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PART TWO: Industry Issues

9. Preferred Price Paths of Biotechnology-Derived Products: Time and Portfolio Affects

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Chapter 9

Preferred Price Paths of Biotechnology-Derived Products: Time and Portfolio Affects

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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 affects is to shorten the product life cycle of 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. Therefore, pricing new and existing products together has become more critical than ever.

This paper develops an analytical approach to preferred pricing time paths of a portfolio of seed products, which simultaneously addresses the goals of encouraging adoption and maximizing a firm's returns within a competitive environment while considering shorter product life cycles. The seed portfolio consists of existing (regular) seed and improved, biotechnology-derived seed whose characteristics are valued by target users within the same market niche. To address this objective, this study uses a dynamic pricing model. One of the benefits of using a DP model in this application is its ability to identify an optimal pricing strategy under a range of conditions through parametric variation of state variables.

Research Setting

Product quality has become a dynamic force in firms' survival. In fact, firms widely use product quality to gain competitive advantage in the market. Firms use product quality to enhance demand, to reduce customers' sensitivity to price, and to expand customer loyalty (Narasimhan et al. 1993). In the agriculture production sector, product improvement is associated with the emergence of biotechnology techniques. The introduction of biotechnology offers the opportunity for marketing channel participants to be more focused on customer demands by providing a large set of improved and differentiated products.

Biotechnology has become an important tool of product differentiation at the input level to the extent that input suppliers have the ability to design inputs, which provide varieties of food products targeting specific and well-identified food market niches (Ray 1995). The increasing use of biotechnology has raised different issues to be considered carefully, such as patents, intellectual property rights, alliances, and so forth. The present study focuses on the issue of product life cycle and the issue of pricing.

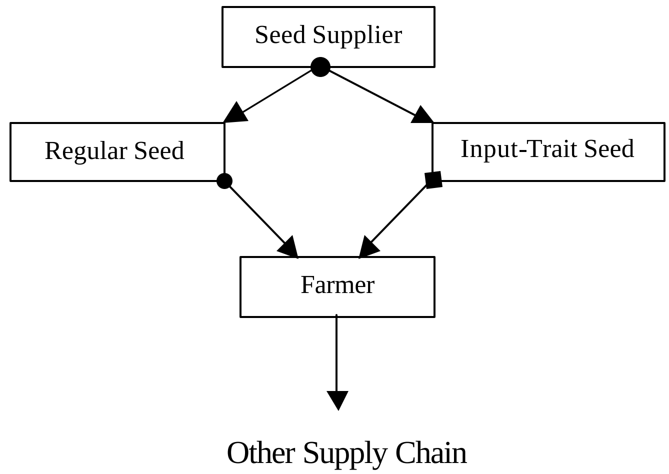
It is commonly believed that biotechnology-derived products, once introduced, have a shorter expected life cycle. Competition among participants shortens the life cycle of new products, but by an uncertain amount. As participants compete on a customer satisfaction basis, they are continuously searching for the best marketing tools for competitive advantage. Also, as customers' needs are continuously changing, input as well as output producers adapt their production systems to that change in order to develop and improve their products accordingly.

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, this study investigates the seed industry for the following three reasons. First, the seed industry and its product introduction systems have undergone rapid change. Biotechnology plays an important role in the improvement of characteristics of existing seeds and in the design of new varieties. 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). In addition, seed firms face competition from other producers of farm inputs whose inputs are substitutes for biotechnology-derived seed characteristics. This paper considers this last form of competition in the evaluation of the portfolio pricing.

Regular corn seed and modified input-trait corn seed (herbicide resistant seed) comprise the seed portfolio in the simplified environment modeled here. With the introduction of biotechnology, farmers have the opportunity to grow modified input-trait seed to satisfy participants' needs in the same market served by regular seed as described in Figure 1. This study ignores recent developments in U.S. marketing channels resulting from the European trade environment concerning genetically modified products. The use of herbicide resistant seed, for example, allows farmers to reduce other input costs by applying less herbicide chemicals. However, herbicide producers are not willing to stand by idly as their markets are invaded. Thus, the preferred pricing time paths may be altered by their competitive reactions.

