeds target the same market.
6. The unit variable cost of producing any type of seed is not materially different.
7. A fixed adopting market size is considered.
8. Farmers are price-takers in both input and output markets.

The objective of the representative seed firm that supplies a competing set of seed varieties in the market is to maximize its portfolio returns over a T-period time horizon. The objective function is Bellman’s recursive equation written below:

\[
V(s_t) = \max_{w_t} (R_t + rV(s_{t+1}))
\]

\[
R_t = \sum_i w_i d_t^i
\]

\[
d_t^i = \left[ (g_t^i (D^M - d_{t-1}^i) + \beta d_{t-1}^i) z_t^i \right] (w_{t-1}^i)^{-\alpha_t^i}
\]

\[
g_t^i = \exp(-\alpha_t^i) d_{t-1}^i
\]

where:
\( V(s_t) \): present value of discounted returns given a vector of state variables at time \( t \),

\( s_t \): value of state variables at time \( t \),

\( R_t \): one period return at time \( t \),

\( d_t^i \): number of acres allocated to a seed type \( i \) at time \( t \),

\( D^M \): maximum adopting market size (in acres),

\( w_t^i \): price of seed type \( i \) at time \( t \),

\( \alpha_t^i \): adopting variable of seed \( i \) (output price elasticity for regular seed elasticity of substitution for input-trait seed, and premium response for output-trait seed) at \( t \),

\( g_t^i \): coefficient of adoption of seed \( i \) at time \( t \),

\( r \): time preference discount factor,

\( \beta \): repeat purchase parameter,

\( t \): time index,

\( i \): seed type index,

\( z_t^i \): marketing mix ratio for seed type \( i \) at time \( t \).

Due to the lack of information mainly on the biotechnology-derived seeds, most of the ranges of data are generated given some data from different published sources (various issues of USDA-ERS, various issues of U.S. Grains, journal articles, University extension, Internet, personal contact with seed consultants and dealers). For instance, the price of the three seeds is the decision variable. The regular seed price ranges from $20 to $30 per acre. The statistics on regular corn seed price per acre averages $25 (USDA, AREI, 1997). The input-trait corn seed’s price differential ranges from $0 to $20 with a minimum gross price of $25 per acre and a maximum of $45 per acre. The output-trait corn seed’s price differential ranges from $0 to $18 with a minimum gross price of $25 per acre and a
maximum of $43 per acre\textsuperscript{4}. The price range of the output-trait corn seed is close to the price range provided by the U.S. Grains Council (1999). This research assumes that both biotechnology-derived corn seeds are not priced below their respective minimum price ($25).

The marketing mix ratio $z_{ij}$ reflects the relative non-price marketing effort of a specific seed firm compared to competitors’ marketing effort. The marketing mix ratio is in terms of promotion mix and distribution channel of the seeds. We model the non-price competition variable in a way that it shows only the relative value compared to competition within the industry. If the relative value of these non-price competition variables is the same within the industry or among participants, a value of 1 is assigned to the marketing mix ratio. However, if the hypothetical seed firm is less competitive than other participants in the industry, the ratio is assigned a value below 1. Otherwise, a value above 1 is a sign of competitiveness of the firm compared to the industry. For simplicity, this ratio is assumed the same for the three seeds. The main question to be addressed is how preferred seed pricing strategy responds when marketing effort is below, equal, or above competitors’ non-price marketing effort.

The market share variable indicates the percentage of acres allocated to seed from a given firm. At each period, a market share for the next state is calculated based on current demands compared to adopting market size. By introducing the biotechnology-derived corn seed, the firm expects to convert some of its regular seed customers as well as the potential adopters from the remainder of the market. The state transition equation reflects the potential changes in a state variable from time $t$ to the next period. The potential change in quantity is captured through a market share state variable. The firm evaluates the effect of pricing strategy on different state variables and the resulting increase or decrease of its market share from one period to the next. Therefore, at each period of time, firm market share for the current period is calculated as current demand (acres) over the total adopting market size and is carried forward as beginning market share in the next period.

\textsuperscript{4} The price range of biotechnology-derived corn seeds is based of personal contacts with seed consultants and dealers.
Due to the lack of incorporation of corn and pesticide price dynamics, this research considers a stable environment for output price elasticity, premium response, and elasticity of substitution variables, which are manually varied to detect their influence on price decisions. It would be interesting to investigate the portfolio pricing effects when these variables change over time, but that is beyond the scope of this research.

