VARIETAL SALES AND QUALITY DIFFERENTIATION: THE CASE OF CERTIFIED SOYBEAN SEED IN THE SOUTHEASTERN U.S.

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Abstract

Variation in annual soybean plantings contributes to uncertainty in supplies of and demand for soybean seed in the southeastern U.S. This study used an expenditure valuation approach in an hedonic analysis framework to estimate returns to soybean seed quality differentiation. Analysis of pooled cross-sectional and time series observations narrowed important quality characteristics to yield and disease resistance attributes. In general, unexpected environmental factors affect seed crops over time, and the demand for other performance attributes is less predictable than for expected yield attributes. The results also suggest that geographical location is not significantly related to sales of varietal soybean seed in the study area.

Key words: seed quality, hedonic input estimation, expenditure valuation.

Soybean and other seed handlers have undergone periods of severe distribution uncertainty since the early 1970's. Some of the uncertainty as to what varieties and quantities of seed to handle may be attributable to impacts of the Plant Protection Act of 1970 and the increased number of soybean varieties. Variation of annual soybean plantings contributes to uncertainty in supplies of and demand for soybean seed. However, the increase in protected and certified seed varieties may also offer opportunities for increased sales within individual market areas. Genetic quality characteristics are transmitted through improved soybean seed from breeding research trials and translated into increased on-farm soybean productivity.

Many studies have examined crop inputs such as fertilizer, water, and energy. Price effects were found not to be the primary source of changing input demands, with technological change and net returns being more important in explaining derived demand (Bishop et al.; Smith et al.). Research on quality of outputs and final products has been extensive (Ladd), but little economic research has been done to estimate the value of seed quality characteristics.

This paper examines returns, as reflected by market sales, to quality characteristics derived through soybean breeding and research in the southeastern U.S. Identification of the value of certain quality characteristics of soybean seed is associated with the sales and market share of certified seed varieties distributed in the Southeast over the period 1984 to 1986. The impacts of quality characteristics on varietal sales and annual seed demand and supply forecasts are further discussed.

RELATED LITERATURE

Economic research in the estimation of the value or derived demand for inputs and their quality characteristics is sparse (e.g., Ladd and Martin; Carl et al.). Quality-related research has been extensive in commodity and product characteristics and pricing. Price analysis of product characteristics was used by Waugh for fresh vegetables. Waugh stated that market prices of many commodities tend to vary with certain physical characteristics, and the relation of these characteristics to price may be determined by statistical analysis. More than two decades after Waugh's work, the next significant theoretical

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works on product quality characteristics appeared separately by Theil and Houthakker in 1952 (Ladd). Theil argued that a consumer's utility is determined not only by the quantities of goods consumed but by qualities that the goods possess.

Griliches subsequently used the hedonic method for estimating fertilizer demand effects as did Fettig and Rayner and Cowling for tractors. With the exception of Ladd and Martin, more recent developments in hedonic modeling for agricultural goods have been primarily in outputs (Wilson; Brorsen et al.; Jordan et al.). Following Rosen, these studies developed hedonic models based on the assumption that products are differentiable by the amount of certain characteristics in the goods and that price reflects this differentiation. Thus, various characteristics are important factors in determining the overall market price of a product.

ECONOMIC MODEL

The theoretical model outlined here is based upon Rosen's framework. Rosen hypothesized that goods are valued for their utility-bearing attributes or characteristics. That is, a product can be described as a good possessing both various amounts and types of attributes. For a particular product i possessing j different characteristics, the price at which the product sells depends on the amount of each characteristic embodied in the product expressed as

$$(1)\ P_i = P(x_{i1}, x_{i2}, \ldots, x_{ij}),$$

where P_i = observed market price of product i, and x_{ij} = amount of some characteristic j per unit of product i.