FIGURE 1 Seed Value Chain



Previous Studies

Several studies have investigated the pricing strategies of a firm producing multiple products that compete in the same market. Urban (1969) analyzed a product line model to find the best marketing mix for each product. Brand interdependency was tested through direct and cross elasticities, and the sensitivity of three marketing variables (price, promotion, and place). Little and Shapiro (1980) theoretically showed that cross-elasticity, own-elasticity, and margins determine the optimal price. Kadiyali et al. (1996) extended the product line-pricing problem within a duopolistic setting, considering a rival's reaction. Their empirical test on firms selling laundry detergent proved that a leader-follower strategy was an option when pricing different products. Since the emergence of biotechnology-derived products, few studies have analyzed the pricing problem within this sector. Tauer and Love (1989) investigated the potential economic impacts of herbicide-resistant corn in the USA, using simulation techniques. They found that U.S. corn production would increase about 2 to 4 % while corn prices might drop by 20 or more cents per bushels. Their analysis focused on the economic impacts at the farm level.

The present study considers the pricing problem at the input firm level taking into account market conditions, farmers' behavior, and competition from herbicide producers. The seed producers extend their product line with a biotechnology-derived seed that competes with the firm's existing seeds in the same market. However, direct competition within the seed industry is omitted. Although, direct competition may restrict the price received by a firm, the objective here is to identify the desired price given the characteristics of the market. Market dynamics are considered through the elasticity of substitution. This situation best describes participants in the biotechnology business where competition within the industry is expected for some time in the future because seeds are in either an introductory phase or an experimental phase.

Model Parameterization

Hybrid corn seed is a nondurable product, which is sold each growing season. The demand for each variety at time t consists of new acres allocated to a specific seed variety and the repeat customers (previous acres) of the variety.[2] The assumptions upon which the model is built include the following:

1. The seed firm and the farmer are profit-maximizers.
2. Farmers respond to output price by adjusting acres. Thus, output price elasticity drives seed purchase.
3. Competition is considered through elasticity of substitution.
4. Adoption is related to the benefits provided by each seed type.
5. Biotechnology-derived corn seeds and hybrid seeds target the same market.
6. The unit variable cost of producing any seed variety is the same.
7. A fixed adopting population size is considered.
8. Farmers are price-takers in both input and output markets.
9. Constant price for regular seed.
10. Biotech seed price is always greater than regular seed price.

Although the cost of production is assumed the same for both products, it is also assumed that the development costs of the input-trait seed are higher as are the benefits to the user. Therefore, the input-trait seed will be priced at a non-negative differential to the regular seed. The price differential is a choice variable in order to maximize the seed producer's return over time. The price of biotech seed is calculated as below:

$$w_t^I = w_t^R + \boldsymbol{q}_t^R \tag{1}$$

where w_t^I, w_t^R, and $\boldsymbol{q}_t^R$ are the price of biotech seed, the price of regular seed price, and the price differential, respectively, at time t. The problem of the firm consists of finding an acceptable price differential that provides adequate returns above development costs.

This study uses dynamic programming (DP) to examine the pricing time paths of the corn seed portfolio. The recursive equation is the following Bellman's equation:

$$V(s_t) = \underset{W_t}{Max}(R_t + rV(s_{t+1})) \tag{2}$$

$$R_t = \sum_i w_t^i * d_t^i$$

$$d_t^i = \left[\boldsymbol{a}_t^i * (D^M - d_{t-1}^i) + \boldsymbol{b} * d_{t-1}^i\right] * (w_t^i)^{-(h_t^i)} \tag{3}$$

$$\boldsymbol{a}_t^i = \exp(-\boldsymbol{h}_t^i) * d_{t-1}^i$$

where

$V(s_t)$: present value of discounted returns given a vector of state variables (output price elasticity, elasticity of substitution, and market share) 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,

s_t : value of state variables (output price elasticity, elasticity of substitution, and market share) at time t,

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

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

h_t^i : elasticity variable of seed i (output price elasticity for regular seed and elasticity of substitution for input-trait seed) at time t,

α_t^i : coefficient of adoption of seed i at time t,

r : discount factor,

β : repeat purchase parameter,

t : time index,

i : seed type index.

A dynamic programming algorithm (DP) is selected because of its flexibility in identifying an optimal decision under a range of conditions through parametric variation of state variables. In addition, the DP algorithm facilitates comparative analyses under uncertain time horizons. The DP algorithm requires the development of a number of components (Bellman and Dreyfus 1962). The first component is the objective function in the form of equation (2). The second component is the incorporation of state variables to depict the market conditions that impact the decision variable (equation (3). These state variables change over time by the means of transitions that describe the changing of market conditions.

