#9923

# CALCULATING PROFIT NEUTRAL LAND AND PRICE POLICIES

This paper shows that introduction (or removal) of land set aside and government price supports can be coordinated so that they do not change the profits of agricultural producers. A profit function is estimated for a subsector of Brazilian agriculture and used to simulate profit neutral changes in land used and output prices.

Carlos A Arnade and Sandra Grigsby
Aggregate Indicators Branch
ERS 1301 New York ave
Wash DC
phone 202-219-0705



AAEA, 1991

1991

Soil conservation

Carlos A Arnade
Aggregate Production Models
ERS-USDA
Phone 202-219-0705

#9936

# INTRODUCTION

The concept of revenue neutral tax and spending policies has proven popular in the United States and it's effects on agricultural firms has been analyzed by Holloway (1990). Applying a similar concept to recipients of a soil conservation program may make the programs more acceptable to a public with lower average incomes than landowners. This leads to the problem of designing a soil program so that participating landowners earn profits equal to what they would earn outside the program.

This paper introduces a technique for calculating profit neutral changes in land use and agricultural prices. This technique can be used to simultaneously introduce (remove) a land set aside program (to conserve soil) and set support prices (for program participants) without changing farm profits. Profit neutral changes are then calculated for a subsector of Brazilian agriculture.

The technique introduced in this paper is one alternative to producer compensation techniques described by Larson (1988) and Just, Hueth, and Schmitz (1982). These authors adapt the consumer compensation technique (see Varian p. 209) by writing producer utility as a function of profits and wealth. A lump sum income payment is added to producer wealth to maintain expected utility when expected prices of the production activity changes.

Pope et al. (1983) uses a similar lump sum payment to measure the certainty equivalent of a risky situation for producers. In the above cases maintenance of producer utility is the object of compensation so that a Slutsky equation is required to convert compensated supply and input demand functions into empirically observable functions.

In this paper part of a quasi-fixed input is set aside or brought into use to maintain producer profits when known prices change. Since profits are the object of compensation there is no need to specify a utility function and no need to convert compensated supply and input demand functions into empirically observable functions. Therefore the technique used in this paper is parsimonious in the number of empirical steps needed to calculate compensation levels, does not demand data beyond that required for estimation of a profit function, and avoids the subjective concept of utility.

The next section defines the functions that calculate profit neutral tradeoffs between producer prices and producer levels of a quasi-fixed input. The following section provides a theoretical justification for these functions. The final part of the paper provides estimates a profit function and estimates of profit neutral tradeoffs between land set asides and prices for a subsector of Brazilian agriculture.

# PROFIT NEUTRALITY

A profit neutral change in prices and quasi-fixed input leaves profits unchanged. Therefore profit neutrality is defined as:

1) $\pi^* = g(P, W, V) = g(P', W', V') = g(P,' W', V + Z)$

where $\pi^*$ is a level of profits, $g(P, W, V)$ is a multioutput restricted profit function, whose arguments are represented by an output price vector P, an input price vector W, and quasi fixed input V.[1] Output price vectors and input price vectors <u>after</u> a policy change are represented by P′ and W′. The quasi-fixed input <u>after</u> a policy change is represented by V′. Therefore Z represents the amount the quasi-fixed input must be changed (set aside or brought into use) after a price change to restore the original level of profits.

Figure 1 illustrates profit neutral combinations of a <u>single</u> output price and the quasi-fixed input. Since the profit function is nondecreasing in both output prices and the fixed input a constant profit frontier (shown in figure 1) has a downward slope. Since the profit function is convex in output prices and concave in the fixed input the constant profit frontier in figure 1 is drawn as having an S shape. The appendix further discusses the shape of this frontier.