The lack of price variation or discrimination by variety in the study area for soybean seed, however, necessitated an alternative dependent variable.[1] Due to this peculiarity of the soybean seed market, market sales volume by variety was considered more suitable for expressing the derived demand. Thus, in this study, quality of seed is associated with market sales volume. Furthermore, it was assumed there were no substitution possibilities for characteristics which were embodied only in a competing variety (e.g., resistance to Cyst Race 4 in variety i could not be substituted directly by such resistance in variety k). Given this latter assumption, the derived demand for an individual variety is based upon its own bundle of characteristics. Using the implicit functional form, the model is expressed as

$$(2)\ Q_i = Q(x_{i1}, x_{i2}, \ldots, x_{ij}),$$

where Q_i = sales volume of soybean seed variety i; and x_{ij} = amount of characteristic j per unit of soybean seed variety i.

DATA AND EMPIRICAL MODEL

Responses from experiment stations or certifying agencies about varietal characteristics and certified seed limited the regional analysis to Alabama, Georgia, North Carolina, and South Carolina. Information on quality characteristics of soybean seed measured in field trials in each state was obtained from the respective Agricultural Experimental Stations for the years 1984 to 1986. Guidelines for quality ratings variables were consistent with *The Uniform Soybean Tests, Southern Region* (U.S.D.A.).

Certified seed distribution data were collected from each state Crop Improvement Association. All data for each variety were summed by foundation, registered, and certified seed. Nearly 93 percent of the reported soybean seed sales were certified seed (Jeong). Reported volume (bushels) or acreage units (acres of each variety produced) were transformed into common weight units (pounds) for analysis. The general form of the estimated model is as follows:

$$(3)\ Q_i = f(\text{MGP6, MGP7, MGP8, SHT, LDG, SRK, CYS3, CYS4, YRS, YIELD, DUM85, DUM86, DUMAL, DUMNC, DUMSC}),$$

where Q_i is the quantity of certified soybean seed (pounds) sold, by variety, in the relevant local or regional market.[2] Quality variables included in the analysis and their respective measurements are as follows: maturity group, taken as the date when pods are dry and most

[1]Respondents to a survey of southeastern soybean seed handlers and distributors indicated no price differentials were charged for soybean seed in the study area. Available handling firm price lists from the time period were consistent with that finding. Thus the price of each variety i is assumed equal and constant, $P_1 = P_2 = \ldots = P_m$.

[2]Given no variation in prices (i.e., prices are constant), then quantity as indicated in equation (3) measures the sales effect.

leaves have dropped, was measured by binary intercept shifters to reference varieties from groups V through VIII (these variables were named MGP6, MGP7, and MGP8, with group V representing the base maturity group); shattering (SHT), generally measured on a scale from 1 to 5, with 1 being most resistant, was treated as a binary variable equal to 1 for scale values 1 and 2, 0 for others; lodging (LDG), measured on a scale of 1 to 5, with 1 having almost all plants erect, was treated as a binary variable equal to 1 for scale values 1 and 2, 0 for others; southern root knot resistance (SRK), measured on a scale of 1 to 5, with 1 being very resistant and 5 being very susceptible, was set equal to 1 for scale measures 1 and 2, 0 for others; and soybean cyst nematode reaction to races 3 and 4 (CYS3, CYS4), was measured with binary values set to 1 being very resistant and 0 otherwise.[3]

In addition to characteristics identified above, two continuous variables were included as quality indicators. These were average experimental yield (YIELD) and number of years since the variety was released to the market (YRS). Average experimental yield was reported for each variety in major soybean-producing areas of each state. Seed handlers reported that trial yield data were key indicators for future demand of new and replacement varieties for their producer customers (Jeong). The number of years since introduction was suggested to have a length-of-usage, or dependability and trust, effect on demand for seed varieties. Demand for a variety was hypothesized to depend somewhat on loyalty or satisfaction with previous use. Only when newer varieties were introduced and accepted, or when resistance to disease or other adverse conditions weakened demand for the established variety, would the older variety be replaced.

Three model scenarios were specified to obtain estimates of the value of seed characteristics. The first model was specified to evaluate the state-level market area effects of performance characteristics on sales and market shares. The cross-sectional data were pooled through time (i.e., observations of each variety for each of the three years, 1984 through 1986, were retained as one set) to determine the influence of performance characteristics on the varietal sales specific to each state. Dummy variables DUM1985 and DUM1986 were used for annual sales shifts from the base year, 1984, in pooling time-series data in estimation.

