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A REVIEW OF AGRICULTURAL SUPPLY RESPONSES FOR INTERNATIONAL POLICY MODELS

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Abstract

This study summarizes agricultural own-price supply responses in developed and developing countries. A literature review of studies that have estimated price elasticities of supply, including the limitations of each study, is presented. The various methodologies employed to estimate supply elasticities and their shortcomings are explained. Finally, issues of interest to policy analysts are discussed and evaluated based on the literature reviewed.

While it is recognized that some studies are better than others due to different theoretical and methodological approaches, the existing literature has provided a wide range of estimates for supply elasticities. Therefore, the "weight of the evidence" is used as a criteria to draw the following conclusions regarding policy issues.

A comparison of supply elasticities for aggregate farm output and for individual crops in the same country supports the hypothesis that individual crops have a higher own-price supply response than aggregate farm output. Moreover, by reviewing the elasticity estimates for developing countries, the weight of the evidence indicates that cash crops have larger own-price supply elasticities than subsistence food crops. The elasticities of supply are also compared among developed and developing countries for specific

commodities. The majority of the studies, for the majority of commodities, rank developed countries as having larger own-price supply elasticities than developing countries. Another important finding from the literature reviewed for several developing countries is that the policies directed toward increasing output prices are expected to be more successful in increasing output than those that subsidize input prices. Finally, many of the studies reviewed in this manuscript support the importance of non-price variables such as credit availability, irrigation, fertilizer usage, and education in increasing output.

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By

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May, 1986

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A REVIEW OF AGRICULTURAL SUPPLY RESPONSES FOR INTERNATIONAL POLICY MODELS

I. INTRODUCTION

In order to increase agricultural production and support the farm family, most of the farm programs in developed as well as developing countries have concentrated on agricultural price policies. These policies call for estimates of farmers responses to price, i.e., the price elasticities of supply. These elasticities have been used to predict:

1. The effect of government farm policies such as price support programs, import and export taxes or subsidies on quantity produced.

2. The impact of demand shifters such as changes in export demand, income, or population on prices and quantity of output.

This study summarizes the agricultural price supply responses in developed as well as developing countries. The specific objectives of this study are:

1. To explain the methods that have been used to estimate own-price supply elasticities and explore the shortcomings of each method.

2. To investigate whether the supply elasticities are greater in developed countries than developing countries.

3. To see whether there exists a systematic pattern in supply responses by developing countries to certain economic and policy variables.

In the first part of this paper the formula for calculating supply elasticities (short-run and long-run) and various methods used in estimating these elasticities are presented. In the second part, a literature review of the estimates of price elasticities of supply is given. Finally, the shortcomings of the estimates are discussed.

II. VARIOUS METHODS FOR ESTIMATING OWN-PRICE SUPPLY ELASTICITY

Direct Estimation of the Supply Function

The own-price elasticity of supply measures the percentage change in quantity supplied, acres under planting (or area harvested), or yield as a result of a one percent change in the price of the crop. The elasticities are usually calculated at the means of the variables and are unit free.

The specification of a supply function for commodity i is of the general form:

$$Y_i = B_0 + B_1P_i + B_2P_j + B_3P_c + B_4T + B_5W + e \qquad (1)$$

where:

Y_i = the quantity supplied of commodity i

P_i = the price of commodity i

P_j = the price of other related commodities

P_c = the price of inputs used to produce i (cost of production)

T = the technology variable

W = the weather

The own-price elasticity of supply is measured from this direct supply function as:

$$E_i = B_1 \frac{\overline{P}_i}{\overline{Y}_i} \qquad (2)$$

Where E_i is the elasticity of supply with respect to own price, and $\overline{P}_i$ and $\overline{Y}_i$ are the mean values for P and Y

Dynamic Supply Analysis

The static aggregate supply function is sufficient for studies of supply elasticities if one assumes perfect competition, profit maximization, perfect knowledge, and no fixed factors of production. In this case, assuming all of the usual assumptions of static economics and perfect competition, the supply curve would be the same as the marginal cost curve. However, if we relax the static assumptions, we have to consider dynamic supply analysis. In a dynamic analysis, supply adjustment through time and the factors affecting both the speed and magnitude of the adjustment are considered. In agricultural supply response, the reaction to a change in a causal variable is spread over a number of time periods. This lapse of time between cause and effect is referred to as a lag and may be of fixed duration or "distributed" over time.