Suppose land is a quasi-fixed input. Suppose producers who participate in a soil set aside program face restrictions on their land use and in return receive some form of price support. Suppose policy makers want these two policy instruments to be jointly administered so that participants remain on the same profit frontier as they would as nonparticipants. The profit neutral land adjustment (Z) must be calculated. This land adjustment term (Z) will be a function of the initial prices, the new prices, and the initial level of profits. To see this, invert the profit function in equation 1 at the pre-change price level to get:

2) $V = g^{-1}(\pi^*, P, W)$

Invert the profit function at the post-change price level to get:

3) $V' = V + Z = g^{-1}(\pi^*, P', W')$

Therefore Z can be written as:

4) $Z = g^{-1}(P', W', \pi^*) - g^{-1}(P, W, \pi^*)$

Equation 4 shows that differences between two inverted profit functions evaluated at different prices <u>but at a constant level of profits</u> will be equal to the Z term in equation 4. If a restricted profit function is estimated and inverted then it is possible to estimate profit neutral combinations of land use and output prices. The next section justifies the existence of the functions in equation 4.

## THE INDIRECT TRANSFORMATION FUNCTION.

In discussing constrained profit maximization Henderson and Quandt [1971] briefly note that "an entrepreneur might desire to minimize the quantity of X (their quasi-fixed input) in order to obtain a specified revenue" [e.g. Henderson et. al. (1971 p.93)]. There is little evidence that economists have investigated the implications of producers which follow this decision though the behavior implied by other optimizing decisions (profit maximization, cost minimization) are well established [see Blackorby et. al. (1978), Chambers (1988)].

A way of defending the resource minimizing decision is to point out that it represents a tractable way of modeling producers with lexicographic preferences. Having reached a specified profit level producers may then only desire to preserve their land, water, (or even labor) resources. Certainly there exists producers with these preferences. However, more importantly, producers who participate in profit neutral land set aside programs, and receive compensatory prices, will behave as if they are resource minimizers. To see this and explore the Henderson and Quandt suggestion write a transformation function as:

(5) $H(Y, X,) = V$.

Where Y is a vector of outputs, X is a vector of variable inputs, and V is a quasi-fixed input.

Resource minimizing producers choose the mix of outputs and variable inputs which minimizes use of the quasi-fixed input while constraining profits to equal or lie above a minimum level. The indirect transformation function represents the solution to this problem and can be written as:

$$6)\ V(P, W, \pi^*) = \min_{Y,X} H(Y,X)$$

$$\text{s.t.: } PY - WX \geq \pi^*$$

where s.t. denotes the phrase "subject to" and $\pi^*$ represents a fixed level of profits.

Notice equation 6 represents the dual problem to maximizing profits while holding the fixed input at a predetermined level. When there are M outputs in the vector Y, and N inputs in the vector X (and when output and input decisions are independent)[2] the first order conditions to the above problem are:

$$7)\ a)\ Hy_i' = \tau P_i \quad \text{for } i = 1,2,\ldots M$$

$$b)\ Hx_j' = -\tau W_j \quad \text{for } j = 1,2,\ldots N$$

$$c)\ \pi^* = PY - WX.$$

where $Hy_i'$ is the derivative of the transformation function with respect to the ith output, $Hx_j'$ is the derivative of the transformation function with respect to the jth input and $\tau$ is the Lagragian multiplier and is equal to the inverse of the shadow price of the fixed input.[3]

Recall that the derivative of the transformation function with respect to an output is the inverse of the marginal product of that output with respect to the fixed input [Henderson et. al. (1971)]. Using this and writing the shadow price of the fixed input as $W_v$ the conditions in 7a and 7b can be rewritten as:

8) a) $W_v{*} = P_i{*}F^{i\prime}v$ for $i = 1,2,\ldots M$

b) $Hx_j' = -\,W_j/W_v$ for $i = 1,2,\ldots N$

where $F^i v'$ is the marginal product of output i with respect to the fixed input.

Equation 8a demonstrates that the fixed input will be allocated across products until it's marginal value product in each of it's uses equals it's shadow price. Equation 8b states that the marginal rate of substitution between the fixed input and the variable inputs equals the negative ratio of the variable input price to the shadow price of the fixed input.

These first order conditions can be solved to obtain compensated supply and demand functions whose arguments are output prices and the predetermined profit level. Compensated supply (demand) functions are nonincreasing (nondecreasing) in their own prices. Substituting the compensated supply and demand functions into the transformation function in equation 5 produces the indirect transformation function. The indirect transformation function is continuous and homogenous of degree zero in prices and profits, is nondecreasing in profit and nonincreasing and quasi-concave in prices. [4]

Since the resource minimization problem in equation 6 is dual to the profit maximization problem the indirect transformation is the inverse of the profit function. (This relationship is analogous to the relation between a consumer expenditure function and an indirect utility function.) An indirect transformation function evaluated at prices $P'$ and $W'$ and profit level $\pi^*$ is equal to the inverse profit function in equation 3. Since equation 3 defines the choices of producers who enter a land set aside program; program participants are equivalent to resource minimizers who receive prices equal to $P'$ and $W'$ and earn profits equal to $\pi^*$.