This paper assumes that the market conditions of regular seed are known in terms of market share and the associated hybrid seed price. Thus, the problem is to find the best price differential to apply to biotech seed. As a result, the decision variable of this paper is the price of the biotech seed given the following state variables: output price elasticity associated with the regular seed, elasticity of substitution associated with the modified input-trait seed (biotechnology-derived seed)[3], and market share. The DP algorithm also requires specification of a search grid. To parameterize the DP model, the relevant range of decision and state variables must be identified.

Output Price Elasticity State Variable

The output price elasticity used for regular seed is corn acreage/corn price elasticity. Empirical results (Fernandez-Cornejo 1993) have outlined the inelastic characteristics of the own-price elasticity of demand of seed. Since a farmer is a price taker in the input market (Huffman and Evenson 1989, Shumway 1983), the output price elasticity is used instead of elasticity of demand. The corn acreage allocation depends on the market price of corn[4]. The farmer allocates more or less acreage to corn whenever the corn price is high or low. We use 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 of the state variable. With a mean of .118 and a standard deviation of .067, we consider a range of output price elasticity between .07 and .15, incorporating 95% of the associated normal distribution. This range is consistent with the output price elasticity estimated by McIntosh and Shideed (1989), whose estimates range from 0.05 to .18 over the period of 1957-82. The use of output price elasticity estimates from a free market regime is consistent with the present U.S. farm program.

This paper considers a stable trend of output price elasticity. It would be interesting to evaluate the pricing strategy when the output price elasticity is changing over time. However, without associated corn price dynamics such an exercise adds little value.

Elasticity of Substitution State Variable

The elasticity of substitution used in the case of input trait seed reflects the opportunity to reduce the application of pesticides in the production system. Herbicides constitute the largest class of applied pesticides for major crops such as corn, cotton, soybeans, and wheat (57 %)[5]. A median value of 0.30 for the Allen elasticity of substitution (Chambers 1988: 94) is assigned from USDA/AREI data. The resultant search grid spans elasticity values from 0.23 to 0.37.

The transition equation for the elasticity of substitution is modeled as a probabilistic transition. Using a hyperbolic tangent approximation of the normal (Taylor 1984), a probability transition matrix of the elasticity of substitution from one state to the next is found. A Markov process is assumed for the elasticity of substitution where

$$\eta_t = \eta_{t-1} + \varepsilon \qquad (4)$$

with the error term distributed *N(0, 0.004489)*. The elasticity of substitution indicates the degree of competition from herbicide-chemicals producers. Without data to support a standard deviation for this distribution, the coefficient of variation for output price is used to derive one.

Coefficient of Adoption

The coefficient of adoption α_t^i is determined by the benefits provided by each of the two seed types. Previous studies (Griliches 1957, Knusdon 1991) have used the logistic diffusion model to estimate the diffusion of crops (hybrid corn and the semi-dwarf wheat varieties) respectively. The general form is the following equation:

$$dN(t)/dt = bN(t)(N^M - N(t)) \qquad (5)$$

where:

$dN(t)/dt$: changes in adoption over time,

b	:	natural rate of adoption,
$N(t)$	:	cumulative numbers of adopters at time t,
N^M-$N(t)$	:	number of potential adopters left at time t.

The model imposes a symmetric diffusion trend with a maximum diffusion rate occurring when at least 50% of the potential cumulative adopters have accepted the product (Knudson 1991, Mahajan and Peterson 1985). For ease of comparison, this paper uses this diffusion model but the natural rate of adoption is an exponential function of the benefits provided by each type of seed (equation 3).

The output price elasticity for the regular seed and the elasticity of substitution for the input-trait seed incorporate the benefits. The output price elasticity reflects the income to be generated from corn production in general whereas the elasticity of substitution reflects more the cost saving associated with the use of input-trait corn seed. These elasticity ranges mentioned earlier are adjusted so that the resultant diffusion coefficient fits the assigned interval. The adjustments are made with a linear function (appendix A). The diffusion rate is used to identify demand for biotech seed. The output price elasticity is used to reshape the market size.

Market Share State Variables

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 the adopting market size. The present study considers a maximum market share of 15% for the hypothetical firm. In the portfolio pricing setting, the market share maximum is allocated between regular corn (9.6%) and input-trait seed (4.8%) because of the dynamics of product introduction. The regular seed is assumed fully adopted in the market. By introducing the input-trait seed, the firm expects to convert some of its regular seed customers as well as the potential adopters from the entire market.