The benefits of each seed are incorporated in the demand model through an adopting variable. The adopting variable \( \alpha_i \) represents users’ attitude toward different benefits of each seed variety (output price elasticity for the regular corn, the substitution effect for the input-trait seed, and the acreage response with respect to premium for the output-trait seed). For the output-price elasticity, we generate estimates using the estimated corn acreage-corn price elasticity from Lee and Helmberger (1985) in the free market regime and develop a search interval for the value. For the elasticity of substitution, we use the results reported by Fernadez-Cornejo (1993) and generate some estimates. For premium response, at this point, no information on high oil corn acreage response with respect to premium paid is available. But, as long as the acreage allocation to high-oil corn is trending up, we generate a range of this coefficient given the range of premium. Note that the expected increase in high-oil acres is about 10% (from 1 million in 1998 to 1.2–1.3 million acres in 1999, U.S. Grains Council, (1999)). The corn price used in this research is $2.50, which is close to $2.42, a 10-year average price, 1989-1998 (Agricultural Statistics, 1999). Given the above information, we generate a range of premium response between 0.06 and 0.14. A low premium implies low acreage response, low oil content, and low expected returns. However, a high premium implies high acreage response, high oil content, and high-expected returns. The coefficient of adoption captures the responsiveness to perceived benefits of each specific variety of corn seed. The trend variable \( b_t \) changes with perceived benefits of each seed type.

The time frame considered in this research is 6 years. According to Ollinger and Pope (1995), this is the estimated development time for new biotech seed varieties. Furthermore,
discussions with industry executives indicate the product life cycle on new corn varieties is often shorter than that. Thus, the research assumes that the variables affecting farmers’ attitudes will remain materially stable for a while.

Although, the analysis is built on the principle of optimization, no discovery of optimal price is expected within this research, but a preferred price path is observed given the assumptions of the model. Furthermore, although the parameterization of the DP model, as developed in Table 2, results in numeric solutions, the magnitude of these solutions is fully dependent upon the assumptions. Therefore, interpretation of price path direction and relative prices between products is more useful than accepting the absolute numbers in the results.

Table 1. DP Model Design

<table>
<thead>
<tr>
<th>DP Search</th>
<th>Range</th>
<th>Grid Size</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Decision Variables</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Price, Regular Corn</td>
<td>$20-$30</td>
<td>10</td>
<td>Using the midpoint approach, the range is $20.5-$29.5</td>
</tr>
<tr>
<td>Price, Input-trait Corn</td>
<td>$25-$45</td>
<td>20</td>
<td>Premium range over a minimum gross price of $25 is $0.5-$19.5 using the midpoint approach</td>
</tr>
<tr>
<td>Price, Output-trait Corn</td>
<td>$25-$43</td>
<td>20</td>
<td>Premium range over a minimum gross price of $25 is $0.45-$17.55 using the midpoint approach</td>
</tr>
<tr>
<td><strong>State Variable: Market Share</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regular Corn</td>
<td>0-10%</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Input-trait Corn</td>
<td>0-8%</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Output-trait Corn</td>
<td>0-7%</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td><strong>Specified State Variables</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Manually Varied:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Market Mix Ratio</td>
<td>0.75-1.15</td>
<td></td>
<td>The model considers the following 0.8, 1.0, and 1.1</td>
</tr>
<tr>
<td>Output Price Elasticity</td>
<td>0.05-0.16</td>
<td></td>
<td>The model considers the values of 0.085 and 0.095</td>
</tr>
<tr>
<td>Substitution Effect</td>
<td>0.10-0.22</td>
<td></td>
<td>The model considers the values of 0.1025 and 0.1125</td>
</tr>
<tr>
<td>Premium Response</td>
<td>0.06-0.14</td>
<td></td>
<td>The model considers the values of 0.096 and 0.112</td>
</tr>
<tr>
<td><strong>Fixed Parameters:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Repeat Purchase</td>
<td>80%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discount Factor</td>
<td>10%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adopting Market Size</td>
<td>65 millions acres</td>
<td></td>
<td></td>
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</tbody>
</table>
Analysis and Discussion

The focus of this section is on how managers should price a set of competing corn seeds within a competitive setting and short product life cycles. A limited number of variables affecting the pricing strategy of the seed firm are considered (Table 1). These different variables reflect either the attitude of farmers toward perceived benefits of using a particular seed variety or the degree of non-price competitiveness of the firm within the industry.