## A BRAZILIAN EXAMPLE

In the past two decades the soil resources in Brazil's eastern states have come under increased pressure as producers have reduced the fallow periods between crops and have increased their use of fertilizers and pesticides. At the same time Brazil's deforestation of the Amazon has become an international issue

[Katzman (1982)]. Better managing the soil resources in Brazil's eastern states could reduce pressure to expand the agricultural land area.

In the past Brazil subsidized fertilizer use, supported wheat prices, and imposed export quotas [Foreign Agricultural Service (1981), Ruff et. al. (1984)]. Brazilian policymakers face pressure to eliminate these distortions, to conserve soil resources, and to slow deforestation. Brazil also has powerful rural interests which could slow agricultural policy changes. This is an ideal setting for simulating profit neutral changes in land use and pricing policies.

The first step in calculating profit neutral land and price tradeoffs is to specify a profit function. A normalized quadratic profit function was specified for a combination of four major Brazilian crops (corn, rice, wheat, and soybeans), two variables inputs (fertilizer, labor), and one quasi-fixed input (the total acreage planted to the four crops). The second step is to estimate the profit function and invert it to obtain an indirect transformation function. The third step is to simulate the effect of price changes on the indirect transformation while holding the profits constant. This final steps provides estimates of the Z term in equation 4.

The profit function was specified as:

$$9)\quad g(P, Ld) = \pi' = \sum_{i=1}^{5} \beta_i P'_i + 1/2\left(\sum_{i=1,j=1}^{5}\sum^{5} \beta_{ij} P'_i P'_j\right) + \sum_{i=1}^{5} \beta_{ik} P'_i Ld$$

where the $\pi'$ are profits normalized on the price of rice $P_i'$ represents the prices of corn (1), wheat (2), soybeans (3), fertilizer (4) and labor (5) normalized on the price of rice, Ld is the land devoted to the four crops and the ß's represent the parameters of the profit function. Shumway (1983) discusses the advantages of a normalized quadratic function.

By Hotelling's Lemma the ith supply and hth demand function can be expressed as:

$$10)\ a)\ Y_i = \delta g/\delta P_i = \beta_i + \sum_{j=1}^{5} \beta_{ij} P' + \beta_{ik}\, Ld$$

$$b)\ X_h = -\delta g/\delta P_h = \beta_h + \sum_{j=1}^{5} \beta_{hj} P' + \beta_{hk}\, Ld$$

The parameters of the profit function were estimated from the system of supply and demand equations similar to 10.

Annual production data, from 1969 to 1987, of the four Brazilian crops and the total acreage planted to these crops was obtained from the United Nations Food and Agriculture Organization [6]. The fertilizer consumed by the four crops was calculated as a percentage of the Food and Agricultural Organizations estimates of total Brazilian fertilizer use. Brazilian budgets from the

Instituto de Economia Agricola (1973-1989) for 21 crops were used along with acreage data to determine this percentage.[5] Annual output and input prices were obtained from publications of the Getulio Vargas institute [1970 to 1988]. Prices were normalized on the price of rice.

Error terms, which were assumed to be additive and normally distributed, were appended to the three supply and two demand equations (corn, wheat, soybeans, fertilizer, and labor) and relative prices were lagged one period to represent naive relative price expectations. This system was estimated using 1969 to 1987 data. Symmetry was imposed by setting $\beta_{ij} = \beta_{ji}$.

Seemingly unrelated regression (SUR) estimators, which are consistent and efficient (relative to OLS estimators), are listed in table 1 along with their T statistics. The estimated parameters were consistent with the properties of a profit function. Most important the matrix of estimated $\beta_{ij}$'s was positive semidefinite at the mean data points. Elasticities of supply and demand were calculated at the means of the data and are reported in table 2. Symmetry and homogeneity restrictions were used to calculate the elasticities for rice.

