



**AgEcon** SEARCH  
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

*The World's Largest Open Access Agricultural & Applied Economics Digital Library*

**This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.**

**Help ensure our sustainability.**

Give to AgEcon Search

AgEcon Search

<http://ageconsearch.umn.edu>

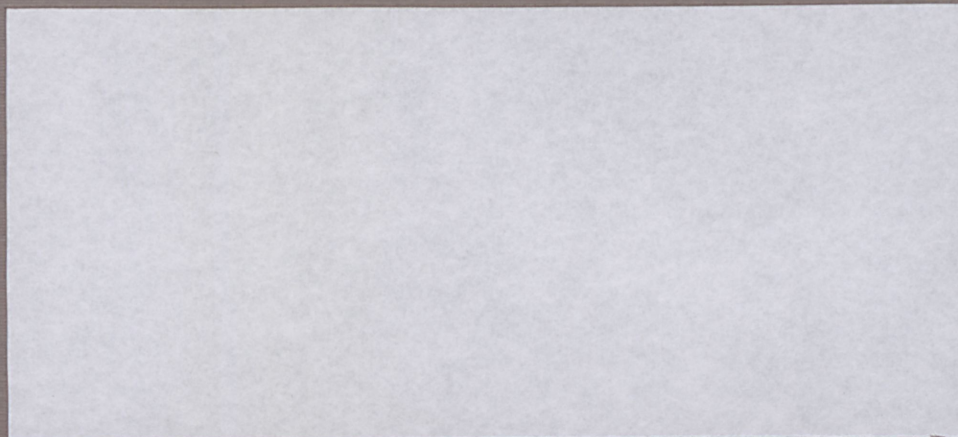
[aesearch@umn.edu](mailto:aesearch@umn.edu)

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

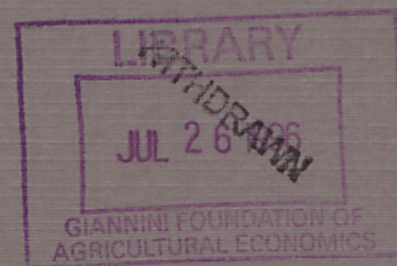
Soybeans



**Organization  
and Performance  
of World Food  
Systems: NC-194**

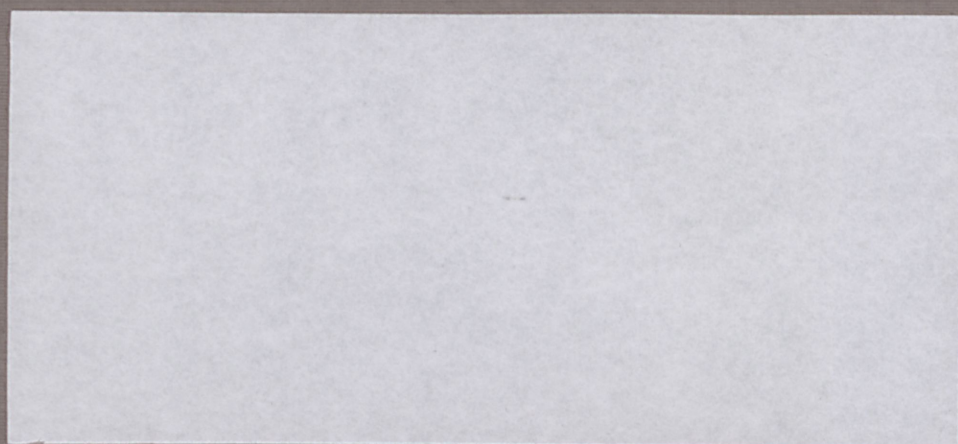


**OCCASIONAL PAPER SERIES**



The work reported herewithin contributes to the objectives of North Central Regional Project NC-194, a joint research project of state agricultural experiment stations and the U.S. Department of Agriculture





**THE CONDUCT OF THE WORLD SOYBEAN  
PROCESSING INDUSTRY**

**\*Fumiko Yamazaki, Philip L. Paarlberg  
and Marie Thursby**

**OP-45**

**DECEMBER 1992**

**\*THE AUTHORS ARE A FORMER GRADUATE STUDENT AND AN ASSOCIATE PROFESSOR IN THE  
DEPARTMENT OF AGRICULTURAL ECONOMICS, AND A PROFESSOR OF ECONOMICS, RESPECTIVELY,  
PURDUE UNIVERSITY, WEST LAFAYETTE, IN**

**THE CONDUCT OF THE WORLD SOYBEAN  
PROCESSING INDUSTRY\***

by

Fumiko Yamazaki, Philip L. Paarlberg, and Marie Thursby\*\*

Department of Agricultural Economics

Purdue University

West Lafayette, Indiana 47907

December 1992

\* Research supported by Cooperative Agreement No. 58-3AEL-8-00089 with the Economic Research Service, U.S. Department of Agriculture. Also contributing were funds from NC-194.

\*\* The authors are a former graduate student and an associate professor in the Department of Agricultural Economics, and a professor of Economics, Purdue University.

## **The Conduct of the World Soybean Processing Industry**

Fumiko Yamazaki, Philip L. Paarlberg, and Marie Thursby

This paper examines the competitiveness of the soybean processing industry. A model of multinational firms with scale economies is specified. An index of the way in which firms compete (conjectural variations) is included and the model is calibrated to market data to estimate the competitiveness of the industry. The results imply that despite its oligopolistic structure, the soybean processing sector may be fairly price competitive. This result is shown to be robust to changes in elasticities of demand in meal and oil, the soybean supply elasticity, and the number of multinational firms. However, it is sensitive to changes in the processing profit margin.

Key words: soybean processing industry, conjectural variations, market conduct

## The Conduct of the World Soybean Processing Industry

Models of the soybean complex generally treat the soybean processing industry as competitive. This is the case regardless of whether the model is intended for policy analysis or for forecasting. Indeed the most interesting aspects of policy analysis performed with these models often concern adjustments in the crushing sector. Changes in policy shift crushing activities across nations, and hence, alter the trade composition between raw soybeans and soybean products.