Based on market share variable, two scenarios are presented. First, the seed firm does not have substantial market share and three seeds are simultaneously introduced as new products. Second, the seed firm does have substantial market share for the regular corn. The biotechnology-derived seeds are introduced as an extension to the regular seed. In this case, the seed firm starts producing one corn seed (regular corn seed). As market demand changes, customers request new and improved seed attributes. The seed firm extends its product line with biotechnology-derived corn seeds (input-trait corn seed and output-trait corn seed).

Thus, we present first the pricing strategy depending on market share condition. Second, we present the impact of farmer’s attitude toward seed attributes and non-price competitive effort on the resulting pricing strategy. Then, the different effects of those influencing factors are summarized in terms of discounted returns.

Impact of beginning market share on the pricing strategy

In the evaluation of the impact of starting market share, a lower value of output price elasticity, a marketing mix ratio of 1, and the repeat purchase parameter (80%) are unchanged over the time horizon. Figure 1 and Figure 2 below present the single pricing time path vs. portfolio pricing of regular seed with respect to beginning market share of zero and beginning of market share of 10% for regular seed.

Beginning market share of the firm has an impact on the pricing time paths of the seed. When the seeds are simultaneously introduced as new products (zero beginning market share (0.0%)),
the results have indicated an increasing pricing trend (penetration strategy) for a single seed as well as a portfolio of competing seeds due to farmer’s learning approach. The seed firm prices low in order to capture market share, and then increase it over time. Seed price increases as market share increases, given a set of market conditions. (Table 2 and Table 3).

Table 2. Single Pricing Time Path of Regular Seed with 0.0% Beginning Mkt Share, Low Output Price Elasticity and Marketing Mix of 1

<table>
<thead>
<tr>
<th>Time</th>
<th>Reg. Price</th>
<th>R&lt;sub&gt;t&lt;/sub&gt; ($000)</th>
<th>rV(s&lt;sub&gt;t+1&lt;/sub&gt;) ($000)</th>
<th>V(s&lt;sub&gt;t&lt;/sub&gt;) ($000)</th>
<th>Ending Share1 (%)</th>
<th>D1 (000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20.50</td>
<td>16,687</td>
<td>463,697</td>
<td>480,384</td>
<td>1.25</td>
<td>814</td>
</tr>
<tr>
<td>2</td>
<td>20.50</td>
<td>49,569</td>
<td>507,080</td>
<td>556,649</td>
<td>3.72</td>
<td>2,418</td>
</tr>
<tr>
<td>3</td>
<td>20.50</td>
<td>113,303</td>
<td>438,616</td>
<td>551,919</td>
<td>8.50</td>
<td>5,527</td>
</tr>
<tr>
<td>4</td>
<td>26.50</td>
<td>172,250</td>
<td>310,227</td>
<td>482,477</td>
<td>10.00</td>
<td>6,500</td>
</tr>
<tr>
<td>5</td>
<td>27.50</td>
<td>178,750</td>
<td>162,500</td>
<td>391,250</td>
<td>10.00</td>
<td>6,500</td>
</tr>
<tr>
<td>6</td>
<td>27.50</td>
<td>178,750</td>
<td>--</td>
<td>178,750</td>
<td>--</td>
<td>6,500</td>
</tr>
</tbody>
</table>

Reg. Price refers to regular corn seed’s price. R<sub>t</sub> stands for Returns ($000) at time t. rV(s<sub>t+1</sub>) refers to present value of returns given state variable at time t+1. V(s<sub>t</sub>) is the sum of R<sub>t</sub> and rV(s<sub>t+1</sub>). D1 stands for Regular Corn Seed Demand (000 acres). Ending Share1 stands for Regular seed share to be carried forward.

