Marginal Implicit Values of Soybean Quality Attributes

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Abstract

Soybean quality is becoming more important as markets realize its impact in relation to utility. Soybean meal protein level impacts animal feed efficiency and soybean seed oil content signifies the amount of oil to be used for food, fuel or industrial purposes. Because differences in quality levels exist, quantifying the impacts of these quality-price differences is essential so that the soybean industry understands the implicit-value of enhancing trait levels within a component pricing system. We examine this quality-price relationship using a hedonic price function to estimate and analyze implicit prices attributed to protein and oil contents of U.S. soybeans. We added a spatial dimension in the model by incorporating inter-state competition in soybean quality attributes. We find price premiums associated with higher levels of protein and oil content in soybeans produced within-state. There are also price discounts associated with higher levels of protein and oil content in soybeans from competing states. This indicates the importance of spatial competition in analyzing implicit values of soybean quality attributes.

Key words: agricultural markets, product quality, characteristic demand, spatial competition, hedonic price analysis, soybeans
JEL Classification: D12, L66, Q11, Q13

Introduction

Using a traditional hedonic model, this paper estimates the marginal implicit values of two quality attributes of U.S. soybeans—protein content and oil content—in order to examine soybean quality-price relationships, both intra-state and inter-state.

Historically, corn and soybean are treated as homogenous products. Because corn and soybean end-value has not been so transparent, it has not been easy to tie end-user preferences with producer decision-making. However, grain and oilseed trait levels are increasing in economic importance as commodity prices rise. Buyers of commodities, as well as industries that utilize derived co-products from processing, become more discriminating in their purchasing decisions. As the animal industry becomes more competitive and cost-conscious, feed manufacturers become more judicious of the nutrient factors of purchased ingredients. Rising demand in edible oil relative to soybean supply has significantly increased oil value, underscoring the market potential of increasing oil content as a percentage of soybean seed weight.

Soybean quality attributes vary from north to south due to climate which in turn affects variation in soybean germplasm seed. Soybean genetics, therefore, differ across geography. If differentiated quality is recognized through implicit premiums and discounts, regional price differences will vary by more than transportation costs. Price differences will also vary as quality attribute levels change.

Taylor (1916) has been cited as the first paper that noted the link between quality and price. Among earlier papers acknowledged as seminal works on hedonic analysis are Waugh (1928), Court (1939), Lancaster (1971), and Rosen (1974), with Court credited with being the first to use the term “hedonic.” Ladd and Martin (1976) and Ladd and

Suvannunt (1976) later adapted the general theory and developed the theoretical foundations of performing hedonic analysis in agricultural products.

Despite the importance of having knowledge on how, or if, commodity prices changes as quality attributes levels change, we find very few studies that perform hedonic analysis on soybeans. We did, however, find some that are related. The United Soybean Board has found that 66 percent of their membership favors a soybean component pricing system (United Soybean Board, 2012). However, there is a lack of attribute content information by which to analyze added value due to increasing attribute contents from protein or oil. Houston, Jeong, and Fletcher (1989) analyzed component pricing of germplasm seed, and their results show producers purchase soybean seed based on agronomic attributes that are yield related. Because the soybean industry represents a commodity marketing system, farmers act rationaly by selecting those agronomic traits that provide them the most opportunity for profityield. Lyford, Yumkella, Mercier, and Hyberg (1997) examined ten export market countries examining both desirable attributes (protein and oil) and undesirable attributes (damaged kernel, foreign materials, splits, and moisture content). Their results found no statistically significant desirable characteristics, but their results show that higher levels of damaged kernel and foreign material are discounted in the final price. They also found that moisture content do not have a statistically significant positive relationship with export price. Because they focused on the U.S. soybean export market, there remains to be a gap in terms of understanding the domestic market. Hyberg, Uri, Mercier, and Lyford (1994) published a similar study that also looks only at the U.S. soybean export market. New to their study that was absent in Lyford, Yumkella, Mercier, and Hyberg, is that country-specific domestic and import strategies are important determinants of soybean prices, in addition to protein and oil content of soybeans. A more recent study by Murova, Mumma, Hudson, and Couvillion (1999) examined the relationship between elevator (farmer) price and attributes test weight, percent damage, and moisture. The elevator price was found to be inversely related to percent damage and moisture, as expected. However, no value added component data, like oil or protein content, was available in their analysis.