Observation of the soybean processing industry shows features which suggest imperfect competition. First, during the post-World War II period, the number of crushing facilities fell. The remaining plants are owned by fewer and fewer firms. Many of these firms are multinational, owning crushing plants in the United States, Western Europe, and South America. In the traditional structure-conduct-performance method, these features of structure suggest imperfect competition. Furthermore, the limited cost data available show the presence of large fixed costs which would imply economies of scale. Also, the annual ratio of soybean throughput to crushing capacity is low in most countries.

Recent developments applying imperfect competition theory to trade models show that the nature of competition is important to the policy results (Krishna and Thursby; Richardson). The presence of imperfect competition, through scale effects for example, can either magnify or offset the effects of trade policy liberalization depending on the specific characteristics of the industry. This means that the assumption by modelers that the industry is competitive may lead to inappropriate policy implications.

This paper examines the nature of competition in the soybean processing industry with the intention of allowing the observed features of the market to determine industry conduct. To accomplish this a traditional model of the soybean processing industry is modified to include fixed exogenous costs, multinational crushing, and the ability to recognize firms' interaction with rivals. Using observed data, this formulation is applied to the United States, Argentina, Brazil, Japan, and the European Community to obtain a parameter which indicates the nature of competition -- the conjectural variation. With the conduct of the market identified, the extent to which the previous research is affected by the assumption of competitive behavior can be judged.

The paper proceeds as follows. First, three critical features of the market are identified which suggest the possibility of imperfect competition in soybean processing. Then previous research on the soybean crushing industry -- both modeling work and industrial organization studies -- are discussed. Previous models show how other researchers have treated the industry and the central role of crushing behavior in policy analysis. The industrial organization studies show the results of traditional industry studies. The next section develops the conceptual model which includes the above mentioned features. Thereafter the model is converted to its empirical form. The final section presents the simulation results and considers their robustness.

### **Characteristics of the Soybean Crushing Industry**

The motivation behind this research is that the soybean processing industry exhibits characteristics which suggest imperfect competition. The purpose of this section is to briefly discuss those characteristics.

The main activity of the soybean processing industry is to convert soybeans into their products -- meal and oil. These joint products are produced in roughly fixed proportions by a



continuous extraction system. Incoming soybeans are rolled into flakes, which are then treated with hexane to separate the oil from the meal. Although there are some variations, such as in the solvent or in the rolling mill, this system is used worldwide.

After the Second World War the sector became increasingly concentrated. Whereas in 1950 there were 250 oil mills (for all oilseeds) in the United States, by 1987 only 88 plants -- of much larger average size -- were in operation (Soybean Blue Book). In 1947, the four largest companies accounted for 44 percent of the value of shipments and the eight largest for 63 percent. By 1982, 61 percent of the value of shipments were accounted for by the four largest companies and 83 percent by the eight largest (U.S. Census of Manufactures). Data for 1987 show that three firms owned 52 percent of the U.S. processing plants and five firms owned 72 percent (Soybean Blue Book). Thus, the number of companies fell and industry concentration increased.

Often firms with extensive U.S. holdings are active in overseas markets as well. For example, Cargill, which owns 19 U.S. crushing plants, also owns 13 plants abroad, including plants in Argentina and Brazil. These South American countries are interesting in that production of soybean is comparatively new. In 1975 there was one firm with 2 plants using solvent extraction in Argentina. By 1987 there were eight firms with 13 plants, of which 3 were owned by U.S. affiliates (Soybean Blue Book). A different trend occurred in Brazil; eighteen plants were operated by 16 firms in 1975, but by 1987 ten firms were running 17 plants. Three of these plants are affiliates of two U.S. firms (Soybean Blue Book).

Another feature which suggests imperfect competition is the presence of scale economies. During the 1950's, the U.S. Department of Agriculture published two studies which showed increasing returns to scale for solvent extraction (Brewster and Mitchell, 1956; USDA/AMS, 1954). A more recent industry study by the International Trade Commission reaffirms the

earlier research by finding large fixed costs associated with processing. Thus, average total cost falls as crushing expands. Scale economies are also reported for Brazil by Faminow and Hillman. Whereas variable costs are independent of the rate of capacity use, fixed costs decline as the rate of capacity use rises. For 1984, 60 percent of capacity operation gives total crushing costs of U.S. \$16.46 per ton. At 100 percent of capacity, average cost is U.S. \$14.16 per ton.

One characteristic of the industry has been chronic excess capacity when measured on an annual basis.<sup>1</sup> Between 1960 and 1980, the peak U.S. capacity use occurred in 1969 at 92 percent and the low point in 1976 at 66 percent. Of the 21 years, 10 years saw capacity use in the 80-90 percent range, 8 years in the 70-80 percent range, and in 2 years under 70 percent (USDA/ERS. FOS-260, FOS-301). Data on capacity use in other countries is limited, but what is available suggests that the U.S. rates are relatively high. Brazil, which had a policy to encourage domestic processing, so overbuilt capacity that data for the middle 1980's suggest a 55 percent capacity use (USDA/FAS. FOP-March 1988).

What emerges from this brief review is a picture of an industry with a structure which could lead to imperfectly competitive behavior. There is clear evidence of concentration, and that concentration has increased. Soybean processing firms are multinational. The data for Cargill shows that of its 32 plants, 13 are overseas. Soybean processing plants have fixed costs which lead to increasing return to scale. Finally there is excess capacity in the industry.

### **Previous Research**

Several studies have analyzed the soybean complex and this section will highlight only a few to illustrate how they relate to the issue of competition in the processing industry. In general the studies can be divided into two groups. The first consists of quantitative models for policy analysis or for forecasting. The second group consists of work coming from the

industrial organization field which seeks to rank food industries in terms of their degree of competition.