Table 3. Portfolio Pricing Time Paths of Regular and Input-trait Seeds with 0.0% Beginning Mkt Share, Low Output Price Elasticity and Elasticity of Substitution, and Marketing Mix of 1

<table>
<thead>
<tr>
<th>Time</th>
<th>Reg. Price</th>
<th>Intrait Price</th>
<th>R&lt;sub&gt;t&lt;/sub&gt;&lt;sup&gt;1&lt;/sup&gt; ($000)</th>
<th>R&lt;sub&gt;t&lt;/sub&gt;&lt;sup&gt;2&lt;/sup&gt; ($000)</th>
<th>V(s&lt;sub&gt;t&lt;/sub&gt;) ($000)</th>
<th>Ending Share1 (%)</th>
<th>Ending Share2 (%)</th>
<th>D1 (000)</th>
<th>D2 (000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20.50</td>
<td>25.50</td>
<td>16,646</td>
<td>26,877</td>
<td>1,211,776</td>
<td>1.25</td>
<td>1.62</td>
<td>812</td>
<td>1,054</td>
</tr>
<tr>
<td>2</td>
<td>20.50</td>
<td>25.50</td>
<td>49,077</td>
<td>79,330</td>
<td>1,286,306</td>
<td>3.68</td>
<td>4.79</td>
<td>2,394</td>
<td>3,111</td>
</tr>
<tr>
<td>3</td>
<td>20.50</td>
<td>35.50</td>
<td>109,183</td>
<td>180,908</td>
<td>1,261,903</td>
<td>8.19</td>
<td>7.84</td>
<td>5,326</td>
<td>5,096</td>
</tr>
<tr>
<td>4</td>
<td>25.50</td>
<td>43.50</td>
<td>165,750</td>
<td>222,111</td>
<td>1,070,361</td>
<td>10.00</td>
<td>7.85</td>
<td>6,500</td>
<td>5,106</td>
</tr>
<tr>
<td>5</td>
<td>26.50</td>
<td>42.50</td>
<td>172,250</td>
<td>221,000</td>
<td>750,750</td>
<td>10.00</td>
<td>8.00</td>
<td>6,500</td>
<td>5,200</td>
</tr>
<tr>
<td>6</td>
<td>26.50</td>
<td>42.50</td>
<td>172,250</td>
<td>221,000</td>
<td>393,250</td>
<td>--</td>
<td>--</td>
<td>6,500</td>
<td>5,200</td>
</tr>
</tbody>
</table>

Reg. Price and Intrait Price refer to Regular and input-trait corn seed’s price. R<sub>t</sub><sup>1</sup> stands for Returns ($000) at time t for regular corn seed. R<sub>t</sub><sup>2</sup> stands for Returns ($000) at time t for input-trait corn seed. V(s<sub>t</sub>) is the sum of R<sub>t</sub> and rV(s<sub>t+1</sub>). D1 and D2 stand for Regular and Input-trait Corn Seed Demand (000 acres). Ending Mkt Share 1 and 2 stands for Regular and Input-trait seed shares to be carried forward.
Figure 1 Single vs. Portfolio Pricing Paths of Regular Seed with Low Elasticity of Substitution, With 0.0% beginning market share and Marketing Mix Ratio of 1

![Figure 1](image-url)

However, with substantial beginning market share, two sets of pricing strategies are indicated given similar market conditions: decreasing and fixed pricing paths. The decreasing pricing path (skimming strategy) consists of setting relatively high prices at the beginning, and then decreasing price over time given special market circumstances such as competition from within and outside the firm. A fixed pricing path is based on a fixed price over time. Decreasing and fixed pricing paths are mainly indicated for the existing seed given certain market conditions (Tables 4 and 5).

Table 4  Single Pricing Time Path of Regular Seed with 10% Beginning Mkt Share, Low Output Price Elasticity, and Marketing Mix of 1

<table>
<thead>
<tr>
<th>Time</th>
<th>Reg. Price</th>
<th>$R_t$</th>
<th>$rV(s_{t+1})$</th>
<th>$V(s_t)$</th>
<th>Ending Share</th>
<th>D1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>27.50</td>
<td>178,750</td>
<td>677,603</td>
<td>856,353</td>
<td>10.00</td>
<td>6,500</td>
</tr>
<tr>
<td>2</td>
<td>27.50</td>
<td>178,750</td>
<td>575,613</td>
<td>745,363</td>
<td>10.00</td>
<td>6,500</td>
</tr>
<tr>
<td>3</td>
<td>27.50</td>
<td>178,750</td>
<td>444,524</td>
<td>623,274</td>
<td>10.00</td>
<td>6,500</td>
</tr>
<tr>
<td>4</td>
<td>27.50</td>
<td>178,750</td>
<td>310,227</td>
<td>488,977</td>
<td>10.00</td>
<td>6,500</td>
</tr>
<tr>
<td>5</td>
<td>27.50</td>
<td>178,750</td>
<td>162,500</td>
<td>341,250</td>
<td>10.00</td>
<td>6,500</td>
</tr>
<tr>
<td>6</td>
<td>27.50</td>
<td>178,750</td>
<td>--</td>
<td>178,750</td>
<td>--</td>
<td>6,500</td>
</tr>
</tbody>
</table>