Price Decision Variables

The DP algorithm searches for the best price vector within a set min-max range. The price for regular seed is held at a constant value of \$25 per acre (USDA, AREI 1997). A "bag" of seed corn is usually sold by kernel count and covers approximately three acres. The input-trait seed's price differential ranges from \$12 to \$26 per acre.

Stages and Search Grid

The time frame considered in this paper 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.

The size of the search loop of the DP program is a multiplicative function of the number of stages, state variables, decision variables, and the number of values of each variable that are evaluated. If K_j is the number of values of variable j to be evaluated, there are J variables, and T is the number of periods evaluated, then the size of the search loop is given by the following expression:

(6) $$\text{Search loop size} = T\prod_{j=1}^{J} K_j$$

Thus, the "curse of dimensionality" comes under consideration quickly as J increases. In this analysis, J is equal to 4 and T is set at 6. A search grid is used, with K_j equal to 20 for all variables. First, this is a preliminary analysis in search of the relevant variables, which is part of the DP method. Second, a coarse grid allows the discovery of the relevant range of each relevant variable, enabling a focus for future analysis.

Analytical Results and Discussion

Presenting DP results is a challenge due to the enormous volume of output. For simplicity and to identify the relevant ranges of state and decision variables, only small portions of the results are discussed here. As mentioned earlier, each state variable affects the pricing strategy of the firm in different ways. Thus, it is interesting to assess pricing strategy associated with each state variable. Depending on the starting conditions of the state variables, a different pricing strategy can be implemented.

The first set of results presents the pricing time paths of input-trait seed with respect to beginning market share. Prices are reported as the regular seed price ($25) plus the differentiated on a per acre basis. The expected elasticity of substitution does not change. The pricing time paths depend on the transitions of the market share.

TABLE 1 Pricing Time Paths of Input-trait Seed with Year 1 Market Share 0.4% and Elasticity of Substitution 0.28

	Expected Remaining Time											
Time Horizon	6		5		4		3		2		1	
	Price	Mkt[a]	Price	Mkt[a]	Price	Mkt[a]	Price	Mkt[a]	Price	Mkt[a]	Price	Mkt[a]
Year 1	37	0.4	37	0.4	37	0.4	37	0.4	37	0.4	37	0.4
Year 2	37	0.8	37	0.8	37	0.8	37	0.8	37	0.8	--	--
Year 3	37	1.9	37	2.0	37	1.9	37	1.9	--	--	--	--
Year 4	45	4.1	47	4.2	47	4.0	--	--	--	--	--	--
Year 5	48	4.8	48	4.8	--	--	--	--	--	--	--	--
Year 6	48	4.8	--	--	--	--	--	--	--	--	--	--

[a]New Market Share at each period (%).

Table 1 and Table 2 describe different pricing strategies with respect to beginning market share. Preferred price increases with increasing market share. Initially, the firm prices low in order to capture market share. As the market share starts increasing, an increasing pricing strategy is adopted. With a slight increase in starting market share percentage (Table 2), a different trend of pricing time paths is observed in which price rises faster.

TABLE 2 Pricing Time Paths of Input-trait Seed with Year 1 Market Share 1.8% and Elasticity of Substitution 0.28

	Expected Remaining Time											
Time Horizon	6		5		4		3		2		1	
	Price	Mkt[a]	Price	Mkt[a]	Price	Mkt[a]	Price	Mkt[a]	Price	Mkt[a]	Price	Mkt[a]
Year 1	37	1.8	37	1.8	37	1.8	37	1.8	37	1.8	37	1.8
Year 2	44	4.1	43	4.0	45	4.1	45	4.1	45	4.1	--	--
Year 3	46	4.5	47	4.5	47	4.8	48	4.8	--	--	--	--
Year 4	48	4.8	48	4.6	48	4.8	--	--	--	--	--	--
Year 5	48	4.8	48	4.8	--	--	--	--	--	--	--	--
Year 6	48	4.8	--	--	--	--	--	--	--	--	--	--

[a]New Market Share at each period (%).

The general conclusion is that the starting market share impacts the pricing strategy of the biotech seed over time. The pricing time path is trending up with respect to market share. However, the remaining time horizon is not a factor in the pricing decision, as both Tables1 and 2 suggest. Year 1 price is the same regardless of the remaining product life.

The second set of pricing strategies evaluated is with respect to the elasticity of substitution where a higher elasticity of substitution indicates greater cost benefits to the user of seed. Table 3 and Table 4 present the pricing time paths of the biotech seed with a starting elasticity of substitution index of 0.31, but 0.4% and 1.8% beginning market share, respectively.