Current models of the soybean complex have their origin in the model developed by Houck, Ryan, and Subotnik (1972). That model separated the products --soybeans, meal, and oil -- into distinct activities, whereas previous models, such as Vandendorre (1966), had used aggregates. The model included demands for meal and oil, along with the supply of soybeans. The processing sector was included with a specification which reflected competitive behavior. Soybeans were transformed into meal and oil via technical identities. The crushing margin -- the spread between the unit value of the meal and oil outputs and the price of soybeans -- was fixed. This specification would determine crushing behavior and is consistent with perfectly competitive behavior by the crushing industry.

Subsequent models retained much of this flavor, but with a slight change. A demand for soybeans was added where the endogenous margin and exogenous capacity determined crush (Williams, 1981). One aspect of these models was that changes in policy would alter crushing across nations. The paper by Williams and Thompson (1984) is an excellent example where they showed that the Brazilian export tax structure had the effect of causing the crushing of too many soybeans in Brazil and too few in the United States. Thus, in the U.S. export picture raw, soybean exports were too high relative to meal and oil. In Brazil the pattern was reversed. The results from such models were extremely important to analyzing farm trade policy, but relied on the assumption that the crushing industry was competitive and could be modeled with demand and supply schedules.

A very different literature emerged from industrial organization work which examines competition across industries. Often this work has relied on the use of four and eight firm concentration ratios to indicate structure. For soybean oil mill products, the 1954 concentration

ratios were 37 percent at the four firm level and 62 percent at the eight firm level. By 1982, the corresponding figures were 56 and 79 percent respectively (U.S. Census of Manufactures).

Connor, *et al.* 1985, using the structure-conduct-performance model, classify 75 national markets for food and tobacco product classes according to three market structural characteristics. Soybean oil mills is classified as a moderately concentrated oligopoly -- with a four firm concentration ratio of between 50 and 65 percent -- with a low degree of product differentiation. A somewhat stronger oligopoly classification emerges if the classification system of Bain (1968) is used. In that system the 1982 industry falls into type II, or high-moderate concentrated oligopoly. That view was also shared by the International Trade Commission (USITC, 1987). Based on industry interviews and on the past performance of firms, they concluded that the soybeans products market appears to be highly competitive, despite the concentration in crushing and the appearance of oligopoly structure.

### **Conceptual Framework**

The objective of this section is to develop a framework which includes the above mentioned features and also allows the nature of the competition in the industry to be inferred from observed data. This is done by drawing on recent developments in oligopoly theory. The behavior of the industry is described in the form of a two stage game (Sutton, 1991). In the first stage firms commit to the fixed costs involved in the crushing of soybeans, while the second stage concerns firm interaction, given the fixed costs. Firms are assumed to produce homogeneous goods from a homogeneous input and no additional fixed costs are incurred beyond those of the first stage. Furthermore, decisions on soybean processing are assumed to be made independently of decisions regarding product imports. This study focuses on the second stage, taking fixed costs as given by the first stage.



Suppose there are  $n$  multinational firms operating processing plants in  $N$  countries. The total profit of the  $i$ th multinational firm is the sum of profits from its worldwide operations. As noted above soybeans are processed into meal ( $m$ ) and oil ( $o$ ) at relatively fixed proportions -- denoted by  $\gamma$ . Revenues are generated by the sale of meal and oil in each country. The costs incurred include the purchase of soybeans and other costs as given by a cost function. Assuming products manufactured in the same country are homogeneous and markets are segmented, the profit maximization problem of multinational firm  $i$  can be presented as:

$$(1) \text{ MAX } \pi_i = \sum_{k=1}^N \pi_i^k$$

$$(a) \text{ s.t. } q_{hi}^k = \gamma_{kh} q_{\beta i}^k$$

$$(b) \quad Q_{\beta}^k = \sum_{i=1}^n q_{\beta i}^k$$

where  $\pi_i$  = the total profit of firm  $i$  from their global operations;

$\pi_i^k$  = the total profit of firm  $i$  operating in country  $k$ ,  $k = 1, 2, \dots, N$ ;

$$= \sum_h P_h^k (Q_h^k) q_{hi}^k - P_{\beta}^k (Q_{\beta}^k) q_{\beta i}^k - \alpha_i^k - \beta_i^k q_{\beta i}^k$$

$P_h^k (Q_h^k)$  = country  $k$ 's inverse demand for commodity  $h$ ,  $h = m, o$ ;

$q_{hi}^k$  = quantity of  $h$  sold by firm  $i$  in country  $k$ ;

$q_{\beta i}^k$  = quantity of soybeans crushed by firm  $i$  in country  $k$ ;

- $P_{\beta}^k$  = supply price of soybeans in country k;  
 $\gamma_{kh}$  = yield coefficient of  $q_h$ ,  $h = m, o$ ;  
 $\alpha_i^k$  = fixed cost of production for firm i in country k,  $\alpha_i^k > 0$ ;  
 $\beta_i^k$  = cost of variable inputs used in crushing soybeans, except for the soybeans themselves,  $\beta_i^k > 0$ .

The fixed proportions production function for meal and oil allows firm profits to be expressed as a function of the quantity of soybeans. In addition, each firm's total cost is assumed to be a linear function of the quantity of soybeans. The larger are the fixed costs,  $\alpha_i^k$ , the stronger are the economies of scale. Marginal cost consists of two parts -- the soybean price and the cost of other variable inputs. The linear cost function assumption is quite strong. This assumption is adopted due to the limited data available on crushing costs -- usually a single observation. This research is concerned with the interaction of existing firms and not questions of entry or exit so that this assumption is tolerable.

Each firm chooses its soybean input (crush) so as to maximize profits as stated by (1), given the inverse demands for oil and meal in each market and the supply of soybeans and other variable inputs in each market. Rather than make an arbitrary assumption about firm rivalry, a conjectural variation is included to reflect each firm's assumption about the behavior of its rivals in each market. That is, the  $i$ th firm's first order condition for profit maximization in each market  $K$ ,  $k = 1, 2, \dots, N$  is given by:

$$(2) \delta \pi_i^k / \delta q_{\beta i}^k = \sum_h \gamma_{kh} P_h^k + \sum_h V_{ki} \gamma_{kh}^2 q_{\beta i}^k \delta P_h^k / \delta Q_h^k - [P_{\beta}^k + \beta_i^k] - V_{ki} q_{\beta i}^k \delta P_{\beta}^k / \delta Q_{\beta}^k = 0$$

where  $V_{ki} = 1 + \sum_{j \neq i} \delta q_{\beta j}^k / \delta q_{\beta i}^k = 1 + C_{\beta i}^k$ ,  $i = 1, 2, \dots, n$ .