Reg. Price refers to regular corn seed’s price. $R_t$ stands for Returns ($000) at time t. $rV(s_{t+1})$ refers to present value of returns given state variable at time t+1. $V(s_t)$ is the sum of $R_t$ and $rV(s_{t+1})$. D1 stands for Regular Corn Seed Demand (000 acres). Ending Share1 stands for Regular seed share to be carried forward.
Table 5 Portfolio Pricing Time Path of Regular Seed with 10% Beginning Mkt Share and Input-trait Seed with 0.0% Beginning Mkt Share, Low Output Price Elasticity and Elasticity of Substitution, and Marketing Mix of 1

<table>
<thead>
<tr>
<th>Time</th>
<th>Reg. Price</th>
<th>Intrait Price</th>
<th>R1(t) ($000)</th>
<th>R2(t) ($000)</th>
<th>V(s) ($000)</th>
<th>Ending Share1 (%)</th>
<th>Ending Share2 (%)</th>
<th>D1 (000)</th>
<th>D2 (000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>27.50</td>
<td>25.50</td>
<td>178,750</td>
<td>24,913</td>
<td>1,563,239</td>
<td>10.00</td>
<td>1.50</td>
<td>6,500</td>
<td>977</td>
</tr>
<tr>
<td>2</td>
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<td>25.50</td>
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<td>10.00</td>
<td>4.47</td>
<td>6,500</td>
<td>2,907</td>
</tr>
<tr>
<td>3</td>
<td>27.50</td>
<td>34.50</td>
<td>177,017</td>
<td>177,986</td>
<td>1,332,958</td>
<td>9.90</td>
<td>7.93</td>
<td>6,437</td>
<td>5,159</td>
</tr>
<tr>
<td>4</td>
<td>26.50</td>
<td>42.50</td>
<td>172,250</td>
<td>221,000</td>
<td>1,075,750</td>
<td>10.00</td>
<td>8.00</td>
<td>6,500</td>
<td>5,200</td>
</tr>
<tr>
<td>5</td>
<td>26.50</td>
<td>42.50</td>
<td>172,250</td>
<td>221,000</td>
<td>750,750</td>
<td>10.00</td>
<td>8.00</td>
<td>6,500</td>
<td>5,200</td>
</tr>
<tr>
<td>6</td>
<td>26.50</td>
<td>42.50</td>
<td>172,250</td>
<td>221,000</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>6,500</td>
<td>5,200</td>
</tr>
</tbody>
</table>

Reg. Price and Intrait Price refer to Regular and input-trait corn seed’s price. \( R_1(t) \) stands for Returns ($000) at time \( t \) for regular corn seed. \( R_2(t) \) stands for Returns ($000) at time \( t \) for input-trait corn seed. \( V(s) \) is the sum of \( R_t \) and \( rV(s_{t+1}) \). D1 and D2 stand for Regular and Input-trait Corn Seed Demand (000 acres). Ending Share1 and 2 stands for Regular and Input-trait seed shares to be carried forward.

Figure 2. Single vs. Portfolio Pricing Paths of Regular Seed with Low Elasticity of Substitution

Pricing strategy with respect to farmers’ attitude towards seed’s attributes

The efficient way to identify the effect of output price elasticity is to hold the value of some variables unchanged and rerun the model. The marketing mix ratio is held at a value of 1, implying that non-price competition effort is the same within the industry. For regular corn seed, a lower value of output price elasticity implies that farmers’ attitude toward corn is relatively less price sensitive than with a higher value of output price elasticity. The degree of responsiveness is presented in
Figure 3. As the graph shows, the increase of seed price is faster with a higher market response than with a relatively lower response.

Figure 3. Single Pricing Time Path of Regular Seed: Low vs. High Output Price Elasticity

A similar trend is observed for the input-trait seed and the output-trait seed as shown in Figure 4 and Figure 5 respectively. In the case of input-trait seed, a lower elasticity of substitution implies that the seed provides less cost saving to the farmer. It may also be an indication of intense competition from pesticide producers in the sense that pesticide producers may compete by reducing their price in order to make the seed less valuable to farmers. However, a higher value implies that pesticide is relatively more expensive and the use of input-trait corn seed provides farmers with relatively more cost savings. The pricing strategy implies the importance of supplying valued seeds.