The above mentioned gaps in the literature indicate that the industry can benefit from further studies specifically analyzing soybean attributes. Gaining added knowledge for how, or if, commodity soybean prices changes as quality attributes levels change will yield implicit premium and discounts for marginal changes in quality attribute levels. Knowing such marginal implicit prices will help soybean industry participants conduct cost-benefit analysis for investing in enhancing quality attributes or in segregating soybeans of different quality level.

Conceptual Model

Soybean crushers and international buyers may consider sampling soybean seed in all production regions to know the quality of soybean seed being produced in a region in any given year. Competition for these soybean quality characteristics implies that some locations receive implicit premiums and others receive implicit discounts based on the relative scarcity or abundance of quality characteristics in a given area.

Following Ladd and Martin (1976), we relate the price paid for a bushel of soybean to the values of the marginal yields of the bushel's characteristics. The price paid (p_i) for a bushel of soybean ($/bushel) in location i is equal to the sum of values of the marginal yields of the bushel's quality characteristics:

(1) $$p_i = \sum_j T_j \times \frac{\partial x_j}{\partial v_i}$$

where j refers to soybean quality characteristics and T_j is the marginal implicit value of the soybean quality characteristic j. $\partial x_j / \partial v_i$ is the marginal yield of quality characteristic j, where x_j is the total quantity of quality characteristic j available in location i, and v_j is the quantity of soybean available in location i.

Following Ladd and Martin, we can assume the marginal yield of quality characteristic j is a constant. Specifically:

(2) $$\frac{\partial x_j}{\partial v_i} = x_{ji}$$

It is reasonable to treat the yield of each characteristic as constant, and this implies a fixed proportion of quality characteristic x_j in input v_i. For example, a one percentage point increase in protein content yields a one percentage point increase in protein for a bushel of soybean. Equation (1) can be re-specified as:

$$p_i = \sum_j T_j x_{ji} \quad (3)$$

The marginal implicit values (T_j) need not be constant. Ladd and Martin showed that if Equation (3) is derived from a functional form that is quadratic for a characteristic j, then the price (p_i) depends on the characteristic level at each observation. Researchers studying how livestock prices varies in relation to livestock characteristic levels have shown that marginal values changed as the level of the characteristic changed (Elliott et al., 2013; Dhuyvetter et al., 1996). Parcell and Stiegert (1999) derived a marginal implicit pricing schedule for wheat quality characteristics by specifying the functional form as non-linear.

Another novelty in this paper is that we consider how a change in the total availability of a quality characteristic in another soybean-producing state affects the value of such quality characteristic in one particular state. This is because when the soybean crop in one state is deficient in supplying an adequate volume of a quality characteristic, processors may look to other states to source commodity soybeans with the desired quality characteristic levels. For example, suppose the Missouri soybean price (p_i) depends on protein availability in both the Missouri soybean production (x_{11}), the Illinois soybean production (x_{12}), and the Iowa soybean production (x_{13}). Equation (3) for the price of a bushel of soybean in Missouri could be specified in a linear combination of regional protein level to account for spatial competition amongst the protein characteristic:

(4) $$p_1 = \beta_1 x_{11} + \beta_2(x_{11} \times x_{12}) + \beta_3(x_{11} \times x_{13}) = x_{11}(\beta_1 + \beta_2 x_{12} + \beta_3 x_{13})$$

where: β_1 represents the coefficient relating changes to Missouri soybean protein content to Missouri soybean price; β_2 represents the coefficient relating changes in the Illinois and the Missouri soybean protein content to Missouri soybean price; β_3 represents the coefficient relating changes in the Iowa and the Missouri soybean protein content to Missouri soybean price; and, $(\beta_1 + \beta_2 x_{12} + \beta_3 x_{13})$ is the marginal implicit price of soybean protein in Missouri, which varies with the level of protein in Illinois and/or Iowa. The choice of the appropriate functional form is discussed later, and the quadratic functional form presented here is for example only.