The term  $\delta q_{\beta j}^k / \delta q_{\beta i}^k$  represents the  $i$ th firm's conjecture about the behavior of the  $j$ th rival in country  $k$  -- that is, how firm  $i$  believes rival firm  $j$  will alter its soybean crushing in response to an increase in crushing by  $i$ . Hence,  $V_{ki}$  represents the  $i$ th firm's conjecture about the effect on industry output of a change in its soybean processing level. Notice that the fixed proportions between soybeans and products imply that each firm has a single conjectural variation parameter in each market,  $C_{\beta i}^k$ .

As traditionally done only symmetric equilibria are considered as firm specific data on size and costs could not be found. As discussed subsequently there are techniques for representing an asymmetric firm industry with a symmetric firm industry proxy. Thus, all  $n$  first order conditions can be written as:

$$(3) \sum_h \gamma_{kh} P_h^k - [P_\beta^k + \beta^k] + (V_k Q_\beta^k)/n [\sum_h \gamma_{kh}^2 \delta P_h^k / \delta Q_h^k - \delta P_\beta^k / \delta Q_\beta^k] = 0$$

since  $q_{\beta i}^k = Q_\beta^k/n$ ,  $\alpha_i^k = \alpha^k/n$ ,  $\beta_i^k = \beta^k$ , and  $C_{\beta i}^k = (n-1) \delta q_{\beta j}^k / \delta q_{\beta i}^k = C_\beta^k$

with symmetry. The condition for equilibrium in each market can then be expressed as:

$$(4) nB^k + Q_\beta^k A^k [1 + C_\beta^k] = 0$$

where  $B^k = \sum_h \gamma_{kh} P_h^k - P_\beta^k - \beta^k$  and  $A^k = \sum_h \gamma_{kh}^2 \delta P_h^k / \delta Q_h^k - \delta P_\beta^k / \delta Q_\beta^k < 0$ .

This behavioral model has the virtue of allowing us to make inferences about the competitiveness of world soybean processing. Given data on crushing margins ( $SPD^k$ ) and processing of soybeans, it is possible to solve for either the slopes of the inverse demands for the products, ( $A^k$ ) or the conjectural variations ( $C_p^k$ ). One can either make an arbitrary assumption about market conduct (choosing  $C_p^k$ ) and then solve for the price effects implied by the slopes of the inverse product demands,  $A^k$ . Alternatively, using econometric estimates of the slopes, the conjectural variations can be determined. The latter procedure follows in the Bresnahan (1989) tradition of estimating parameters of market competitiveness. In the absence of explicit collusion, the conjectural variation,  $C_p^k$ , can range between zero and minus one.<sup>2</sup> For Cournot oligopolists,  $C_p^k = 0$  and each firm takes its rivals' soybean crushing as given. In this case  $V_k$  is unity, reflecting a representative firm's conjecture that a unit increase in soybean crushing will increase industry processing by a unit. For  $C_p^k < 0$  (thus  $V_k < 1$ ) behavior is more competitive. At the extreme,  $C_p^k = -1$ , and each firm conjectures no effect of its behavior on industry processing of soybeans. Under the fixed proportions assumption, this is equivalent to Bertrand competition in the product markets. That is, each firm acts as if it sets its price taking the meal and oil prices of its rivals as given. With homogeneous goods, Bertrand competition corresponds to a conjecture of -1 and in the absence of a binding capacity constraint the firm's first order conditions correspond to those under perfect competition<sup>3</sup>. In this case unit revenue as given by the prices of the products meal and oil will equal unit costs -- soybeans and other variable inputs just as in the case of perfect competition. In the perfectly competitive



limit, (4) implies a crushing margin equal to  $\beta^k$ , the unit cost of non-soybean inputs. With less competitive conjectures, the crushing margin is larger. That is:

$$(5) \sum_h \gamma_{kh} P_h^k - P_\beta^k(\cdot) = \beta^k - (Q_\beta^k/n) [A^k] (1 + C_\beta^k).$$

### Empirical Procedure

For the empirical application, first the number of multinational firms in the world soybean complex is needed. Then, using cost information, and given estimates of the slope and yield coefficients, the conjecture in country  $k$ ,  $C_\beta^k$ , is determined using equation (5). This indicates that in order to find  $C_\beta^k$ , the following data are needed: the crushing margin ( $SPD^k$ ); the cost of variable inputs (or average variable costs) excluding soybeans ( $\beta^k$ ); the yield coefficients ( $\gamma_{kh}$ ); the soybean crush ( $Q_\beta^k$ ); the number of symmetric-sized multinational firms ( $n$ ); the inverse slopes of the demand for soybean meal and soybean oil ( $\delta P_h^k / \delta Q_h^k$ ); and the inverse slope of the supply of soybeans to the crushing industry in each country.

To find the number of symmetric multinational firms in the world soybean processing sector a hypothetical symmetric-firm industry is used as a proxy. In defining this proxy, it is clear that it should not simply be the actual number of soybean processing firms. If these firms are greatly unequal in size, then a simple count of firms understates the effective degree of concentration. One way to adjust for this is to compute the Herfindahl equivalent number of symmetric firms. This is done by setting  $n$  equal to the reciprocal of the Herfindahl index (Helpman and Krugman, 1989, p. 163):

$$H = \sum_i Z_i^2 = 1/n$$

where  $Z_i$  is firm  $i$ 's actual share of sales. This study uses the Herfindahl ( $H_p$ ) index reported in the U.S. Census of Manufactures (1982) which is calculated by squaring the concentration ratio for each company and summing those squares to a cumulative total of the leading 50 companies or the complete universe whichever is lower. Using the  $H_p$  index for 1982 a numbers-equivalent estimate of 10 symmetric firms for the United States is obtained. Similar data were not obtained for the other nations. Thus, the U.S. value is used for each country and sensitivity analysis is performed to assess how important this assumption is.

