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The Effects of Component Pricing on the U.S. Soybean Industry: A Dynamic Simulation Analysis*

by

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Abstract

Incorporating oil and protein content into current soybean grade standards may not have much effect on aggregate U.S. soybean production or producer welfare. However, adoption of such component standards would create economic rents in consistently "above standard" soybean producing regions and shift production to those regions over time.

The Effects of Component Pricing on the U.S. Soybean Industry: A Dynamic Simulation Analysis

Soybeans are currently graded with respect to moisture content, the proportion of damaged, discolored, or diseased beans in the inspected sample, the proportion of the sample composed of foreign matter, and its weight. Only moisture, however, has a direct bearing on the true value of soybeans. The protein and oil content, the two most important determinants of soybean value, have not been included in grade standards for soybeans, largely because of the measurement time and cost involved. The development of an inexpensive and rapid method of measuring the oil and protein content of soybeans in recent years, however, using near-infrared light has given rise to proposals to change current soybean grade standards to include protein and oil content (component standards).

The accuracy of the near-infrared technology has been the subject of much debate.[1] The most important issue for in the U.S. soybean industry, however, is the potential market effects from the adoption of component standards. Any benefits or costs to soybean producers would not likely be distributed evenly across U.S. producing regions for many reasons, most importantly because the chemical composition of soybeans differs among regions. Because there is a biological trade-off between the oil and protein content of soybeans, varieties with a higher content of one generally generally contain less of the other (Smith). The trade-off, though, is much larger for short season varieties grown in the northern U.S. than the longer season varieties grown in the South. Such regional differences in the oil and protein content of soybeans suggest potential regional differences in any benefits or costs of component pricing (Updaw, 1979).

Both Perrin and Updaw (1980) used simple static models of the U.S. soybean market to measure the social costs and benefits of component pricing of soybeans. In general, they conclude that producers in the aggregate may gain under certain conditions but that when measurement costs are included, the net social benefits are not likely to be positive. Updaw and Nichols provide some thoughts on the potential regional effects of component pricing. Their qualitative discussion is basically static, however, ignoring the dynamic effects of the adoption of component standards on regional and aggregate prices and quantities of soybeans and soybean products.

This paper analyzes the likely dynamic effects of implementing component standards on the U.S. soybean industry with an emphasis on the effects on the regional pattern of production. Following a conceptual analysis of component pricing, the model used in the analysis is presented. The results of simulating the imposition of component pricing on the aggregate and regional U.S. soybean markets are then discussed. Finally, a summary and implications for policy are provided.

A Conceptual Analysis of Component Pricing

The U.S. market for soybeans and soybean derivatives in any time period t can be represented graphically as in figure 1. The top row of graphs represents the soybean sector while the middle and bottom rows represent the soymeal and soyoil sectors, respectively. The market soybean supply in any given year (TS_t) is assumed to be completely inelastic with respect to current price and is the result of production decisions in the preceding year in the various producing regions of the country as affected by prices and other factors. For graphical simplicity, two production regions (A and B) are assumed. Also, assuming a greater diversity of cropping alternatives in region A, the long-run supply curve of region A (SA_{LR}) is more price elastic than that of region B (SB_{LR}). Assume that there is an increase in the domestic demand for soyoil in period t-1 from an exogenous increase in income, for example, such that the price of oil in period t-1 increases. As a consequence, the crush demand of soybeans in period t-1 increases leading to an increase in the price of soybeans from PW_{t-1} to PW'_{t-1} and a higher level of soybean production in period t than would have been the case.

Given current standards (i.e., soybean prices are not adjusted for oil and protein content), soybean production in regions A and B would be OA_2 and OB_2, respectively. Because of the increase in the total supply of soybeans from TS_t to TS'_t (= $A_1A_2+B_1B_2$), the excess soybean supply shifts out from ESB_t to ESB'_t resulting in a lower market price of soybeans in period t (PW'_t) and higher volumes of soybean crush (OS_2) and exports (XS_2) than otherwise. Assuming no change in the extraction rates for soymeal and soyoil, the larger crush results in higher meal and oil production (OM_2 and OO_2, respectively). Given the soymeal and soyoil demand curves (DM_t and DO_t, respectively), meal and oil prices are lower and exports higher than otherwise.