## SIMULATION OF PROFIT NEUTRAL TRADEOFFS

The estimated profit function at the mean data points and 1987 data points exceeded calculated profits. This error was included in the indirect transformation function to insure that it equaled the acreage planted to the four crops at the initial prices. If equality did not hold at the initial prices then simulated estimates of land use after the price changes would be less credible.

The indirect transformation function obtained by inverting the estimate of equation 9 was:

$$11)\ Ld = [\pi' - \sum_{i=1}^{5*} \beta_i P'_i - 1/2(\sum_{i=1}^{5} \sum_{j=1}^{5*} \beta_{ij} P'_i P'_j) - \mu] / \sum_{i=1}^{5*} \beta_{ik} P'_i$$

where $\overset{*}{\beta}$'s indicates the estimators of the β's and μ represents the differences between estimated and calculated profits.

The effect of price changes (while holding profits constant) on the estimated indirect transformation function in equation 11 were simulated at both the mean data values and the last year of estimation (1987). The differences in the resulting and initial values of the function in equation 11 provides an estimate of the Z term in equation 4. This represents the estimated change in acreage required to maintain profits (taking account for substitution of inputs and outputs) when prices change.

In all simulations rice prices were assumed to remain constant. Despite this there is an wide number of profit neutral output price tradeoffs for each land set aside. Table 3 reports land area changes as a percentage of the original land in the four crops for a given change in output prices. Tradeoffs listed outside (inside) parenthesis are estimated at the mean (1987) data values.

The simulation results produce some useful insights. First, assuming other prices stay constant (at the mean data points), a 10% rise in soybean prices ensures neutrality of profits when approximately 2.9% of the land is set aside for soil conservation purposes. A 20% rise in soybean price offsets set asides equal to 5.5% of the acreage planted the four crops. A 10% rise in corn prices offsets set asides equal to 2.7% of the land planted to the four crops. Therefore increasing soybean prices either through price supports or increasing internal soybean demand, or encouraging trade liberalization (which is assumed to increase soybean prices) is a good way to compensate for land set asides.

Going the other way an increase in the land area of .8% is enough to offset a 10% reduction in wheat price supports. Therefore a land compensation scheme to maintain profit neutrality when wheat price supports are removed puts little pressure on

nonagricultural land. In one simulation corn prices are assumed to rise 26.4% and soybean prices 6.4% as predicted by Roningen and Dixit's (1989) trade liberalization model. Suppose this world price rise is passed through to Brazilian producers and rice prices do not change. With these price changes the Brazilian government could reduce wheat price supports 20%, allow fertilizer prices to rise 20% and set aside 9.2% of the land planted to the crops for soil conservation, and maintain producer incomes of this subsector of the agricultural economy. Such a world would be ideal. Brazil could reciprocate for a reduction in trade barriers in the developed world by getting out of the costly business of subsidizing fertilizer and wheat, and set aside land for soil regeneration without changing producer profits. The appeal of achieving these objectives without changing the agricultural profits of landowners in society such as Brazil's should be obvious.

## CONCLUSION

Governments can coordinate land use and agricultural pricing policies so that the combined impact of the policies do not change profits of agricultural producers. Therefore the goal of soil conservation can be separated from the goal of influencing farm incomes. If participants in an land set aside program receive price supports the joint goals of price stability (arising from price supports) and soil conservation can be achieved without changing farm incomes. Landowner income benefits (or losses) need not become a reason to avoid a soil conservation program.

This paper introduced a method which determines the combination of price and input policies which are profit neutral. To apply the technique introduced in this paper only requires data on prices and quantities of agricultural outputs and inputs; including a quasi-fixed resource such as land. Complexities arising from making unmeasurable producer utility the goal of compensation schemes are avoided.

Several profit neutral tradeoffs between land use and output prices were calculated for four Brazilian crops. These simulations showed that more land can be set aside by raising soybean prices than by raising prices on other crops. These simulations also showed that profit neutral combinations of policy instruments can be calculated in a simple and straightforward manner.