The costs for non-soybean variable inputs --  $\beta$  -- come from two sources. The cost data reported in the U.S. International Trade Commission study are used for the United States, for Argentina, and for the European Community (Table 1). The data for Brazil is taken from the Faminow and Hillman study (Table 1). Neither study included data for Japan. The value of the marginal cost for Japan is assumed to equal that for the European Community since the plants are likely to be roughly the same age -- i.e. post-World War II.

Estimates of the slopes of the demand schedules for soybean meal and soybean oil as well as those for the soybean supply functions are obtained from the elasticities presented in Table 2. For the slope of the supply facing the crusher in a country, the slope of the inventory of soybeans is added to that of soybean production in the calculation since the supply of soybeans considered here is the total supply faced by the processing sector.

Where possible, the elasticities obtained are from previous work such as Williams, as well as Liu and Roningen. Where no elasticity was found in the previous literature it was estimated using data from the U.S. Department of Agriculture. Additionally, an effort was made

to include policies in place. For example, the Brazilian export tax structure is included. This policy data was obtained from various Oilseeds and Products Circulars published by the Foreign Agricultural Service.

## Results

Given the procedures discussed above, the data can be used to solve for the conjectural variations of soybean processing firms in each country,  $C_{\beta}^K$ . These then indicate the nature of the competition for the industry in each market. The resulting conjectural variations estimates are shown in Table 3. Interestingly, these conjectural values are quite similar across countries, ranging from -0.96 in Argentina to -0.998 in the United States. Thus, in all five countries, the conjectural variation is remarkably close to the Bertrand value of -1. The results divide into three groups. While the conjectural variations for the United States and the European Community differ as greater precision is recorded, they both round to -0.998. Japan and Brazil exhibit somewhat larger deviations from the Bertrand value with conjectural variations of -0.994 and -0.993, respectively. Argentina is estimated to have the largest conjectural variation and the greatest deviation from the Bertrand value with an estimate of -0.96. This may be due to the relative newness of soybeans as a crop in Argentina and the crushing industry during the base period of the late 1980's was an emerging industry. Soybeans first appeared as a major crop in the late 1970's and initially exports were largely in the form of soybeans as there was little crushing capacity. In 1975 there was only 1 firm with 2 plants using solvent extraction methods (Soybean Blue Book). During the early 1980's a crushing industry began to develop and only in the middle 1980's did Argentina begin to mirror the Brazilian pattern of emphasizing product exports. By 1987 there were 8 firms with 13 plants, of which 3 were owned by U.S.

affiliates (Soybean Blue Book). It is possible that the comparatively high conjectural variation for Argentina reflects the youth of the Argentine crushing industry compared to the more mature industries in the other countries analyzed.

From the standpoint of an empirical model none of the conjectural variations estimated are sufficiently different from -1 to greatly affect the second stage equilibrium conditions. A soybean complex model solved with these estimated conjectural variations will closely mimic one based on a perfectly competitive assumption.

### **Sensitivity Analysis**

The conjectural variations estimated for the soybean processing industry in the different countries are quite similar and are close to the value obtained by a Bertrand solution. This is important as it suggests that little is gained empirically by recognizing the oligopoly in the market. Thus, the robustness of these estimates is important, particularly given the assumptions made to obtain them. That is, how consistent are these conjectures for reasonable changes in the values of the elasticities, the number of firms, and the value of the profit margin. If the parameters were obtained by econometric estimation, then confidence intervals for the conjectural variations could be found as in Thursby and Thursby. As previous elasticity estimates are used in this study, sensitivity analysis must be employed. The exogenous parameters are varied and the changes in the conjectural variation are noted.

Due to the lack of data the symmetric-size equivalent found for the United States was used for each country. The consequence of this assumption can be tested by varying the number of firms in each nation. The sensitivity analysis results for changes in the number of symmetric firms indicate that the conjectural variations are relatively stable (Table 4). For example, the conjectural variation values for the United States range between -0.999 and -0.996 as the number



of U.S. firms varies from a low of 5 to a high of 20. The European Community shows a similarly small change as the number of firms is ranged. The conjectural variations for Japan and Brazil show a somewhat larger, yet still small change in response to increasing the number of firms from 5 to 20. The greatest sensitivity to firm numbers is found for the Argentine conjectural variation, which changes from -0.98 with 5 firms to -0.919 with 20 firms. Nevertheless, even with this difference the change is small enough that the solutions from an empirical soybean model are hardly affected. The difference in crushing as the firm number changes from 5 to 20 can be written as:

$$Q_{\beta}^a - Q_{\beta}^{a'} = [(\beta^a - SPD^a)/A^a][(5/(1 + C_{\beta}^a)) - (20/(1 + C_{\beta}^{a'}))]$$

where "/" indicates the variable associated with the number of firms equal to 20. In the Argentine case, the most extreme case, the difference in total Argentine soybean crushing is 0.5 thousand tons on crushings of 4.4 million tons.

Other critical parameters to the estimated values of the conjectural variations are the elasticities which are largely taken from studies by others. These too are ranged in Table 4 from one-half to double the base value. The U.S. conjectural variation ranges from -0.999 to -0.998 with changes in the elasticity of demand for soybean meal from -50 to +200 percent of the base value of -0.399. Similar changes are obtained for the range of the conjectural variation with respect to changes in the elasticity of demand for soybean oil and the elasticity of supply for soybeans. As in the previous results, the Argentine conjectural variation shows the greatest absolute and relative changes. In the case of the elasticity of demand for soybean meal, the conjectural variation at an elasticity of 50 percent below to base value of -0.619 is -0.975. When the elasticity of soybean meal demand rises to 200 percent of the base value the conjectural variation for Argentina rises to -0.937.