The second model was used to delineate the annual, or seasonal, variation in regional seed sales with respect to varietal performance characteristics. Annual observations of sales and associated characteristics were pooled for the four-state study area. Dummy variables, DUMAL, DUMNC, and DUMSC for Alabama, North Carolina, and South Carolina, respectively, were used for state shifters from the base state of Georgia in pooling the cross-sectional data.

The third model was specified to estimate the longer-term market effects of seed performance characteristics on regional varietal sales. Observations for each variety in each of the years 1984 through 1986 were pooled for the four states. Again, dummy variables were used for both annual and state sales shifts from the base year, 1984, and the base state, Georgia.

Since market sales volumes of certain varieties in a particular year were limited in their range (censored), the Tobit model was used in estimating the hedonic quality model (Maddala). This allowed the full sample to be used in the estimation of the model, rather than discarding the zero (i.e., censored) observations of the dependent variable.

VALUE ESTIMATES OF SEED CHARACTERISTICS

Results of state market area, annual regional, and pooled regional effects of performance characteristics on seed sales volumes are presented in the following sections. The estimated coefficients represent total potential additional pounds of seed sales related to each characteristic variable.[4]

[3]Some descriptive indicators, such as flower, hilum, and seed color, were hypothesized to be economically insignificant to soybean seed sales. However, these characteristics were tested before being omitted from further consideration. The results supported the hypothesis, as the relationships between those descriptive characteristics and varietal seed sales were statistically insignificant.

[4]Estimated coefficients presented in this paper represent the latent, or total potential, changes in sales expenditures with respect to the jth performance characteristic, $\partial E(y^*)/\partial x_{ij}$. With the appropriate assumptions, these coefficients can be decomposed into predicted sales effects (predicted shifts in sales), given that varietal sales are positive and predicted sales shifts without the information on nonzero seed sales (see Maddala, p. 160, or McDonald and Moffitt, p. 320).

TABLE 1. ESTIMATED SALES OF CERTIFIED SOYBEAN SEED IN ALABAMA, GEORGIA, NORTH CAROLINA, AND SOUTH CAROLINA, 1984-1986

Quality Variables	Estimated Regression Coefficient (Asymptotic t-value)							
	Alabama		Georgia		North Carolina		South Carolina	
CONSTANT	−9,062,600	(3.352)*	−8,735,700	(3.673)*	−48,645,000	(6.366)*	−23,652,000	(3.161)*
MATURITY VI	−1,539,200	(1.364)	−504,930	(0.899)	−1,453,500	(1.175)	N.A.	
MATURITY VII	−3,230,800	(2.762)*	272,060	(0.522)	−1,815,200	(1.423)	7,423,400	(3.191)*
MATURITY VIII	−3,373,700	(2.490)*	N.A.		−730,700	(0.464)	6,895,700	(3.495)*
SHATTER	−111,240	(0.144)	N.A.		6,131,000	(3.486)*	3,110,070	(1.874)
LODGING	63,110	(0.068)	−55,076	(0.094)	−4,290,300	(4.136)*	3,857,500	(2.650)*
ROOTKNOT	−1,502,800	(1.274)	1,172,200	(2.214)*	−699,510	(0.754)	4,948,900	(2.984)*
CYSTRACE3	1,177,900	(1.349)	−829,270	(1.392)	2,781,200	(2.983)*	363,890	(0.186)
CYSTRACE4	−3,594,700	(2.149)*	−1,112,100	(1.150)	1,624,300	(0.860)	2,175,300	(0.694)
YEARS	125,210	(2.384)*	−9,718	(0.227)	311,430	(3.322)*	311,420	(1.451)
YIELD	224,410	(4.033)*	230,170	(4.706)*	1,190,800	(6.134)*	409,830	(2.253)*
DUM1985	−693,760	(1.078)	−1,565,500	(3.248)*	169	(0.000)	−4,238,000	(3.162)*
DUM1986	−1,250,500	(1.898)	−1,698,100	(3.498)*	−790,510	(0.816)	−4,884,100	(3.528)*
Mean of Dependent Variable (Sales)	1,510,908		1,414,382		3,049,535		1,636,401	
Limit (zero) Obs.	15		13		13		8	
Non-limit Obs.	45		59		104		40	
Predicted[a]	0.683		0.768		0.737		0.810	
Sq. Corr.[b]	0.434		0.614		0.578		0.653	
Log-likelihood fn.	−724.713*		−932.709*		−1,741.355*		−633.126*	

* = 0.05 level of significance.