The next step is to specify a voter preference function or a government expenditure function to determine an optimal point on the constant profit frontier. Also, except when this technique is applied to individual producers, the distribution of gains and losses among producers needs to be addressed. This paper was primarily concerned with demonstrating that it is possible to estimate tradeoffs along the (multidimensional) frontier. In this paper no point was considered superior to any other.

## REFERENCES


(1) Blackorby, C., D. Primont, and R. Russell, *Duality, Separability and Functional Structure* New York: North-Holland, 1978

(2) Chambers, R. *Applied Production Analysis* New York: Cambridge University Press 1988.

(3) Foreign Agricultural Service, "Brazil: Agricultural and Trade Policies" Washington DC: United States Department of Agriculture FAS M-305, 1981.

(4) Food and Agricultural Organization, *Production Yearbook* Rome, Italy: Various issues 1968-1987.

(5) Fundacao Getulio Vargas, "Precios Recebidos Pelos Agricultores" Rio de Janerio, Brazil: Varios issues 1970-1988.

(6) Fundacao Getulio Vargas, "Precios Pagamos Pelos Agricultores" Rio de Janerio, Brazil: Varios issues 1970-1988.

(7) Henderson, J., and R. Quandt, *Microeconomic Theory: A Mathematical Approach* New York: Mcgraw-Hill Book Company 1971.

(8) Holloway, G. "Revenue Neutral Tax Policies" *American Journal of Agricultural Economics* 72(1990) 157-159.

(9) Instituto de Economia Agricola, *Prognostico*, Soa Paulo, Brazil: Various issues 1973-1987.

(10) Just, R., and D. Hueth, and A. Schmitz *Applied Welfare and Public Policy*, Englewood Cliffs NJ: Prentice-Hall, 1982.

(11) Katzman, M., *Ecology, Natural Resources, and Economic Growth: Underdeveloping the Amazon Chicago*, Ill: University of Chicago Press, 1987.

(12) Larson, D., "Exact Welfare Measurement for Producers Under Uncertainty," *American Journal of Agricultural Economics* 70(1988) 597-603

(13) Pope, R., J.P. Chavas, and R. Just "Economic Welfare Evaluations for Producers Under Uncertainty." American Journal of Agricultural Economics 65(1983) 98-107

(14) Ministerio do Planejemento e Coordenacao General, *Anuario Estatistico do Brasil* Rio De Janeiro, Brazil: Various issues 1972-1978.

(15) Roningen, V., and P. Dixit, "How Level is the Playing Field? An Economic Analysis of Agricultural Policy Reforms In Industrial Market Economies?" Washington DC: United States Department of Agriculture, Economic Research Service FAER No. 239, Dec., 1989.

(16) Ruff S., and M. Mielke, Brazil: An Export Market Profile, Washington DC: United States Department of Agriculture, Economic Research Service FAER No. 197, Feb., 1984.

(17) Shumway, R., "Supply, Demand, & Technology in Multiproduct Industry: Texas Field Crops", *American Journal of Agricultural Economics* 65(1983) 748-759.

(18) World Bank, *World Development Report 1986*. New York: Oxford University Press 1986.

(19) Varian, H. R. *Microeconomic Analysis*, New York: Norton & Company 1978.

## APPENDIX: THE CONSTANT PROFIT FRONTIER

Write the profit function as:

$$\pi(P, W, V(P, W, \pi^*)) = \pi^* \qquad (1a)$$

where $\pi^*$ represents a fixed level of profits and $V(P, W, \pi^*)$ is an indirect transformation function. Differentiating equation (1a) with respect to the ith price:

$$\delta\pi/\delta Pi + (\delta\pi/\delta V)*(\delta V/\delta P_i) = 0. \qquad (2a)$$

So that:

$$\delta V/\delta P_i = -(\delta\pi/\delta P_i)/(\delta\pi/\delta V) \qquad (3a)$$

Equation (3a) represents the slope of the constant profit frontier. By Hoteling's Lemma the numerator of the right hand side of (3a) is the supply of the ith commodity and is positive. The denominator is the shadow price of the fixed input which is assumed to be positive. Therefore the constant profit frontier is downward sloping. To calculate the curvature of the frontier take the derivative of 3a with respect to $P_i$ or:

$$\delta(\delta V/\delta P_i)/\delta P_i = -[(\delta\pi^2/\delta P_i^2)(\delta\pi/\delta V) - (\delta\pi^2/\delta V_i\delta P)(\delta\pi/\delta P)]/[\delta\pi/\delta V]^2 \qquad (4a)$$

Using Hoteling's Lemma equation 4a is greater than zero if:

$$= (\delta\pi^2/\delta V\delta P)Y_i > (\delta Y/\delta P_i)(\delta\pi/\delta V) \qquad (5a)$$

Multiplying by the ith output price equation 5a can be rearranged as:

(6a)

$\varepsilon_{wp} > \varepsilon_{yp}$.