Comparing Table 1 and Table 3, with the same market share but different elasticity of substitution, price increases faster with a higher elasticity of substitution. The same trend is also observed when comparing Table 2 and Table 4.

TABLE 3 Pricing Time Paths of Input-trait Seed with Year 1 Market Share 0.4% and Elasticity of Substitution 0.31

	Expected Remaining Time											
Time Horizon	6		5		4		3		2		1	
	Price	Mkt[a]	Price	Mkt[a]	Price	Mkt[a]	Price	Mkt[a]	Price	Mkt[a]	Price	Mkt[a]
Year 1	37	0.4	37	0.4	37	0.4	37	0.4	37	0.4	37	0.4
Year 2	38	1.3	38	1.3	38	1.4	38	1.4	38	1.3	--	--
Year 3	50	3.9	51	4.6	51	4.8	50	4.6	--	--	--	--
Year 4	51	4.6	51	4.8	51	4.8	--	--	--	--	--	--
Year 5	51	4.8	51	4.8	--	--	--	--	--	--	--	--
Year 6	51	4.8	--	--	--	--	--	--	--	--	--	--

[a]New Market Share at each period (%).

TABLE 4 Pricing Time Paths of Input-trait Seed with Year 1 Market Share 1.8% and Elasticity of Substitution 0.31

	Expected Remaining Time											
Time Horizon	6		5		4		3		2		1	
	Price	Mkt[a]	Price	Mkt[a]	Price	Mkt[a]	Price	Mkt[a]	Price	Mkt[a]	Price	Mkt[a]
Year 1	43	1.8	43	1.8	44	2.1	44	2.1	44	2.1	44	2.1
Year 2	49	4.0	50	3.9	50	4.0	50	4.1	51	4.5	--	--
Year 3	51	4.7	51	4.6	51	4.7	51	4.8	--	--	--	--
Year 4	51	4.8	51	4.8	51	4.8	--	--	--	--	--	--
Year 5	51	4.8	51	4.8	--	--	--	--	--	--	--	--
Year 6	51	4.8	--	--	--	--	--	--	--	--	--	--

[a]New Market Share at each period (%).

The different results in Table 1, Table 2, Table 3, and Table 4 show that remaining time impacts the evolution of pricing strategy of the biotech seed. In year 1, a low pricing strategy is considered in order to increase the market share. However, if there is enough time remaining over the product life cycle, seed price is more responsive to elasticity of substitution and market share.

From these different tables, we can conclude that both the elasticity of substitution and the market share drive the pricing strategy of the biotech seed. The results also indicate that the remaining period has a little impact on preferred pricing of the seed. However, a further investigation of the sensitivity of the price to any change of the output price elasticity is warranted. Furthermore, the results indicate 1) that firms with little knowledge of their markets elasticity can make poor choices, and 2) a relevant product development strategy remains finding a product that can capture market quickly.

Conclusion and Implication for Future Work

This paper develops an analytical pricing model for a seed firm that extends its products line with a biotech seed, which has valuable attributes. The model considers the affects of the remaining time over the product life cycle on the desired price, the substitution effects, and the market share. The results indicate that starting market conditions with respect to the elasticity of substitution and market share affect the pricing strategy of the firm. Also, the pricing strategy is not different for shorter or longer planning horizons.

These results seem to be consistent with Little and Shapiro's theoretical findings. This paper has considered a stable output price elasticity and competition from herbicide producers. Further investigation is needed for a better understanding of the impact of market dynamics on the pricing strategy of firms supplying a portfolio of seed. First, the inclusion of both direct (within the industry) and indirect (from herbicide producers) competition is necessary in pricing strategy. Second, It would be interesting to assess how seed price may change when the output price elasticity is no longer constant as assumed in this paper.

Appendix A - Adjustment Equation

$\boldsymbol{a} = \exp(-f(\boldsymbol{h}))$ with $f(\boldsymbol{h}) = a + b\boldsymbol{h}$

$\boldsymbol{h}^i$ adjusted = $-(a + b\boldsymbol{h}^i)$

Calculate a and b for both seeds using the following expressions

$$\boldsymbol{h}^1 adjusted = -(a + b\boldsymbol{h}^1)$$
$$\boldsymbol{h}^2 adjusted = -(a + b\boldsymbol{h}^2)$$

Replace $\boldsymbol{h}^i$ and $\boldsymbol{h}^i$ with the estimates (0.07 and 0.15) for the output price elasticity and (0.23 and 0.37) for the elasticity of substitution in order to find a and b parameters.