[a]Predicted probability of Y > Limit (zero), given average X (I).

[b]Squared correlation between observed and expected values.

State Market Area Effects

Estimates of the state market area model for the contiguous southeastern states of Alabama, Georgia, North Carolina, and South Carolina are presented in Table 1. Squared correlations between observed and expected values ranged from .434 in Alabama to .653 in South Carolina. Values of the likelihood ratios tested significant at the 5 percent level in the results for each state.

Compared to maturity group V, varieties in maturity groups VII and VIII were significantly less desirable in overall Alabama state sales during the planting years 1984 to 1986. Yield was statistically significant, as was anticipated from survey results of southeastern soybean seed handlers. The yield coefficient in the Alabama equation indicated a 224,410 pound increase in potential seed variety sales per one bushel increase in yield per acre. Years since release was also positively associated with sales of certified soybean seed in Alabama. That is, for an additional year since release, 125,210 pounds of potential seed sales increase would be expected. Resistance to soybean cyst race 4 had a significant, but negative, relationship with the selection of soybean seed varieties in Alabama. Very few varieties tested superior for this trait, and their sales were small and declining during the study period. This suggests that resistance to cyst race 4 was relatively unimportant in the study area and time period. The coefficient for the dummy variable 1986, DUM1986, was significant at a 10 percent level, indicating a negative adjustment for an overall decrease in soybean seed sales in 1986.

For Georgia, yield variation was statistically significant in the purchasing decision of certified soybean seed from Georgia seed handlers. The potential increase in sales of seed expected from a one-bushel-per-acre increase in anticipated average yield was 230,170 pounds of seed. Soybean root knot resistance was also significant and had the anticipated sign, implying that more resistant varieties have higher market sales volumes. Sensitivities to soybean cyst races 3 and 4 were not significant in the selected time period, but such resistance factors may be more important in smaller, selected market areas within the state. Lodging and years released before 1987 did not appear statistically significant, nor did maturity groups which were represented and tested as indicators for varietal selection. DUM1985 and DUM1986 for the annual sales shifts were significant in Georgia, indicating substantially decreased soybean acreages and seed sales from 1984 levels.

North Carolina had the largest number of soybean seed varieties among the states studied. Among the characteristic effects, yield had a significant influence on the sales volume of certified soybean seed in North Carolina, while resistance to soybean root knot and sensitivity to soybean cyst race 4 were generally not statistically important indicators of sales in North Carolina. However, resistance to soybean cyst race 3 and to shattering were significant and positive. Lodging resistance was significant and negatively associated with sales in this area. Years released, or variety loyalty, appeared to indicate positive market share influence for soybean seed sold in North Carolina. Newer varieties lessen potential for diseases and have generally higher yields. However, older varieties were still preferred, possibly due to their perceived reliability of yield and resistance.

South Carolina had few observed certified soybean seed varieties. Maturity groups VII and VIII had highly significant and positive coefficients associated with certified soybean seed sales in South Carolina. Trial yield data were also significant and consistent with expectations. Varieties which were more resistant to soybean root knot were likely to have higher market shares of certified soybean seed in South Carolina. Lodging and shattering resistance (significant at the 10 percent level) were also relevant indicators associated with seed sales in this state. Annual sales shifts (DUM1985 and DUM1986) were highly significant, indicating annual decreases of soybean seed sales in South Carolina during this period.