Where $\varepsilon_{wp}$ is the elasticity of the shadow price with respect to the output price and $\varepsilon_{yp}$ is the elasticity of the supply of the good with respect to its output price. If the elasticity of the shadow price with respect to the output prices is greater than the supply elasticity, equation (4a) is positive and the constant profit frontier is bowed inward or convex shaped. If the elasticity of the shadow price with respect to the output price is less that the supply elasticity the constant profit frontier is bowed outward or concave shaped.

The output supply elasticity will always be positive by the convexity of the profit function. The sign of the shadow price elasticity is indeterminant. Therefore the constant profit frontier can be either a convex or concave downward sloping frontier.

However by Young's theorem equation 6a is equivalent to:

(7a)

$(\delta Y/\delta V)*(P/W) > \varepsilon_{yp}$

The first term on the left side of 7a decreases as V rises due to diminishing marginal productivity of the fixed input. The constant profit frontier is likely to take on the shape drawn in Figure 1; convex at low levels of V, and concave at high levels of V.

ENDNOTES

1. The properties of a multioutput profit function are described in Chambers (1988).

2. In only a very restrictive group of transformation functions does changes in the total level of inputs change individual outputs.

3. Necessary conditions for obtaining a second order conditions (a positive semi-definite bordered Hessian) are easily derived.

4. It is also easy to show that ith compensated supply is equal to minus the ratio of the derivative of the indirect transformation function with respect to the ith price and the derivative of the indirect transformation function with respect to profits. Readers should not confuse this indirect transformation with a similarly named but very different function in Blackorby, Primont, and Russell (1978).

5. Brazilian budgets for each of the four crops were used to determine this percentage for the years 1973 to 1987. The 1973 budget data and 68 to 72 acreage data was used to estimate fertilizer allocated to the four crops from 1968 to 1972.

## TABLE 1. ESTIMATED PARAMETERS OF THE NORMALIZED PROFIT FUNCTION AND INDIRECT TRANSFORMATION FUNCTION FOR FOUR BRAZILIAN CROPS

| PARAMETER | ESTIMATOR | (T) | PARAMETER | ESTIMATOR | (T) |
|---|---|---|---|---|---|
| B1 | -53614.6 | (-.02) | B13,B31 | 433285 | (.29) |
| B2 | -3851509 | (-3.00) | B14,B41 | -425769 | (-1.16) |
| B3 | -18601930 | (-6.19) | B15, B51 | 3095.1 | (2.30) |
| B4 | -8846158 | (-2.80) | B22 | 2677560 | (3.86) |
| B5 | 5033.1 | (4.58) | B23, B32 | -284610 | (.42) |
| B1K | .559 | (7.78) | B24, B42 | 43656 | (.24) |
| B2K | .173 | (4.99) | B25, B52 | -88.2 | (-.099) |
| B3K | 1.07 | (13.64) | B33 | 1604783 | (1.01) |
| B4K | .102 | (10.28) | B34, B43 | 114067 | (.59) |
| B5K | .00004 | (.921) | B44 | -1036032 | (-6.54) |
| B11 | 4347764 | (1.57) | B45, B54 | 979 | (1.73) |
| B12,B21 | -499818.5 | (-3.00) | B55 | -7.6 | (-1.80) |

Notes: See equation 9 for parameter identification. Variable identification is: 1 is corn, 2 is wheat, 3 is soybeans, 4 is fertilizer, 5 is labor, K is land. For example B12 is the parameter on the interaction term between normalized corn and wheat prices. The size of the estimators reflects the units in which the data was measured. Land represents the total acreage devoted to four crops. (T) represents the estimated T statistic.