The interregional effects refer to the impact on price in one state from changes in soybean attribute levels observed in other states. The value of characteristics in a particular state is determined by the aggregate supply and demand for a characteristic. Parcell and Stiegert (1999) use a similar approach to account for interregional wheat quality characteristic competition. For example, protein and oil levels cannot generally be varied in the production system. When the soybean crop in one state is deficient in supplying an adequate volume of protein content or high oil, processors may look to other regions to source commodity soybeans with the desired characteristic levels. We therefore model these characteristics spatially.

Empirical Model

The hedonic equation to be estimated is:

$$Price_{it} = \alpha \sum_{i=1}^{n} \gamma_i State_i + \beta_1 Protein_{it} + \beta_2 Prt\_AS_{it} + \beta_3 Prt\_OT_{it} + \beta_4 Oil_{it} + \beta_5 Oil\_AS_{it} + \beta_6 Oil\_OT_{it} + \varepsilon_{it} \quad (4)$$

Utilizing a test based on Box and Cox (1964), we determined that the appropriate functional form of Equation (4) is a linear specification. Variable definitions are presented in Table 1. The subscript i refers to the i^{th} state. Each equation contains twenty-six binary terms representing state dummy variables to capture differences in transportation costs to major demand points (Missouri is the default due to proximity to the Gulf as a residual market). States further from the Mississippi River are expected to receive a lower price because of increased transportation. A caveat to this historical price-location relationship is that the West Coast ports have recently been updated to accommodate unit train off-loading of grains and oilseeds destined for Asia markets. An increasing amount of grain and oilseed goes by train west.

The next three terms are the states' protein average ($Protein_{it}$), the interaction of state protein average and the harvest-weighted protein average of all adjacent states (Prt_AS_{it}), and the interaction of state protein average and the harvest-weighted protein average of all other states (Prt_OT_{it}). These harvest-weighted average protein content variables aim to measure the intraregional availability of each soybean protein quality attribute (to account for the interregional effects of surrounding soybean-producing states). For example, the average level of protein content outside of Missouri is the harvest-weighted average of protein content in surrounding soybean-producing states of Arkansas, Illinois, Iowa, Kansas, Kentucky, Nebraska, Oklahoma, and Tennessee. Table 2 lists down the states included in this study together with their corresponding adjacent states.

The next group of terms follows a similar pattern of variables, where the soybean quality attribute is average soybean oil content (Oil_{it} for own state, Oil_AS_{it} for adjacent states, and Oil_OT_{it} for all other states).

Soybean protein and oil are expected to be related positively to price. Protein and oil are the most critical component sought by soybean crushers. Soybean protein content is a predictor of how well the soybean meal will yield digestible protein. Soybean oil content is a prediction of oil value to be sold for industrial, fuel, or food use. Increases in the level of protein content or oil content in adjacent states would be expected to decrease price in state *i*. Similarly, an increase in the level of protein content or oil content in all other states would be expected to decrease the price in state *i*.

Data Issues and Estimation Method

We use a Rich dataset on average Data on state average soybean protein content. Oil content data were obtained from the American Soybean Association International Marketing reports from 2003 to 2011. Annual state average price data was downloaded from the U.S.D.A. National Agricultural Statistics Service website. Table 1 presents the data description and summary statistics.

We conducted several tests, including those based on Levin, Lin, and Chu (2002), Hadri (2000), Breitung (2000), Breitung and Das (2005), and Im, Pesaran, and Shin (2003), to confirm that the panel data on soybean price, protein content, and oil content are stationary.

When using panel data, cross-sectional heteroskedasticity, time-series autocorrelation, and cross-panel dependence are typical concerns. We tested the null hypothesis of homoskedasticity versus the alternative of groupwise heteroskedasticiy using the modified Wald test (Greene, 2000). We found no evidence to reject the null hypothesis of equal variances between states. To test for autocorrelation, we used a Wald test proposed by Wooldridge (2002) . This resulted in a test statistic of 161.931

and a corresponding p-value of 0.0000, indicating that the null hypothesis of no autocorrelation was strongly rejected. Finally, to test for cross-panel dependence, we used the CD tests proposed by Pesaran (2004). The results reject the null hypothesis of no cross-sectional dependence. This means that the cross-sectional units are not independent.