Assume now that content of both the oil and protein of the soybeans produced in region B are above some chosen component standard while the opposite is the case for region A and that these regional differences are discernible to the market. In this case, the increase in soyoil demand and price in period t-1 means that soybean producers in region B will receive a premium for their soybeans in t-1 and, consequently, a price (PB_{t-1}) which is higher than the average market price (PW'_{t-1}). In region A, however, the opposite occurs. The size of the premium or discount received in any region depends on a number of factors, including the relative changes in the prices of soyoil and soymeal and the relative protein and oil content of the soybeans in each region.[2]

Because the price realized by the soybean producers in region B is higher (PB_{t-1}) and in region A is lower (PA_{t-1}) than when regional differences in oil and protein content are not recognized, production also tends to be higher in region B and lower in region A in period t than otherwise. In this example, the component standards are chosen such that the increase in soybean produc-

production in region B (B_2B_3 in figure 1) is exactly offset by the production decrease in region A (A_2A_3) from the adoption of the standards. This results in the same increase in total soybean production from TS_t to TS'_t in both cases, with or without including oil and protein content in current grade standards. The choice of component standards is, of course, arbitrary and could affect the level of total production.

If the extraction rates for soyoil and soymeal remain constant, component pricing has no effect on the oil or meal markets in period t in this example. However, because the ratio of high oil soybeans to total soybean production is higher, the oil extraction rate and the level of soyoil production would also be higher (SO^*_t in figure 1). The result would be a lower oil price in the market and larger domestic consumption and exports of soyoil than otherwise. At the same time, the ratio of high protein soybeans to total production would be less resulting in a decline in the meal extraction rate and a lower meal production (SM^*_t in figure 1). A consequent increase in the price of soymeal to PM^*_t would reduce the levels of both domestic consumption and exports of soymeal.

The sizes of the regional oil and protein discounts and premiums to producers in period t are ambiguous because the extent of the meal and oil price changes from component pricing depend on domestic and foreign factors that determine the price responsiveness of domestic and export demand for soymeal and oil. The actual effects of the adoption of component standards are a matter for empirical investigation, requiring a model that can measure the simultaneous changes in both regional and aggregate prices and quantities.

The Model

The regional U.S. soybean model utilized in this study includes 37 behavioral equations and 63 identities which are divided into three simultaneous blocks: a soybean block, a soymeal block, and a soyoil block. Each block specifies the manner in which production (acreage), demand, stocks, excess supply, export demand, and prices behave in response to changes in variables like prices, income, livestock production, technology, and population. The model parameters are estimated by means of a truncated two-stage least squares (2SLS) procedure over the period 1960-1982.[3]

The model is a standard representation of soybean markets following Williams and Thompson with four major exceptions. First, to focus on the U.S. soybean market, the world market behavior of importing and other exporting countries is represented by three net export demand functions facing the U.S. for soybeans, meal, and oil. Second, the U.S. soybean acreage function is disaggregated into acreage functions for seven regions which include states of reasonably similar production conditions: the Cornbelt, the Lakes, the Plains, the Delta, the South, the Atlantic, and an Other region.[4]

Third, in order to analyze the effects of the adoption of component grade standards, the model includes a regional soybean component pricing mechanism which adds an oil and/or a protein premium or discount to the regional farm prices of soybeans in each period. The net premium or discount realized by producers in a given year in each region depends on the strength of the various factors that affect the relative prices of oil and meal, the given regional protein and oil composition of soybeans, and the national component standards adopted. For oil, the general oil premium (or discount when less than zero) is the following:

(1) $$DO_{ik} = PO \cdot (X_{ik} - X_s)$$

where, for any region k, DO_{ik} is the oil premium (or discount if negative) per pound of soybeans, X_{ik} is the total pounds of oil in a pound of soybeans, and X_s is the standard number of pounds of oil per pound of soybeans.[5] The discount for meal is similar but more complicated because there is a relationship between the pounds of meal produced from a bushel of soybeans and the recoverable oil. The component pricing system is a modification of that developed by Updaw, Bullock, and Nichols. In the modified system, the rates of soyoil and dry matter processing loss are allowed to vary over time. Also, the protein discount system is less cumbersome.