Annual Variation in Regional Seed Sales and Characteristics

The annual sales models for the four-state southeastern region (Table 2) demonstrated reasonable cross-sectional model fits, ranging from .422 for 1986 to .470 for 1984. Likelihood ratio tests indicated significance at the 5 percent level in all three cases. The actual number of certified soybean seed varieties with non-zero sales in each reported year is

TABLE 2. ESTIMATED SALES OF CERTIFIED SOYBEAN SEED IN SOUTHEAST AREA (ALABAMA, GEORGIA, NORTH CAROLINA, AND SOUTH CAROLINA), 1984–1986

Quality Variables	Estimated Regression Coefficients (Asymptotic t-value)					
	1984		1985		1986	
CONSTANT	−152,810,000	(3.478)*	−99,075,700	(3.946)*	−64,389,000	(3.675)*
MATURITY VI	−2,009,400	(0.155)	−5,743,400	(0.777)	−4,626,100	(0.911)
MATURITY VII	−6,175,000	(0.466)	−5,811,200	(0.773)	−3,487,400	(0.667)
MATURITY VIII	6,869,600	(0.466)	−3,253,600	(0.386)	−4,787,600	(0.815)
SHATTER	1,880,200	(0.168)	−1,120,500	(0.175)	−1,598,900	(0.353)
LODGING	2,512,400	(0.285)	−4,464,300	(0.898)	−1,742,500	(0.500)
ROOTKNOT	12,634,000	(1.271)	4,606,900	(0.835)	1,634,500	(0.118)
CYSTRACE3	2,852,300	(0.290)	787,600	(0.140)	2,629,700	(0.670)
CYSTRACE4	−37,342,000	(2.034)*	−4,203,400	(0.450)	1,730,400	(0.269)
YEARS	1,094,700	(1.360)	516,890	(1.133)	250,850	(0.799)
YIELD	3,657,300	(4.248)*	2,456,100	(4.860)*	1,640,500	(4.643)*
ALABAMA	−12,636,000	(1.104)	−4,198,600	(0.636)	440,140	(0.095)
NCAROLINA	−12,645,000	(0.953)	7,064,600	(0.907)	−3,246,600	(0.600)
SCAROLINA	5,793,800	(0.334)	14,966,000	(1.444)	8,325,500	(0.499)
Mean of Dependent Variable (Sales)	2,966,074		1,893,520		1,482,152	
Limit (zero) Obs.	13		17		19	
Non-limit Obs.	86		82		80	
Predicted[a]	0.676		0.670		0.647	
Sq. Corr.[b]	0.470		0.455		0.422	
Log-likelihood	−1,628.367*		−1,511.007*		−1,447.093*	

* = 0.05 level of significance.

[a]Predicted probability of Y > Limit (zero), given average X (I).

[b]Squared correlation between observed and expected values.

underestimated in the model. Stated another way, more varieties were sold each year than would be predicted by the quality differentiation evident.

Yield variation appeared consistently important in sales decisions for seed during the three years (Table 2). Resistance to soybean cyst race 4 was significant in 1984, while other variables were not statistically significant in any one year. Maturity groups VI, VII, and VIII were negatively related to market sales compared to group V in 1985 and 1986, but were not significant, demonstrating recent trends toward breeding varieties compatible to broader geographic areas in the Southeast (Henning and Eddleman). The resistance to soybean root knot and soybean cyst race 3 were weakly, but positively, related to market sales volume in the four-state area. Variety loyalty, measured by years since release, seemed to be an indicator of increasing market sales in the study area though not statistically significant at the 10 percent level. As a whole, the state dummy variables, ALABAMA, NCAROLINA, and SCAROLINA, did not appear statistically significant during the selected time period (1984–1986), indicating that geographical location was not highly correlated with varietal soybean seed sales in the study area.

Seed Characteristics and Regional Sales

Aggregate soybean seed sales were estimated over the time period 1984 to 1986 (Table 3). The annual cross-sectional data were pooled through time, resulting in three observations of each variety. Dummy variables ALABAMA, NCAROLINA, and SCAROLINA were used for state sales shifts relative to Georgia sales to handle the pooling of cross-sectional data in the estimation. 1985 and 1986 accounted for annual shifts in regional sales relative to 1984 in the pooling of time series observations. The squared correlation between the observed and expected values in the pooled estimation was .420, and the likelihood ratio test was significant at the 5 percent level.