Figure 4. Single Pricing Time Path of Input-trait Seed: Low vs. High Elasticity of Substitution
For the output-trait seed, the pricing strategy depends on the acreage response as premiums paid to farmers change, given a marketing mix ratio. This acreage response coefficient is referred to as “premium response.” The assumption is that when the premium paid is low, farmers may not be willing to allocate more acreage to output-trait seed. But the reverse may be observed in the case that farmers are paid higher premiums to grow those specialty seeds. The premium response is an indication of the degree of acreage response given a change in the value of premium paid. The price of supplemental fats affects the premiums paid for high oil corn. Figure 3 presents the pricing time paths of output-trait seed. With a higher premium response, the price increases more rapidly than with a lower response. This price trend is similar to Figure 3 related to regular seed and Figure 4 related to input-trait seed.

Figure 5. Single Pricing Time Path of Output-trait Seed: Low vs. High Premium Response

Pricing strategy with respect to non-price competitive efforts

In addition to beginning market share and farmers’ responsiveness, this research has emphasized the relative impact of two marketing mix variables that influence firm sales: promotion mix and distribution channels. Given the existing market share and the seed benefits, the different pricing strategies indicated earlier are affected by the degree of non-price competitive effort of the firm. Depending on the degree of competitiveness of the firm relative to its competitors, the increase in the seed price is faster in a more non-price competitive position \(Z = 1.1\) than in neutral \(Z = 1\) or
less competitive position with $Z = 0.8$ (Figure 6). The effects are the same in the case of single pricing as well as in the case of a portfolio of competing seeds.

**Figure 6. Single Pricing Time Path with Low Output Price Elasticity and Different Marketing Mix**

Recall that the seed firm’s objective is to maximize its discounted returns. This objective is pursued through a seed diversification strategy. By supplying more than one seed variety on the market, the seed firm is able to serve simultaneously several market segments. The results indicate that the single product price is relatively higher than the two-seed portfolio pricing, which is in turn relatively higher than the three-seed portfolio pricing. Figure 7 presents the different pricing paths of input-trait seed as priced as a single product as well as within either a portfolio of two or a portfolio of three seeds within a neutral marketing position (marketing mix ratio of 1). A similar result is reported in Figures 1 and 2 for the regular corn seed.

**Figure 7. Single vs. Portfolio Pricing Paths of Input-trait Seed with Low Elasticity of Substitution**
The downward shift in the portfolio pricing paths of input-trait seed as well as of the regular seed can be explained by the fact that there might be a complementarity relationship between these three seeds even though they are substitutes, as stressed in Urban’s work. This relationship is seen through negative cross-price elasticities between seeds as reported in Table 6. In case of low elasticities, a low pricing strategy is indicated in order to expand firm’s market share. With high elasticity, the seed firm expands through high price.

When there is substantial initial market share, evidence of negative cross-price elasticity between seeds is associated with low elasticities despite non-price marketing effort. However, when without initial market share, there is evidence of negative cross-price elasticity between seeds only in the case of low responsiveness regardless of non-price competitive position. But, there is no clear indication whether the negative cross-price elasticity is caused by the price change of a specific seed variety. Furthermore, the construction of the objective equation provides for exponential incorporation of time, forcing a delay in adoption. This delay generally models a learning curve. However, the slope of this curve with respect to seed technology, time and other variables is unknown. Also, the general computation of cross-price elasticity does not incorporate a simultaneous pricing move. But, this research does consider a simultaneous pricing strategy. By doing so, this synchronized pricing move may have an impact on the results. Consequently, it would be interesting to direct further investigation into the elements of the cross-price elasticity and the adoption equation.

| Table 6 Evidence of Negative Cross-Price Elasticity for Portfolio of both Two and Three Seeds |
|----------------------------------------------------------------------------------------------------------------------------------|---------------------------------|---------------------------------|
| Low Elasticity with Marketing mix of ratio 0.8 |
| Low Elasticity with Marketing mix ratio of 1.0 |
| Low Elasticity with Marketing mix ratio of 1.1 |
| High Elasticity with Marketing mix ratio of 0.8 |
| High Elasticity with Marketing mix ratio of 1.0 |
| High Elasticity with Marketing mix ratio of 1.1 |
| With Existing Market Share For Regular Seed | Without Existing Market Share For Regular Seed |
| Yes | Yes |
| Yes | Yes* |
| Yes | Yes* |
| No | No |
| No | No |
| No | No |