Finally, in order to allow soybean production shifts among regions of differing component levels to be translated into oil and meal production shifts in any given year, regional oil and meal extraction rates are calculated in the model from the regional oil and protein compositions. The regional extraction rates, in turn, are weighted by regional production to derive national average oil and meal extraction rates.

Simulation Analysis of Component Pricing

The effects of component pricing depend to some extent on the choice of standards. Accordingly, the model was simulated over 1960 to 1982 given a range of possible combinations of oil and protein standards from 16 to 21 percent for oil and 41 to 47 percent for protein in the meal. In effect, for each combination of oil and protein standards, the respective simulation asked the question: "What would have been the effect of adopting component standards on U.S. soybean and soybean product prices and quantities if the standards had been set at X percent for oil and Y percent for protein in 1960 and remained in effect through 1982?" The result was a 6x7 matrix of all model variables for each year of each simulation. Because of space limitations, however, only two limited sets of results are discussed here: 1) the dynamic adjustments of selected variables given an arbitrary choice of standards of 18 percent oil and 44 percent protein meal (18/44 standard) and 2) the effects on selected variables in one year (1980) across the range of possible standards. The year 1980 is selected in the latter case because it is at the end of the simulation period and incorporates any dynamic effects.

Dynamic Effects of Component Pricing

The simulation of an 18/44 standard resulted in an increase in aggregate U.S. planted acreage of soybeans over the base case (the standard actually in effect in each year) in all but three years of the simulation. These increases, however, were generally less than two percent over the base, indicating that the production gains in the above standard regions were only marginally greater than the losses in the below standard regions. The slightly higher aggregate soybean output resulted in a slightly lower-than-baseline value of the U.S. average farm price of soybeans over time.

Four of the seven regions consistently gained acreage (the Cornbelt (CB), the South (SO), the Delta (DL), and the Atlantic (AT) in that order) while the others consistently lost acreage (figure 2). The Cornbelt realized the largest absolute gain of nearly 1 million acres by the end of the sample period. In percentage terms, however, the South gained more soybean acres than any other region (nearly 7 percent over the base). Soybean farmers in both regions earned net premiums over time and the premiums tended to be larger than the decrease in average price associated with the generally higher aggregate production of soybeans. The same was the case for the Delta and Atlantic regions but to a much lesser extent.

The estimated long-run price elasticity of soybean acreage in the South, however, is much higher (4.98) than in the Cornbelt (2.18), Delta (1.78), or Atlantic (2.22) regions leading to a relatively greater price response by farmers in the South over time to premium-enhanced soybean prices. This reflects the wider production alternatives available in the South and a greater degree of substitutability among crops given changes in relative prices. Also, farmers in the Cornbelt and Delta regions grow many government-controlled crops, such as feedgrains, cotton, and rice and are relatively slow to switch out of program crops, give up acreage base, and forego program benefits given a change in the relative price of soybeans.

Combinations of Component Standards

The choice of standards could have a significant effect on the aggregate and regional production of soybeans over time. In general, a standard of 20 percent oil and 44 percent protein would be fairly neutral with regard to aggregate production over the long run. Higher combinations of either or both would tend to reduce aggregate output and push up the average market price. Lower combinations would produce the opposite effect. Regionally, the higher protein and oil standards are set, the smaller is the likely acreage gain or the greater is the loss over time because premiums tend to be smaller and discounts larger.

In the Cornbelt, for example, planted acreage of soybeans would have increased in 1980 under all except the 21/46 and 21/47 combinations, the two highest protein standards and the highest oil standard (figure 3). Holding the protein standard constant at 44 percent and varying the oil standard resulted in an average range in the increase in Cornbelt acreage of about 1.4 million acres, over 4 percent of actual acreage in 1980. The range of the soybean acreage increase from varying the protein standard and holding the oil standard constant at 18 percent was about .65 million acres, over 2 percent of actual acreage. The Cornbelt remained the largest producing region under all combinations of standards. The results were generally the same for all regions with the highest variation in acreage occurring in the South.