Many theories have tried to explain the reason for "distributed lags." Koyck and Nerlove have suggested three general reasons for the existence of distributed lags: 1) technical reasons, 2) institutional reasons, and 3) subjective or psychological reasons. Technical

reasons refer to the fact that production or output of physical goods requires time. Institutional reason consider such factors as customs and established contracts that block the immediate reaction to a stimulus for change. The subjective reasons for distributed lags include the existence of uncertainty and the nature of the formulation of expectations by producers (Trapp). The subjective reasons for distributed lags originate from the fact that the current quantity of supply is a function of expected prices rather than actual current prices. Farmer's planting activity is assumed to be an investment decision that is based on expected future prices with various probabilities attached to them. That is, the farmer compares the present value of the future flow of revenues with the present value of the future flow of costs, all a function of price expectations among other factors. The profit maximizing farmer would then decide on the planting activity based on the potential profitability of various crops.

Price expectations obviously involve uncertainty. Marc Nerlove (1958) has made a significant contribution in this area by developing a model that explains price expectations and supply responses. There have been many pre-Nerlovian studies formulating price expectations. The earliest and simplest explanation of agricultural price expectations is embodied in the so-called Cobweb Model. According to the Cobweb Model producers are influenced solely by the most recent season's price and price expectations are that the last season's price will prevail in the next period.

Richard Goodwin (1947) suggested a more sophisticated adaptive approach to expectations which allowed for a "learning" process on the

part of farmers (Askari and Cummings, 1976, p.26). In his approach, the present expected price (P_t^e) was formulated as the actual price in the last period plus or minus some proportion of the change in the actual price between two periods ago and the last period:

$$P_t^e = P_{t-1} + \delta(P_{t-1} - P_{t-2}) \qquad (3)$$

A criticism of this model is that, similar to the Cobweb Model, farmers are assumed to have very short memories.

L. M. Koyck (1954) developed a more satisfactory approach. In a geometric lag model, Koyck acknowledged the fact that in many time-series models a substantial period of time may pass between the economic decision-making period and the final impact of a change in a given policy variable such as prices. In Koyck's approach, past experience is allowed to be of infinite duration, while more recent information is weighted more (Askari and Cummings, 1976, p. 26). The weights of the lagged explanatory variables are all positive and decline geometrically with time. The model is as follows:

$$Q_t = a + B(P_{t-1} + wP_{t-2} + w^2P_{t-3} + \ldots) + e_t \qquad o \leq w < 1 \qquad (4)$$

where:

Q_t = the quantity supplied

P_t = the price of output

Equation (4) represents a distributed lag model because the influence of prices on the mean output is distributed over a number of lagged values of prices. It is a geometric lag model because the

weights given to prices decline in a geometric progression (Kmenta, pp 473-474). Lagging equation (4) one period and calculating $Q_t - wQ_{t-1}$ we find that:

$$Q_t = a(1-w) + wQ_{t-1} + BP_{t-1} + U_t \qquad (5)$$

This model (equations 4 and 5) have been rationalized in two different ways: adaptive expectations model and partial adjustment model.

<u>Adaptive Expectations Model</u>. In this model, the quantity supplied is a function of expected output price.

$$Q_t = A_o + A_1 P_t^e + e_t \qquad (6)$$

Since the expected price is not directly observable, the following equation states how it is determined.

$$P_t^e - P_{t-1}^e = B(P_{t-1} - P_{t-1}^e) \qquad o \leq B \leq 1 \qquad (7)$$

where:

P_t^e = the expected price

P_{t-1} = the last period's actual price

B = the coefficient of expectation and is constant

"Such a formation of expectations is based on the idea that the current expectations are derived by modifying previous expectations in light of the current experience." (Kmenta, p. 474).