Higher expected yield-producing and disease-resistant varieties were preferred by soybean seed handlers and purchasers in the study area. Yield variation was a statistically

TABLE 3. ESTIMATED AGGREGATE CERTIFIED SOYBEAN SEED SALES IN THE SOUTHEAST AREA, 1984–1986[a]

Quality Variables	Estimated Regression Coefficient	(Asymptotic t-values)
CONSTANT	−97,436,000	(5.110)*[b]
MATURITY GROUP VI	−4,586,200	(0.813)
MATURITY GROUP VII	−2,697,500	(0.467)
MATURITY GROUP VIII	−1,608,300	(0.249)
SHATTER RESISTANCE	−708,030	(0.143)
LODGING RESISTANCE	−1,909,500	(0.498)
SOUTHERN ROOTKNOT RESISTANCE	5,957,900	(1.406)
CYST RACE 3 RESISTANCE	2,271,400	(0.526)
CYST RACE 4 RESISTANCE	−9,597,700	(1.317)
YEARS SINCE INTRODUCED	563,720	(1.616)
EXPERIMENTAL YIELD	2,629,400	(6.962)*
ALABAMA	−2,942,700	(0.581)
NORTH CAROLINA	868,910	(0.147)
SOUTH CAROLINA	9,912,300	(1.270)
1985 SEASON	−10,288,000	(2.536)*
1986 SEASON	−15,312,000	(3.747)*
Mean of Dependent Variable (Sales)	2,113,915	
Limit (zero) Observations	49	
Non-limit Observations	248	
Predicted[c]	0.641	
Squared Correlation[d]	0.420	
Log-likelihood	−4,638.061*	

[a]Analysis includes Alabama, Georgia, North Carolina, and South Carolina.

[b]* = 0.05 level of significance.

[c]Predicted probability of Y > Limit (zero), given average X (I).

[d]Squared correlation between observed and expected values.

significant factor at the 1 percent level. Soybean root knot resistance and resistance to cyst race 4 were influential in sales decisions in the Southeast, though not statistically significant at generally accepted levels. Maturity groupings were insignificant in predicting total regional certified soybean seed sales but may be useful in select areas or in particular years. For the study area, varietal loyalty appeared to have a weakly significant relationship with seed sales.

Generally, unexpected environmental factors have affected seed crops over time, and the demand for quality attributes other than yield variation may be less predictable. These results are consistent with the goal of preferring certain seed characteristics in order to obtain higher and less variable yields in the long run.

CONCLUSIONS AND IMPLICATIONS

From the results of the hedonic analysis framework, several characteristics appeared to be important indicators for soybean seed sales decisions in the southeastern U.S. Geographical location was not an important indicator of total varietal soybean seed sales, but there were important differences in quality characteristics demanded in state and regional seed markets. The experimental, or expected, yield attribute was highly significant to seed sales over the time period studied (1984–1986) within the four states. Expected yield increases can portend significantly larger potential sales and thus market share. This information is rapidly transmitted from breeding and variety experimental trials through the extension system or sales representatives to the soybean seed handlers and producers.

Nematode resistance was also quite important but rather more location-specific. Disease-resistance attributes reduce variability of yields, especially in susceptible locations. Henning and Eddleman suggested that soybean breeding research has developed varieties adaptable to broad areas under production in the South, and Bradley et al. concluded that niche corn hybrids would disappear as superior germplasm is identified for adapting varieties to wide geographical areas. Results of this study support observations of that trend and its potential economic importance for seed firms and field crop producers.

The number of years since release may have a length-of-life effect on demand for varieties of seed, and established varieties were preferred by soybean seed handlers in the study area. Loyalty to seed variety was influential in the stocking and sales of soybean seed and was particularly strong in Alabama and North Carolina. This suggests that quality differentiation must be well-established prior to introduction of newer varieties. During periods of declining acreages, multiplicity of seed cultivars increases the risk of unprofitable sales or losses on select varieties. Though the demand for quality attributes other than expected yield may vary over time and place, the objective underlying soybean seed variety preference is to obtain consistently higher productivity through selection of varieties with bundles of characteristics which are locally appropriate. Experimental field trial results are quite useful leading indicators of such varieties.

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