Summary and Implications for Policy

A shift to component standards and pricing is not likely to have a substantial net impact on aggregate soybean production and price over time, or, therefore, on soybean producer welfare as previous research has concluded. Nevertheless, if the oil and protein composition of soybeans is regionally determined, component standards would create economic rents in those regions where above standard soybeans could be consistently produced. As a consequence, soybean acreage would likely shift over time from the former regions to the latter. The Cornbelt and the South are the most likely beneficiaries while the Lakes and Plains states would likely lose the most acres. Component pricing would also result in a greater degree of both variability in production and uncertainty in production decisions in all regions. This is particularly the case in those regions in which farmers are more highly responsive to price changes like the South and the Plains.

The choice of component standards would affect the magnitude of the aggregate and regional acreage impact. The higher the standard is set, the more likely is aggregate production to be negatively affected. At the same time, acreage gains in above standard soybean regions would be smaller while losses in the below standard regions would be larger. Consequently, producers in all regions would tend to favor standards as low as possible. Nevertheless, the optimal short-run strategy for producers in the regions with the highest oil and protein content soybeans like the South may be to press for high standards in order to minimize or eliminate any gains in competing regions. Processors, on the other hand, would tend to favor high standards to maximize the component content of the soybeans purchased and minimize the premiums paid. This is particularly true since high standards could lead to an overall reduction in soybean production, driving up prices of oil and meal.

Economic rents arising from component standards could induce research in below component standard regions to develop soybean varieties higher in oil and/or protein content. Regional rents, therefore, could be competed away over the long run such that component standards would have no lasting effect on either aggregate production or the regional pattern of production. It is not clear, however, whether it is technically possible to develop such varieties without significant sacrifices in yield per acre, at what rate such new varieties could be developed or whether the rate of development would differ significantly among regions. Nevertheless, future research in this area would need to consider such a possibility.

Footnotes

[1]Hilliard and Daynard, for example, conducted a comparison of the micro-Kjeldahl test for protein content and the ether-extract test for oil content (the traditional methods) with the near-infrared system on identical samples of soybeans. They concluded that the near-infrared measurements were accurate.

[2]It is assumed that in period t-2 the discounts or premiums received by producers in both regions are zero. This assumption is only for graphical convenience and implies that growers in all regions faced the same price when making their production decisions for period t-1. By making this assumption, the initial equilibrium points are the same in period t-1 with or without the imposition of component pricing.

[3]The 2SLS principal components estimator used here, and first proposed by Kloek and Mennes, is consistent inasmuch as it may be reduced to an instrumental variables estimator (Brundy and Jorgenson, pp. 216-217). This technique is frequently used in the estimation and simulation of large econometric models.

[4]The states included in each region are as follows: Cornbelt-Iowa, Illinois, Ohio, Indiana, and Missouri; Lakes-Michigan, Wisconsin, and Minnesota; Plains-Kansas, Nebraska, N. Dakota, and S. Dakota; Delta-Louisiana, Mississippi, and Arkansas; South-Florida, Georgia, Alabama, Tennessee, Kentucky, Texas, and Oklahoma; Atlantic-Maryland, Delaware, Virginia, N. Carolina, and S. Carolina; and Other-New York, New Jersey, Pennsylvania, and West Virginia.

[5]This assumes zero loss of oil in processing only for ease of exposition. The assumption is relaxed in the analysis.