* Indicates that there is no change in the quantity demanded of one seed variety with respect to the price change of another seed variety. This result might be explained by the fact that either the required maximum market share is fixed or there is a simultaneous pricing move of the seeds.
Impact on the discounted returns of the seed firm

By extending the seed line, the three portfolio scenarios present relatively higher discounted returns than returns in the case of single seed pricing. Table 7 summarizes the changes in the discounted returns from low elasticities to high elasticities under the single pricing (input-trait seed) vs. portfolio pricing of two seeds scenarios (regular and input-trait seeds). These results are similar for single pricing as well portfolio pricing of three seeds.

Table 7  Single Vs. Portfolio Pricing of Two Seeds: Changes in Discounted Returns From Supplying Less Valued To High Valued Seeds

<table>
<thead>
<tr>
<th>Marketing Mix Ratio</th>
<th>Single Pricing: Change in Discounted Returns of Input-trait Seed/ no Mkt share (000)/Low Elasticity</th>
<th>Returns (000)/High Elasticity</th>
<th>Change (%)</th>
<th>Portfolio Pricing: Change in Discounted Returns with Substantial Mkt Share (000)/Low Elasticity</th>
<th>Returns (000)/High Elasticity</th>
<th>Change %</th>
<th>Change in Discounted Returns without Substantial Mkt Share (000)/Low Elasticity</th>
<th>Returns (000)/High Elasticity</th>
<th>Change (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z=0.8</td>
<td>651,375</td>
<td>799,084</td>
<td>22%</td>
<td>1,380,600</td>
<td>1,674,020</td>
<td>21.3%</td>
<td>945,702</td>
<td>1,341,486</td>
<td>41.8%</td>
</tr>
<tr>
<td>Z=1.0</td>
<td>777,045</td>
<td>844,546</td>
<td>8%</td>
<td>1,563,239</td>
<td>1,750,528</td>
<td>12.0%</td>
<td>1,211,776</td>
<td>1,473,350</td>
<td>21.0%</td>
</tr>
<tr>
<td>Z=1.1</td>
<td>804,786</td>
<td>862,042</td>
<td>7%</td>
<td>1,652,030</td>
<td>1,766,363</td>
<td>6.9%</td>
<td>1,321,712</td>
<td>1,517,511</td>
<td>14.8%</td>
</tr>
</tbody>
</table>

Change is the percentage increase in discounted returns over the planned horizon from low to high seed elasticities.

The discounted returns with high elasticities are higher than the results with low elasticities. But, portfolio returns are higher than the returns reported in the case of single seed. Within the portfolio, the seed firm maximizes its returns faster when there is substantial market share of the existing seed (regular seed) and both seeds are simultaneously priced regardless of marketing mix ratio and elasticities. However, with respect to elasticities, the discounted returns considerably change in the case of no existing market share for input-trait seed. For instance, given a neutral non-price competitive position, there is larger change in the discounted returns when both seeds are priced as new products (21.0%) compared to 12% with substantial market share and concurrent pricing, and 8% in the case of single pricing of input-trait seed. The same trend is observed with both remaining non-price competitive positions. Also, the result implies that the seed firm needs a better
understanding of the additional expenditures related to R&D of each seed variety in order to undertake improvement in seed attributes. To improve simultaneously different attributes of both seeds, substantial investments are needed in all cases, but the seed firm might invest more when both seeds are priced as new seeds on the market. For input-trait seed, the result can also provide an indication of degree of competition from pesticide side. It may imply that any action from the pesticide industry has important consequences on the input-trait seeds.