In summary, due to the existence of autocorrelation and cross-sectional dependence in the data, we estimate (4) using feasible generalized least squares. We transformed the estimators using Prais and Winsten (1954) to account for the autocorrelation and the standard errors panel-corrected to account for cross-panel dependency.

Results

The econometric estimates of Equation (4) are reported in Table 3. The model explained more than 80% of the variation in soybean prices. All the main variables are significant and have the expected signs.

Soybean protein and oil content is related positively to own state's price. This means that higher levels of protein and oil content in soybeans are associated with higher soybean prices. On the other hand, soybean prices are related negatively, to adjacent states' average protein and oil content, as well as other states' average protein and oil content. This means that, as the protein and oil content in soybeans produced in other states increase, the price of own-state soybeans declines, indicating the presence of spatial competition in soybean quality attributes.

In terms of magnitude, the results show that soybean oil content has a greater effect on soybean prices than soybean protein content. This may indicate higher preference for oil quality attributes in soybeans than protein quality attributes. The results also show that the negative effect of soybean protein and oil content from adjacent states on own-state soybean prices is less than the effect of those from all other states. This is a very interesting finding and would initially serve to indicate that the decrease in demand for soybeans within state associated with an increase in soybean quality attributes from states farther away is larger than the decrease in demand associated with the same increase in soybean quality attributes from adjacent (and thus nearer) states.

Conclusions

Soybean quality is becoming more important as markets realize its impact in relation to utility. Soybean meal protein level impacts animal feed efficiency and soybean seed oil content signifies the amount of oil to be used for food, fuel or industrial purposes. Because differences in quality levels exist, quantifying the impacts of these quality-price differences is essential so that the soybean industry understands the implicit-value of enhancing trait levels within a component pricing system.

Results of this paper's hedonic model indicate price premiums for two soybean quality attributes, protein and oil. These results suggest that there is indeed an incentive for U.S. farmers to produce soybeans with higher quantities of protein and oil. This is particularly important given the seeming general disconnect between demand and supply: farmers are focused on maximum yields, while customers care only about the soybean quality attributes, especially protein and oil (Illinois Soybean Board, 2012). Gaining knowledge of the value of these soybean quality attributes can help farmers' bottom line by providing insights on what buyers value more. In light of the increasing importance of high-quality products to U.S. foreign customers, understanding the effect of soybean quality to price can boost U.S. market share in the global trade for soybeans.

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Table 1. Description of Variables and Summary Statistics

Variable Names	Definition	Expected Effect on Price	Average	Standard Deviation
$Price_{it}$	Average soybean price in state i and time t ($/bushel)		8.51	2.45
$Harvest_{it}$	Total soybean harvest in state i and time i (million bushels)		110.52	126.73
$Protein_{it}$	Average soybean protein content in state i and time t (%/bu)	+	35.36	1.13
Prt_AS_{it}	Interaction term: average protein content in state i (%/bu) multiplied by the harvest-weighted average of soybean protein content in all adjacent states at time t	−	35.22	0.73
Prt_OT_{it}	Interaction term: average protein content in state i (%/bu) multiplied by the harvest-weighted average of soybean protein content in all other states (besides own and adjacent states) at time t	−	34.97	0.47
Oil_{it}	Average soybean oil content in state i and time t (%/bu)	+	18.88	0.71
Oil_AS_{it}	Interaction term: average oil content in state i (%/bu) multiplied by the harvest-weighted average of soybean protein content in all adjacent states at time t	−	18.91	0.50
Oil_OT_{it}	Interaction term: average oil content in state i (%/bu) multiplied by the harvest-weighted average of soybean protein content in all other states (besides own and adjacent states) at time t	−	18.81	0.34