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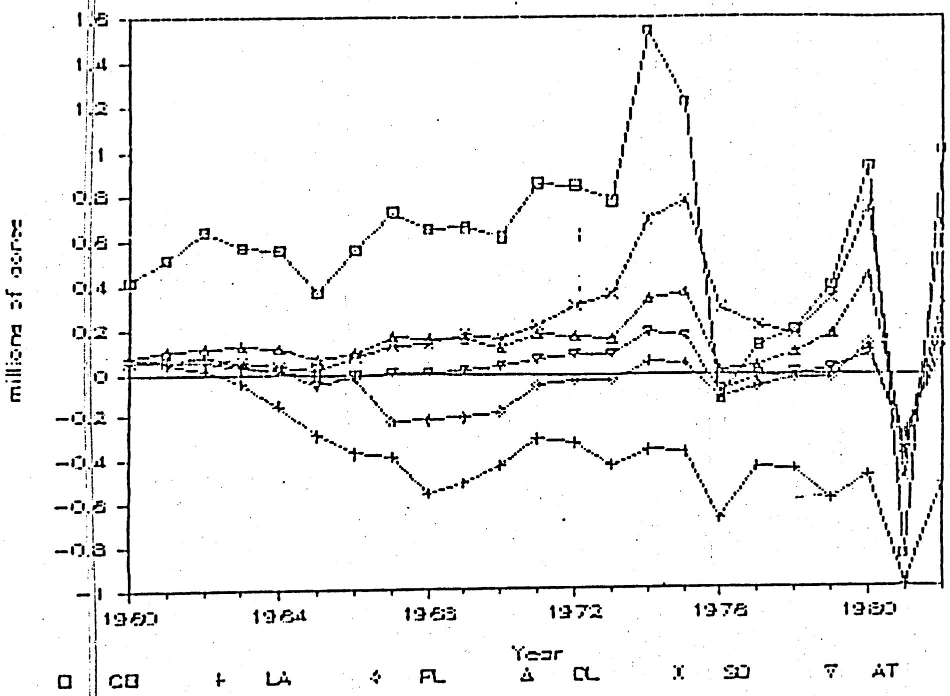

Figure 2. Change in regional soybean acreage from adoption of an 18/44 component standard

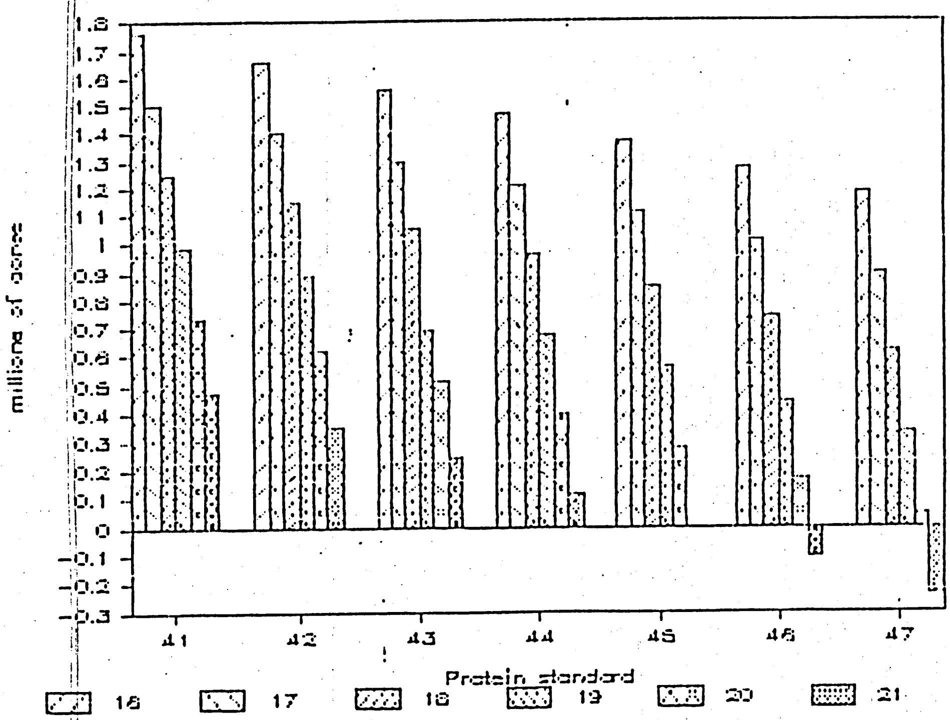

Figure 3. Changes in Cornbelt soybean acreage from various combinations of component standards, 1980