Equation (7) can be re-written as:

$$P_t^e = BP_{t-1} + B(1-B)P_{t-2} + B(1-B)^2 P_{t-3} + \ldots \qquad (7a)$$

Substituting (7a) into (6) we will have:

$$Q_t = A_o + A_1 B[P_{t-1} + (1-B)P_{t-2} + (1-B)^2 P_{t-3} + \ldots] + e_t \qquad (8)$$

Note that equation (8) is in the same form as equation (4).

Lagging equation (8) one period and calculating $Q_t - (1-B)Q_{t-1}$

we will have:

$$Q_t = A_o B + A_1 B P_{t-1} + (1-B) Q_{t-1} + \eta_t \qquad (9)$$

Again, equation (9) is in the same form as equation (5).

Partial Adjustment or Habit Persistence Model. This model gives an alternative rationalization of the geometric lag model. In this model the optimal or desired level of output (Q_t*) is a linear function of actual lagged prices:

$$Q_t^* = A_o + A_1 P_{t-1} + e_{t1} \qquad (10)$$

Since the optimal level of output is not observable, the following equation is used to determine its level:

$$Q_t - Q_{t-1} = \delta(Q_t^* - Q_{t-1}) + e_{t2} \qquad o < \delta \leq 1 \qquad (11)$$

where: δ is the adjustment coefficient which shows the rate of adjustment of Q to Q^*.

> The values of Q^* are not directly observable, but we assume that an attempt is being made to bring the actual level of Q to its desired level, and that such an attempt is only partially successful during any one time period. The reasons why a complete adjustment of Q_t to Q_t^* is not achieved in a single period may be varied; they may include technological constraints, institutional rigidities, persistence of habit, etc (Kmenta, p. 476).

Re-writing equation (11) we will have:

$$Q_t^* = \frac{1}{\delta} Q_t + \frac{(\delta-1)}{\partial} Q_{t-1} + \frac{1}{\delta} e_{t2} \qquad (12)$$

Substituting for Q_t^* from equation (10) into equation (12) we will have:

$$Q_t = A_o \delta + A_1 \delta P_{t-1} + (1-\delta) Q_{t-1} + v_t \qquad (13)$$

We can see that equation (13) is in the same form as equations

(5) and (9).

By combing the adaptive expectation and the partial adjustment model we will have a compound geometric lag model:

$$Q_t^* = A_o + A_1 P_t^e + e_t \qquad (14)$$

Nerlove's model, which will be explained below, represents a compound geometric lag model.

Nerlove's Model. Nerlove (1958) originated the work on the dynamics of supply. Nerlove acknowledged the fact that entrepreneurs respond to expected price. He then queries whether entrepreneurs attempt to forecast the price or whether they instead try to anticipate the normal level of future prices. If entrepreneurs respond to expected "normal" prices, the question must be asked as to what is "normal?" (Askari and Cummings, 1976, pp. 28-31). Nerlove begins by postulating that such expectations depend upon what prices have actually been in the past. That is, in general, past prices govern expectations about "normal" price levels. However, all past prices do not have equal weights; the more recent prices have a greater weight.

Nerlove's model is based on the concept that the expected "normal" price for producers is equal to last period's expected "normal" price plus or minus some degree of adjustment depending upon the elasticity of expectation[1] and last period's actual price (equation 7). In Nerlove's Model of Adaptive Expectations, sellers adapt their expectations of price according to past mistakes, in that the change in expected price is proportional to the deviation between actual and expected prices in the last period. Rewriting

equation (7):

$$P_t^e = P_{t-1}^e + B(P_{t-1} - P_{t-1}^e) \qquad 0 \leq B \leq 1 \tag{15}$$

The value of zero for B implies that actual prices are totally divorced from expectations. The value of one implies a Cobweb-type model where expected prices are identical with last year's realized price. Nerlove's model dynamically describes a supply response model for which distinct estimates of all the parameters can be obtained using either a maximum likelihood technique or a least squares technique. In Nerlove's model, optimal output (Q_t^*) is a function of expected prices (P_t^e), non-price shifters and the weather (Z_t):

$$Q_t^* = a_0 + a_1 P_t^e + a_2 Z_t + U_t \tag{16}$$

Q_t^* can also be defined as expected or long-run equilibrium output.