Equation (5) shows that the profit margin (crushing margin) is important to the estimated conjectural variation. The margin is dependent on prices of soybeans, meal, and oil with calculated margins very sensitive to the individual prices used. That is, differences in the price data can lead to considerably different calculated margins. Thus, it is appropriate to consider how sensitive the estimated conjectural variations are to changes in the profit margin.

The crushing margin is an important variable in the calculation of the conjectural variations in several ways. The spread between the value of products and the soybean price is where the degree of imperfect competition ought to be reflected. Also as shown in Table 2 the price of soybeans represents such a large portion of the value of products produced that the margin is relatively small. This means that small differences in the prices used for the model greatly affect the margin. The estimated conjectural variations indeed show the greatest sensitivity to changes in the profit margins. When the profit margin in the United States doubles, the estimated value of the conjectural variation rises from -0.998 to -0.900 (Table 5). The sensitivity analysis also indicates that in this model, the conjectural variation for the United States is more sensitive to changes in the profit margin than are the conjectural variations for the other countries. A 10 percent increase in the profit margin leads to a 0.01 increase in the conjectural variation of the United States. For Argentina, the EC, Brazil, and Japan 10 percent increases in the profit margins cause conjectural variation increases of 0.006, 0.004, 0.002, and 0.001, respectively. Solving an empirical model of the soybean complex with such changes in the U.S. conjectural variation leads to a significant decline in U.S. soybean crushings; hence, U.S. exports of soybeans increase. Increased U.S. soybean exports reduces exports of soybeans from Argentina and Brazil. Thus, the sensitivity analysis suggests that the most critical data for determining the nature of competition in the soybean processing sector are the crushing margins. This means that slight differences among data sources for the three prices can greatly affect the

estimated nature of the competition. Other parameters such as firm numbers and elasticities did not greatly alter the estimates of the conjectural variations obtained with this model.

## Conclusions

Observation of the soybean processing sector shows firms to be multinational oligopolists operating with scale economies. Given such features, this study infers the conduct of the industry. To do that, a model of the industry is developed using conjectural variations as indicators of the nature of competition. Based on a Herfindahl index of the U.S. Census of Manufactures, the number of symmetric-sized soybean processing firms is ten. From elasticities of the supply of soybeans and of demands for soybean meal and oil, conjectural variations of the processing sector are calculated. The resulting conjectural variations range from -0.998 for the United States to -0.96 for Argentina. The relatively close values of these conjectural variations across countries indicates a similar behavior for the soybean processing industry in the United States, the European Community, Japan, Argentina, and Brazil. Also, these conjectural variations are relatively close to the Bertrand conjectural variation of -1. This analysis suggests that, despite the oligopolistic industry structure, the soybean processing sector is relatively price competitive.

In interpreting these results it should be noted that this conclusion is subject to the usual criticisms of calibration procedures. There are no confidence intervals on these conjectural estimates, so that no statistical inference is implied. The calculated conjectural variations follow from the assumption that the model specified is the true model and market data are equilibrium data.

Because confidence intervals cannot be calculated, sensitivity analysis for critical parameters is performed. The results indicate that the conjectural variations obtained are

relatively stable for changes in the values of the elasticities used in the calculations. Hence, the conduct estimated for the soybean processing industry remains relatively consistent with application of the different price elasticities found in the empirical literature. The same situation occurs for firm numbers. Thus, the use of 10 symmetric firms in the sector does not seriously affect the results obtained. However, significant changes in the calculated conjectural variations do occur when the crushing margin is changed. Especially for the United States the level of the crushing margin significantly influenced the conduct estimated. This indicates the importance of data used to calculate the crushing margin to the estimated of market conduct.



## Footnotes

- <sup>1</sup> Annual capacity figures are misleading as plants require added capacity to handle seasonality in both product demand -- for livestock feed -- and in soybean supply.
- <sup>2</sup> Collusion implies  $C_{\beta}^k = n - 1$ .
- <sup>3</sup> In models where firms set capacity first and then compete in price, it has been shown that equilibrium outcomes may mimic Cournot or Stackelberg outcomes, or there may be non-degenerate mixed strategy equilibria. See Faith (1991).

## References

American Soybean Association. Soya Bluebook. St. Louis, MO. Various issues. (Soybean Blue Book. 1947-1964; Soybean Digest Blue Book. 1965-1972; Soybean Digest Bluebook. 1973-1979; Soya Bluebook. After 1980).

Bain, J.S. Industrial Organization. New York: John Wiley and Sons, Inc., 1968.

Bresnahan, T.F. "Empirical Studies of Industries with Market Power." In R. Schmalensee and R. Willing (eds.) Handbook of Industrial Organization. Amsterdam: North Holland, 1989. Chapter 17.

Brewster, J.M. and J.M. Mitchell. Size of Soybean Oil Mills and Returns to Growers. Market Research Report No. 121. Agricultural Marketing Service, U.S. Department of Agriculture. 1956.

Connor, J.M., et al. The Food Manufacturing Industries: Structure, Strategies, Performance, and Policies. Lexington, MA: Lexington Books, 1985.

Faith, T. "Bertrand-Edgeworth Competition with Sequential Capacity Choice," Krannert School of Management Working Paper No. 997. Purdue University, January 1991.

Faminow, M.D. and J.S. Hillman. "Causes of the Rapid Development of Brazil's Soybean Industry: A Study of Policy-Response to the 1973 U.S. Soybean Embargo." Working Paper. Department of Agricultural Economics, University of Arizona, May 1986.

Helpman, E. and P.R. Krugman. Trade Policy and Market Structure. Cambridge, MA: The MIT Press, 1989.

Houck, J.P., M.E. Ryan, and A. Subotnik. Soybeans and Their Products: Markets, Models, and Policy. Minneapolis, MN: University of Minnesota Press, 1972.