## TABLE 2: ESTIMATED ELASTICITIES

| QUANTITIES: | corn | wheat | soybeans | rice | fertilizer | labor |
|---|---|---|---|---|---|---|
| PRICES | | | | | | |
| corn | .135 | -.105 | .024 | -.20 | .092 | -.437 |
| wheat | -.027 | .98 | -.027 | -.24 | -.017 | .022 |
| soybeans | .023 | -.103 | .151 | -.16 | -.043 | .237 |
| rice | -.163 | -.775 | -.129 | .48 | .170 | .548 |
| fertilizer | -.018 | .013 | .009 | .04 | -.314 | .193 |
| labor | .050 | -.010 | -.027 | .08 | .111 | -.563 |

Notes: a 10 percent rise in price of corn increases the supply of corn by 1.35% and reduces wheat supply by -1.05%. Homogenity and symmetry restrictions were used to obtain the elasticities involving rice.

## TABLE 3: PROFIT NEUTRAL PRICE AND LAND CHANGES

| PRICE CHANGE 1/ 2/ 3/ | PROFIT NEUTRAL CHANGE IN LAND AREA |
|---|---|
| SOY PRICES RISE 10% | 2.9% (4.0%) FALL IN LAND |
| SOY PRICES RISE 20% | 5.5% (7.5%) FALL IN LAND |
| WHEAT PRICES FALL 10% | .8 % (1.2%) RISE IN LAND |
| WHEAT PRICES FALL 20% | 1.5% (2.3%) RISE IN LAND |
| CORN PRICES FALL 10% | 2.7% (1.7%) RISE IN LAND |
| CORN PRICES FALL 20% | 5.5% (3.6%) RISE IN LAND |
| CORN PRICES RISE 10% | 2.6% (1.7%) FALL IN LAND |
| CORN PRICES RISE 20% | 5.1% (3.4%) FALL IN LAND |
| <u>Liberalization simulations</u> | |
| FERTILIZER PRICE RISE 20% AND: WHEAT PRICES FALL 20% AND SOY PRICE RISE 6.4% AND: CORN PRICE RISE 26% | 9.22% (5.89%) FALL IN LAND |
| FERTILIZER, SOY, CORN, PRICES RISE 20% AND: WHEAT PRICES PRICE 10% | 10.9.% (9.8%) FALL IN LAND |

1/ For example if 2.9% of the amount of land planted to the four crops were taken out of production and all other prices held constant, soybean prices would have to rise 10% to ensure producer profits did not change. 2/ A change in rice prices is not considered because it is more difficult to simulate changes in the numeriare variable.

TABLE 4: QUANTITY DATA USED IN ESTIMATION OF PROFIT FUNCTION

| | PRODUCTION OF THE FOUR CROPS IN METRIC TONS | | | | FERTILIZER CONSUMED BY THE FOUR CROPS METRIC TONS | LABOR 1/ EMPLOYED IN FOUR CROPS THOUSANDS | HECTARES 2/ PLANTED TO THE FOUR CROPS |
|---|---|---|---|---|---|---|---|
| | WHEAT | CORN | SOY | RICE | | | |
| 1968 | 856170 | 12814000 | 654480 | 6652400 | 242489 | 3697 | 15735381 |
| 1969 | 1373700 | 12693000 | 1056600 | 6394300 | 262870 | 3831 | 16587653 |
| 1970 | 1844300 | 14216000 | 1508500 | 7553100 | 438841 | 4112 | 18051340 |
| 1971 | 2011300 | 14130000 | 2077300 | 6593200 | 500733 | 4186 | 19299850 |
| 1972 | 982900 | 14891000 | 3222600 | 6760600 | 739075 | 4256 | 19583250 |
| 1973 | 2031300 | 14186000 | 5011600 | 7160100 | 787776 | 4394 | 20172850 |
| 1974 | 2858500 | 16273000 | 7876500 | 6764000 | 937865 | 4565 | 22951900 |
| 1975 | 1788200 | 16335000 | 9893000 | 7781500 | 1052136 | 4716 | 24916970 |
| 1976 | 3215800 | 17751000 | 11227000 | 9757100 | 1491603 | 5838 | 27730340 |
| 1977 | 2066000 | 19256000 | 12513000 | 8993700 | 1745636 | 5023 | 28013080 |
| 1978 | 2690900 | 13569000 | 9540600 | 7296100 | 1720756 | 3925 | 27341700 |
| 1979 | 2926800 | 16306000 | 10240000 | 7595200 | 1947604 | 3172 | 28857630 |
| 1980 | 2701600 | 20372000 | 15156000 | 9775700 | 2222075 | 3586 | 29590570 |
| 1981 | 2209600 | 21117000 | 15007000 | 8228300 | 1362631 | 2875 | 28043380 |
| 1982 | 1827000 | 21843000 | 12836000 | 9734600 | 1424580 | 3423 | 29675370 |
| 1983 | 2236700 | 18731000 | 14582000 | 7741800 | 1113725 | 3313 | 25830440 |
| 1984 | 1983200 | 21164000 | 15541000 | 9027400 | 1641037 | 3347 | 28532740 |
| 1985 | 4320300 | 22018000 | 18279000 | 9024600 | 1579442 | 3212 | 29383120 |
| 1986 | 5638500 | 20541000 | 13335000 | 10405000 | 1750959 | 3672 | 31096630 |
| 1987 | 6000000 | 26925000 | 16876000 | 10475000 | 1859671 | 3274 | 32073370 |