This equation together with:

$$P_t^e - P_{t-1}^e = B(P_{t-1} - P_{t-1}^e) \qquad 0 \leq B \leq 1 \tag{17}$$

and

$$Q_t - Q_{t-1} = \delta(Q_t^* - Q_{t-1}) \qquad 0 \leq \delta \leq 1 \tag{18}$$

yields a structure that describes dynamically a supply response model.

Equation (18) implies that actual output in each period is adjusted as a fraction of the difference between the desired (long-run) output and the previous period's actual output (partial adjustment model).

After substituting the values of Q_t^* and P_t^e given by (16) and (17) into (18) we will have:

$$Q_t = A + (1-\delta)Q_{t-1} + a_1\delta \Sigma_{i=1}^{\infty} B(1-B)^{i-1} P_{t-i} + a_2 z_t + e_t \quad (19)$$

This model (represented by equations (16), (17), and (18) reduces to a pure adaptive expectations model if $\delta=1$ and to a pure partial adjustment model if B=1, and to a simple regression model if $\delta = 1$ and $B = 1$.

The major criticism to the Nerlovian Model is that farmers' expectations of prices do not necessarily change with observed price changes if the farmers view these changes to be transient. Therefore using equation (17) to approximate the formation of price expectations may overestimate real expected price changes and as a result underestimate the true aggregate supply elasticity.

Short-Run vs Long-Run Supply Elasticities

This study is interested not only in the short-run supply elasticities, but also in the long-run elasticities. A short-run supply elasticity measures the short-run supply response to a given change in price. It is usually defined as the supply response evolving in one year[2]. A long-run supply elasticity measures supply response to a given change in price after sufficient time has passed for full adjustments to the price change to take place. That is, a long-run supply elasticity is the supply response over many years.

For example, a supply elasticity of 0.10 in the short-run and 1

in the long run implies that a once-and-for-all increase of 10 percent in farm prices would increase output by 1 percent in one year and 10 percent after many years. In a geometric lag supply model of the form:

$$Q_t = A(1-w) + BP_t + wQ_{t-1} + U_t \qquad o \leq w < 1 \tag{20}$$

The short-run supply elasticity with respect to own price is calculated as:

$$e_{sr} = \frac{\%\Delta Q}{\%\Delta P} = \frac{\Delta Q/Q}{\Delta P/P} = \frac{\Delta Q}{\Delta P} \cdot \frac{P}{Q}$$

Usually the point supply elasticity is measured at the variable means, that is:

$$e_{sr} = \frac{\Delta Q}{\Delta P} \cdot \frac{\overline{P}}{\overline{Q}} = B \cdot \frac{\overline{P}}{\overline{Q}}$$

Again, this short-run supply elasticity shows the response of output over one year or less to a once-and-for-all change in price. For calculating the long-run supply elasticity it is assumed that enough time is allowed for all the adjustments to this sustained price change to take place. The long-run supply elasticity with respect to price which is implied by a geometric lag model is calculated as follows:

$$Q_t = A(1-w) + BP_t + wQ_{t-1} + U_t \qquad o \leq w < 1$$

Period	$\Delta Q/\Delta P$
t	B
t+1	$B + wB = B(1+w)$
t+2	$B(1+w+w^2)$
t+j	$B(1+w+...+w^j)$

In the long run as $j \to \infty$

$$\frac{\Delta Q}{\Delta P_t} = \frac{B}{1-w}$$

Therefore, the long-run supply elasticity is equal to the short run supply elasticity divided by the adjustment coefficient which is (1-w). The larger the coefficient of the lagged dependent variable (w), the lower the adjustment coefficient (1-w) will be, which means it takes a longer time for the output to adjust to its long-run value after a price change. In other words the long-run own-price supply elasticity will be much greater than the short-run elasticity. The lower the coefficient of the lagged dependent variable, the faster output reaches its long run equilibrium value, and therefore short-run elasticity will be closer to its long-run value.

In a Nerlovian type supply function, own-price short-run and long-run supply response is likely to be underestimated by conventional empirical procedures (Tweeten, December 1985). The following discussion on the bias in supply elasticity estimates is from Tweeten, December 1985, Appendix B.