Krishna, K. and M. C. Thursby. "Trade Policy with Imperfect Competition: A Selective Study," in Imperfect Competition and Political Economy: The New Trade Theory in Agricultural Trade Research. C. A. Carter, A. F. McCalla, and J. A. Sharples (eds). Boulder, CO: Westview Press, 1990. pp. 9-35.

Liu, K. and V.O. Roningen. "The World Grain-Oilseeds-Livestock (GOL) Model, A Simplified Version." Staff Report No. AGES850128. Economic Research Service, U.S. Department of Agriculture. February 1985.

Richardson, J.D. "Empirical Research on Trade Liberalization with Imperfect Competition: A Survey." OECD Economic Series. No. 1/2. Spring 1989.

Sutton, J. Sunk Costs and Market Structure. Cambridge, MA: The MIT Press, 1991.

Thursby, M.C. and J.G. Thursby. "Strategic Trade Theory and Agricultural Markets: An Application to Canadian and U.S. Wheat Exports to Japan." In C.A. Carter, A.F. McCalla,

and J.A. Sharples (eds.). Imperfect Competition and Political Economy: The New Trade Theory in Agricultural Trade Research. Boulder, CO: Westview Press, 1990. pp. 87-106.

United States Department of Agriculture. Agricultural Marketing Service. Processing Costs of Soybean Oils Mills, 1951-1952. May 1954.

United States Department of Agriculture. Economic Research Service. Fats and Oils Situation. FOS Series. Various issues.

United States Department of Agriculture. Foreign Agricultural Service. Foreign Agriculture Circular: Oilseeds and Products. FOP Series. Various issues.

United States Department of Commerce. Bureau of the Census. Census of Manufactures. Various issues.

United States International Trade Commission. U.S. Global Competitiveness: Oilseeds and Oilseed Products. USITC 2045. December 1987.

Vandenborre, R.J. "Demand Analysis of the Markets for Soybean Oil and Soybean Meal." Journal of Farm Economics. Vol. 48, No. 4. November 1966: 920-934.

Williams, G.W. The U.S. and World Oilseeds and Derivatives Markets: Economic Structure and Policy Interventions. Ph.D. Thesis. Purdue University. May 1981.

Williams, G.W. and R.L. Thompson. "Brazilian Soybean Policy: The International Effects of Intervention." American Journal of Agricultural Economics. Vol. 66, No. 4. November 1984: 488-498.



Table 1: Average Cost of Processing Soybeans, 1986

Cost	United States	Argentina	European Community	Brazil <sup>1</sup>
-- Dollars per Metric Ton --				
Soybean Price:	210.89	154.59	287.19	154.59
Variable Processing Costs:				
Labor	3.33	1.54	3.61	1.12
Fuel/Utilities	6.26	3.73	4.90	8.51
Repairs	2.53	1.38	2.16	0.92
Solvent	0.37	0.61	0.37	0.16
Total	12.49	7.26	11.04	10.71
Fixed Costs <sup>2</sup> :				
Depreciation & Amortization	2.47	2.23	2.12	
Other	2.73	1.41	4.05	
Total	5.20	3.64	6.17	3.45
<b>Total Costs:</b>	<b>228.58</b>	<b>165.49</b>	<b>304.40</b>	<b>168.75</b>

<sup>1</sup> Costs for Brazil are referenced from Faminow and Hilmann and USITC.

<sup>2</sup> These are the processing costs are based on crushing at full capacity.

Sources: U.S. International Trade Commission, 1987, and Faminow and Hillman, 1986.

Table 2: Base Data Used for the Calculation of Conjectural Variations

Item	United States	Argentina	European Community	Japan	Brazil
<b>Yield:</b>					
Meal	0.7895	0.7963	0.7958	0.7760	0.7777
Oil	0.1832	0.1670	0.1762	0.1823	0.1879
<b>Elasticity:</b>					
Meal	-0.3990	-0.6190	-0.2839	-0.0437	-0.2000
Oil	-0.1484	-0.4040	-0.5638	-0.2979	-0.1627
Beans	0.5000	0.4539	3.5739	0.1000	0.1105
Stocks	-1.0183	-0.7927	-0.6248	-0.0495	-0.0256
<b>Price:<sup>1</sup></b>					
Meal	162.67	144.98	211.59	47.00	2215.47
Oil	462.33	366.99	583.44	129.39	5769.07
Beans	201.11	154.29	257.19	55.01	2583.10
Margin	12.74	22.467	14.023	5.057	223.714
Cost	12.49	7.260	13.248	2.298	159.766
<b>Use:<sup>2</sup></b>					
Meal	17.8300	0.2912	18.6500	3.1700	2.4800
Oil	4.6600	0.0800	1.4100	0.7000	1.8100
Soybeans					
Crush	29.5900	4.3702	12.8801	3.8400	13.3400
Stocks	11.6901	1.9300	0.600	0.7930	4.0700
Output <sup>2</sup>	53.5200	7.0200	0.4600	0.2367	16.5600

<sup>1</sup> For the United States and Argentina -- U.S. \$ per ton.  
 For the European Community -- ECU per ton.  
 For Japan -- thd. Yen per ton.  
 For Brazil -- CZ per ton.

<sup>2</sup> Million Metric tons.

Sources: Elasticities -- either estimated or from Williams; Liu and Roningen.  
 Other Data -- Foreign Agricultural Service, Oilseeds and Products Circulars.  
 Brazilian Prices -- Economic Research Service including estimates of producer and consumer subsidy equivalents, 1984/85-86/87 Average on U.S. crop years.

Table 3: Estimated Conjectural Variations for the Soybean Processing Industry by Country

Country	Conjectural Variation
United States	-0.998
Argentina	-0.960
European Community	-0.998
Japan	-0.994
Brazil	-0.993

Table 4: Sensitivity Analysis of the Conjectural Variations with Respect to Firm Numbers and Elasticities.