Endnotes

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[2]This assumes that each grower has identified an agronomically optimum rate of seed.

[3]Biotechnology-derived corn seed and input-trait seed are interchangeably used in this paper.

[4]Relevant farmer output mix decisions (e.g. corn versus soybeans) are not considered.

[5]USDA/AREI/ production inputs.

References

Bellman, R. E. and S. E. Dreyfus. 1962. *Applied Dynamic Programming.* Princeton, N.J.: Princeton University Press.

Chambers, R. G. 1988. *Applies Production Analysis: A Dual Approach*. Cambridge: University Press.

Cooper, R. G. 1993. *Winning at New Products: Accelerating the Process from Idea to Launch*. Second Edition. Addison-Wesley Publishing Co.

Ducos, C. 1987. Semence et Biotechnology: une analyse économique. in *Le Droit du GénieGénétique végétal*, ed. M.A. Hermitte, 75-99 Paris: Libraries Techniques.

Engelke, G. L. 1997. Advances in Corn Hybrids Bring Change. *Feedstuffs*, 69(20), May.

Fernadez-Cornejo, J. 1993. *Demand and Substitution of Agricultural Inputs in the Central Corn Belt States*. USDA, Economic Research Service, Technical Bulletin 1816.

Griliches, Z. 1957. Hybrid Corn: An Exploration in the Economics of Technological Change. *Econometrica*, 25:501-522.

Huffman, W. E. and R. E. Evenson. 1989. Supply and Demand Functions for Mutltiproduct U.S. Cash Grain Farms: Biases Caused by Research and Other Policies. *American Agricultural Economics Association*, August:761-773.

Kadiyali, V., N. J. Vilcassim, and P. K Chintagunta. 1996. Empirical Analysis of Competitive Product Line Pricing Decisions: Lead, Follow, or Move Together? *Journal of Business*, 69(4):459-487.

Knudson, M. K. 1991. Incorporating Technological Change in Diffusion Models. *American Journal of Agricultural Economics*, August:724-733.

Lee, D. R. and P. G. Helmberger. 1985. Estimating Supply Response in the Presence of Farm Programs. *American Agricultural Economics Association*, 67(2):193-203.

Little, J. D. C. and J. F. Shapiro. 1980. A Theory for Pricing Nonfeatured Products in Supermarkets. *Journal of Business*, 53(3):S199-209.

Mahajan, V. and R. A. Peterson. 1985. *Models for Innovation*. Beverly Hills CA: Sage Publications.

McIntosh, C. S. and K. H. Shideed. 1989. The Effect of Government Programs on Acreage Response over Time: The Case of Corn Production in Iowa. *Western Journal of Agricultural Economics*, 14:38-44.

Monroe, K. 1990. *Pricing: Making Profitable Decisions*. 2nd ed. McGraw-Hill Inc.

Narasimhan, R., S. Ghosh, and D. Mendez. 1993. A Dynamic Model of Product Quality and Pricing Decisions on Sales Response. *Decisions Sciences*, 24(5), 1993:893-908.

Ollinger, M. and L. Pope. 1995. *Plant Biotechnology: Out of the Laboratory and Into The Field.* USDA, Economic Research Service, Agricultural Economic Report Number 697. Washington DC.

Ray, D. 1995. Forces Shaping Tennessee Agriculture into the Next Century. Paper Presented at "Tennessee Agriculture: Status and Outlook reports" Meeting Governor's Council on Agriculture and Forestry October 24. http://apacweb.ag.utk.edu/apac/govdoc.html

Shumay, C. R. 1983. Supply, Demand, and Technology in a Multiproduct Industry: Texas Field Crops. *American Agricultural Economics Association*, 65:748-60.

Tauer, L. W. and J. Love. 1987. The Potential Economic Impact of Herbicide-Resistant Corn in the USA. *Journal of Production Agriculture*, 2:202-207.

Taylor, C. 1984. A Flexible Method for Empirically Estimating Probability Functions. *Western Journal of Agricultural Economics*, 9:66-76.

Urban, G. 1969. A Mathematical Modeling Approach to Product Line Decisions *Journal of Marketing Research*, 6:40-47.

USDA. 1996. *AREI/ Production Inputs/Pesticides*.