With respect to non-price marketing efforts, the discounted returns associated with low elasticities expect to change by $116,577,000 with substantial market share and fixed price for regular seed, $182,639,000 with substantial market share for regular seed, and $266,045,000 without substantial market share, respectively, when the seed firm improves its marketing position from less competitive to a neutral non-price competitive position. The cost effectiveness of updating existing distribution channels and promotion can explain the relative small change in the discounted returns in the case of substantial market share compared to the discounted returns without market share. Analogous changes are observed when the seed firm moves from a neutral non-price competition to a higher non-price competitive position, but at smaller pace ($58,540,000 with some initial market share and fixed regular price; $88,791,000 with substantial market share and simultaneous pricing; and $109,936,000 without initial market share). The discounted returns considerably change when the seed firm improves its marketing effort from less to more non-price competitive situation. Thus, to maximize its returns, the seed firm should examine its non-price competitive situation. These results are in line with Dorfman and Steiner as well as Spence, who point out the positive influence of non-price marketing efforts on product demand. This result implies that it is lucrative to increase non-price marketing effort when the discounted returns for additional quantities (sales) are higher than when there is small contribution from additional sales (Ross et al., 1990). But a further investigation on the cost-effectiveness of this strategy is useful. In addition, the results indicate that a sustainable high pricing strategy is associated with substantial non-price competitive effort.
Conclusion

This paper has focused on pricing strategies of a set of competing seeds. The seed portfolio comprises a regular corn seed and two biotechnology-derived corn seeds (with cost-lowering input-trait and value enhanced output-trait). Given the changes in customer’s preference, biotechnology techniques have played an important role in meeting customer’s needs in the seed industry. However, pricing these competing seeds to generate satisfactory returns within a limited product life cycle is one of the problems. This research examines the sensitivity of the pricing paths of this portfolio of seeds with respect to market changes using DP approach.

The results indicate that managers should consider (incorporate) market conditions when setting a pricing strategy for these competing seeds. The different market conditions incorporated in the DP model considerably impact the pricing paths of both single and portfolio pricing paths. The analysis reveals that single and portfolio pricing time paths of competing seeds are affected by the firm’s initial market share, farmers’ responsiveness to perceived seed benefits, and the firm’s competitiveness outside and within the seed industry.

Other things being constant, the seed firm maximizes its returns faster when it captures substantial market share at the time improved seeds are introduced. For instance, for a 6-year planning horizon, the discounted returns associated with high elasticities are about $1,750,528 with substantial initial market share for regular seed versus $1,473,350 without initial market share for regular seed, within an equally competitive environment (Table 7). In terms of pricing strategy, either a skimming or a fixed pricing strategy is indicated for the existing seed given farmers’ response to seed benefits and non-price marketing effort in order to maintain market share. A penetration pricing strategy is indicated for new seeds being introduced.

As the seed firm expands its product line, the single pricing path is comparatively higher than the portfolio-pricing path of the competing seeds as shown in Figure 5.6. This descending trend can be explained by the implicit competition between seeds’ attributes despite their substitution function. The implicit competition is seen through negative cross-price elasticity.
With respect to the non-price marketing effort, a sustainable high price is possible with a higher degree of non-price marketing effort. Also, the outcomes have pointed out the substantial differences between being uncompetitive (marketing mix ratio of 0.8) and being either equally competitive (marketing mix ratio of 1.0) or substantially more competitive (marketing mix ratio of 1.1) versus the weak differences in results between equally competitive and substantially more competitive. Noting that the difference between 0.8 and 1.0 is 0.2 and the difference between 1.0 and 1.1 is 0.1; the issue is the cost effectiveness of investing in promotion and distribution channels and the need to analyze carefully the particular parameters that characterize the market.

With respect to farmers’ responsiveness to perceived benefits, this study finds that low elasticities generate a lower pricing trend and a slower market share expansion. The reverse is seen in the case of high elasticities. The need for strong seed benefits is reflected in the potential changes in the discounted returns of the seed firm. The research findings have also revealed the substantial changes in the discounted returns from having farmers with lower perceived value versus higher perceived value in seed benefits. Given the difference between the numbers used to represent farmers’ attitudes, the time value comparison of additional expenditures associated with seed improvement is more than necessary. In both cases, it is not a given or a certainty that such investments will be beneficial. The results have shown that farmers’ acceptance of a seed variety will have an impact on seed price or actions from the seed firm even though they are theoretically and empirically price-takers in the input markets. Finally, an eventual action from the pesticide industry may have an impact on seed firm pricing strategy.

One might argue that the fixed characteristic of the repeat purchase parameter might explain some of the results. Also, the fixed nature of cost structure and adopting market share may have an impact on the result. A clear knowledge of the cost structure of the seed firm would be useful in computing profit generated by the firm when expanding its product line. Once the cost structure is known, the seed firm can easily evaluate the contribution of additional marketing expenditures or R&D expenditures required for seed attribute improvement.
Reference:


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USDA, *AREI Productions Inputs/Pesticides*. 1997

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