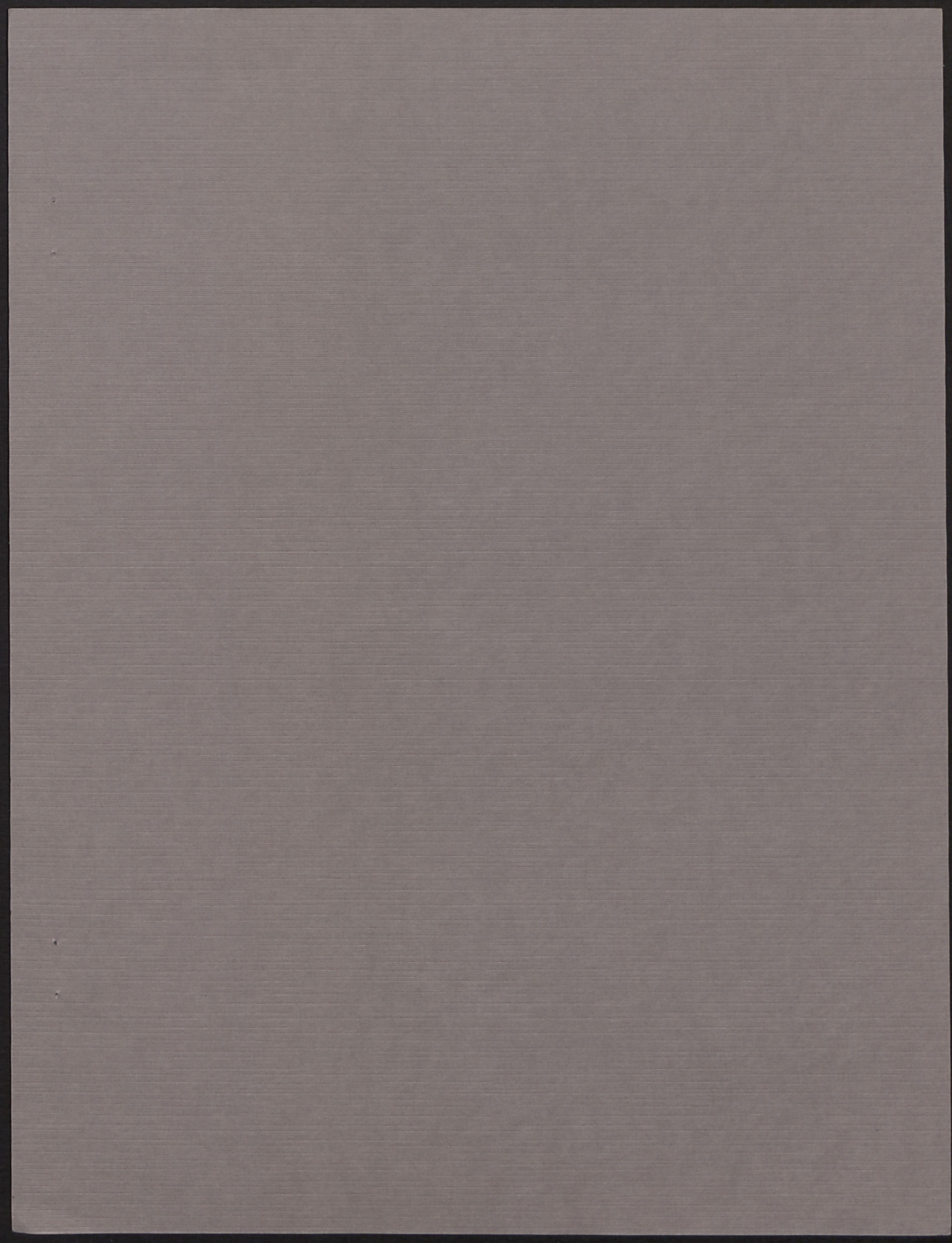
Item	Conjectural Variations Calculated				
	United States	Argentina	European Community	Japan	Brazil
<b>Firm Numbers:</b>					
5	-0.999	-0.980	-0.999	-0.997	-0.997
10 (Base)	-0.998	-0.960	-0.998	-0.994	-0.994
15	-0.997	-0.939	-0.997	-0.991	-0.990
20	-0.996	-0.919	-0.996	-0.988	-0.987
<b>Elasticity Changes:</b>					
<b>Meal Demand<sup>1</sup></b>					
-50 percent	-0.999	-0.975	-0.998	-0.995	-0.995
Base	-0.998	-0.960	-0.998	-0.994	-0.994
200 percent	-0.998	-0.937	-0.998	-0.993	-0.992
<b>Oil Demand<sup>1</sup></b>					
-50 percent	-0.999	-0.997	-0.998	-0.994	-0.994
Base	-0.998	-0.960	-0.998	-0.994	-0.994
200 percent	-0.997	-0.948	-0.998	-0.994	-0.993
<b>Supply Soybeans<sup>1</sup></b>					
-50 percent	-0.998	-0.961	-0.999	-0.997	-0.996
Base	-0.998	-0.960	-0.998	-0.994	-0.994
200 percent	-0.998	-0.959	-0.996	-0.988	-0.990

<sup>1</sup> Base elasticity values are reported in Table 2.

Table 5: Sensitivity Analysis of the Conjectural Variations with respect to Changes in the Profit Margin.

Percent Changes in the Profit Margin	Calculated Conjectural Variations				
	United States	Argentina	European Community	Japan	Brazil
Base <sup>1</sup>	-0.998	-0.960	-0.998	-0.994	-0.994
10	-0.988	-0.954	-0.994	-0.993	-0.991
50	-0.949	-0.930	-0.978	-0.989	-0.982
100	-0.900	-0.900	-0.958	-0.983	-0.971

<sup>1</sup> Base crushing margins are reported in Table 2.





This material is based in part on work supported by the U.S. Department of Agriculture, Cooperative State Research Service, under Agreement No. 89-34210-04238 and successor(s).

Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture.

Additional information on NC-194 and a complete list of project publications can be obtained from:

*Executive Director, NC-194  
Department of Agricultural Economics  
The Ohio State University  
2120 Fyffe Road  
Columbus, Ohio 43210-1099  
(614)292-2194*