Table 2. Soybean-Producing States

State	Adjacent States That Also Produce Soybeans
1. Alabama	Mississippi, Tennessee
2. Arkansas	Louisiana, Mississippi, Missouri, Oklahoma, Tennessee, Texas
3. Delaware	Maryland, New Jersey, Pennsylvania
4. Illinois	Indiana, Iowa, Kentucky, Michigan, Missouri, Wisconsin
5. Indiana	Illinois, Kentucky, Michigan, Ohio
6. Iowa	Illinois, Minnesota, Missouri, Nebraska, South Dakota, Wisconsin
7. Kansas	Missouri, Nebraska, Oklahoma
8. Kentucky	Illinois, Indiana, Missouri, Ohio, Tennessee, Virginia
9. Louisiana	Arkansas, Mississippi, Texas
10. Maryland	Delaware, Pennsylvania, Virginia
11. Michigan	Illinois, Indiana, Minnesota, Ohio, Wisconsin
12. Minnesota	Iowa, Michigan, North Dakota, South Dakota, Wisconsin
13. Mississippi	Alabama, Arkansas, Louisiana, Tennessee
14. Missouri	Arkansas, Illinois, Iowa, Kansas, Kentucky, Nebraska, Oklahoma, Tennessee
15. Nebraska	Iowa, Kansas, Missouri, South Dakota
16. New Jersey	Delaware, New York, Pennsylvania
17. New York	New Jersey, Pennsylvania
18. North Carolina	Tennessee, Virginia
19. North Dakota	Minnesota, South Dakota
20. Ohio	Indiana, Kentucky, Michigan, Pennsylvania
21. Oklahoma	Arkansas, Kansas, Missouri, Texas
22. Pennsylvania	Delaware, Maryland, New Jersey, New York, Ohio
23. South Dakota	Iowa, Minnesota, Nebraska, North Dakota
24. Tennessee	Alabama, Arkansas, Kentucky, Mississippi, Missouri, North Carolina, Virginia
25. Texas	Arkansas, Louisiana, Oklahoma
26. Virginia	Kentucky, Maryland, North Carolina, Tennessee
27. Wisconsin	Illinois, Iowa, Michigan, Minnesota

Table 3. Hedonic Regression Results
Dependent Variable: State Soybean Prices, 2003 to 2011

Parameter	Coefficient	Std. Error	Parameter	Coefficient	Std. Error
Intercept	15.4888 ***	4.3744			
	Protein Content			Oil Content	
$Protein_{it}$	3.7656 ***	0.9982	Oil_{it}	7.7904 ***	1.2556
Prt_AS_{it}	– 0.0178 **	0.0082	Oil_AS_{it}	– 0.0866 ***	0.0247
Prt_OT_{it}	– 0.0950 ***	0.0263	Oil_OT_{it}	– 0.3307 ***	0.0618
			State Dummy Variables		
Alabama	2.1221 ***	0.5415	Nebraska	0.5838 **	0.2814
Arkansas	0.3708	0.3430	New Jersey	0.6455	0.4642
Delaware	1.0735 ***	0.4016	New York	0.6068	0.4956
Illinois	0.5816 ***	0.1554	N. Carolina	1.5198 ***	0.4504
Indiana	0.4643 **	0.2139	N. Dakota	0.1930	0.4426
Iowa	1.7132 ***	0.4659	Ohio	0.5554 **	0.2325
Kansas	0.2762	0.2187	Oklahoma	0.4265 **	0.2133
Kentucky	0.1207	0.2211	Pennsylvania	0.5670 *	0.2959
Louisiana	1.2622 **	0.5540	S. Dakota	1.0826 **	0.4994
Maryland	1.1518 ***	0.4228	Tennessee	0.3053	0.3279
Michigan	0.5707 **	0.2463	Texas	1.1146 **	0.4727
Minnesota	1.1924 **	0.4953	Virginia	1.4576 ***	0.4002
Mississippi	1.0693 **	0.5124	Wisconsin	0.8105 **	0.3390

Notes:

1. Model R-squared = 0.8038.
2. ***,**,* denote coefficients significantly different from zero at the 1%, 5%, 10% levels, respectively.
3. For the state dummy variables, Missouri is assigned as the base.