1/ Calculated using labor expenditures on the four crops relative to all agricultural labor expenditures and using Food and Agricultural Organization's estimates of agricultural labor in Brazil.

2/ There is some double cropping of wheat and soybeans For the purposes of this paper this acreage can be considered separate. For example setting aside some wheat land could be considered equal to not double cropping and wheat and soybeans

TABLE 5: AVERAGE NOMINAL PRICES OF BRAZILIAN CROPS AND INPUTS

| | SOYBEANS CRZ 1/ PER KILO | WHEAT CRZ PER KILO | CORN CRZ PER KILO | LABOR CRZ PER MONTH | FERTILIZER CRZ PER KILO | RICE CRZ PER KILO |
|---|---|---|---|---|---|---|
| 1968 | 0.27 | 0.32 | 0.15 | 66 | 0.24 | 0.27 |
| 1969 | 0.38 | 0.39 | 0.19 | 86 | 0.27 | 0.32 |
| 1970 | 0.43 | 0.47 | 0.21 | 109 | 0.30 | 0.42 |
| 1971 | 0.53 | 0.5 | 0.24 | 137 | 0.4 | 0.6 |
| 1972 | 0.60 | 0.53 | 0.35 | 168 | 0.4 | 0.8 |
| 1973 | 1.20 | 0.64 | 0.43 | 217 | 0.5 | 0.8 |
| 1974 | 1.18 | 0.99 | 0.67 | 313 | 1.3 | 1.3 |
| 1975 | 1.30 | 1.5 | 0.91 | 426 | 1.6 | 2.0 |
| 1976 | 1.80 | 1.8 | 1.08 | 594 | 1.7 | 1.9 |
| 1977 | 2.80 | 2.4 | 1.16 | 847 | 2.0 | 2.2 |
| 1978 | 3.50 | 3.4 | 2.18 | 1252 | 2.5 | 3.9 |
| 1979 | 6.00 | 4.7 | 3.60 | 1870 | 3.8 | 7.0 |
| 1980 | 9.70 | 8.2 | 7.50 | 3273 | 9.5 | 12.0 |
| 1981 | 16.00 | 21 | 12.30 | 6846 | 19.6 | 19.0 |
| 1982 | 30.00 | 42 | 20.35 | 13068 | 36.3 | 40.0 |
| 1983 | 117.0 | 100 | 83.30 | 26141 | 84.3 | 107.0 |
| 1984 | 358.0 | 331 | 233.00 | 108698 | 313.8 | 281.0 |
| 1985 | 959.0 | 1393 | 475.00 | 393149 | 920.0 | 1077.0 |
| 1986 | 2080.0 | 3230 | 1500.00 | 943557 | 1076.4 | 2300.0 |
| 1987 | 5500.0 | 6200 | 2010.00 | 2673411 | 3249.4 | 4900.0 |

1/ Output prices are listed in cruzerios per kilo