Errors in the independent variables bias estimates of supply elasticities toward zero. The ordinary least squares estimate of the price coefficient (B) in a direct supply function of the form:

$$Q = A + BP + e$$

is:

$$E(b) = E\left(\frac{\Sigma(q + e)(P + u)}{\Sigma(P + u)^2}\right) \tag{20a}$$

where u is the error in the independent variable P. Assuming the error in q is independent of p, and the error in p is independent of q and e, the above equation can be written as:

$$E(b) = \frac{\Sigma qP}{\Sigma P^2 + \Sigma u^2}$$

The errors in independent variables will bias the short- and long-run elasticities downward as $Eu^2 > 0$.

However, misspecification error that is caused from failure to include a relevant independent variable may bias the estimates of elasticities downward or upward, depending on the sign of the simple correlation of the omitted variable and P and the direction of the effect of the omitted variable on Q. If the omitted variable is positively correlated with price, and has a negative impact on output, for example price of substitutes, the estimates will be biased towards zero. That is, if the output price increase is accompanied with competing crop price increase, there may be a substitution of other crops for the crop under study. Therefore, the own-price supply elasticity which should measure the response of output with regard to its own price assuming all other prices are constant, will be underestimated. If the omitted variable is positively correlated with price and has a positive impact on output, the supply elasticity is biased upward. However, if the omitted variable is negatively correlated with price and has a positive impact on output, then the

supply elasticity estimate would be biased downward. An example for this case is technology that via its effect on output supply will lower the price. Therefore, if the technology variable is not included in the supply equation, the estimates of short-run and long-run elasticities will be biased towards zero. On the other hand, the omission of the technology variable may also bias the long-run supply elasticity upward. This is because technology can have a large impact on output and its omission would bias the coefficient of the lagged dependent variable upward and therefore biases the adjustment coefficient towards zero. Everything else being the same, this will cause an upward bias in the long-run own-price supply elasticity.

The formulation of price expectation is also very important:

> Failure to include all relevant past prices in expectation variables biases supply response towards zero (Tweeten, December 1985, p. 48).

Farmers' expectations of future prices may not only be based on the immediate past prices but several period's last prices. Therefore, omission of the relevant lagged prices may underestimate the short- and long-run supply responses.

In some of the supply response studies in the literature, the lagged dependent variable is excluded from the direct supply functions. When not specified, we assume the calculated elasticities to be short-run. However, these elasticities underestimate the true short-run elasticities if a negative correlation exists between the lagged dependent variable and prices.

Weighted Average of Input Demand Elasticities

Another approach that has been used to estimate aggregate supply elasticity from time series data is the weighted average of all the elasticities of demand for individual agricultural inputs with respect to the price of output (Griliches 1959).

Tweeten and Quance (1969) used the following formula to estimate aggregate supply elasticity for U.S. farm output:

$$E_{op} = \Sigma_{i=1}^{n} E_{oi} E_{ip} \tag{21}$$

where:

E_{op} = the supply elasticity of output with respect to its own price

E_{oi} = the elasticity of output with respect to input i

E_{ip} = the elasticity of demand for input i with respect to the price of output

This approach[3] has an advantage over the direct supply function estimation as it requires no data on the technology variable which is hard to measure and which is not available for individual commodities (Tweeten, July 1985, p. 11). If data are available,[4] this method is likely to provide unbiased estimates of input and aggregate supply elasticities.

Aggregation of Area and Yield Elasticities

Supply elasticities for crops can also be computed from area and yield responses to price. That is, the total elasticity of farm crops with respect to crop prices can be calculated by aggregating the acreage elasticity and the yield elasticity with respect to price (Tweeten and Quance, p. 348).

$$E_Q = E_A + E_Y \tag{22}$$

where:

E_Q = the supply elasticity of commodity output with respect to commodity price

E_A = the elasticity of acreage with respect to commodity price

E_Y = the elasticity of yield with respect to commodity price adjusted for the negative effect of higher acreage on yields as production moves to lower yielding land. In other studies the formula for own price supply elasticity calculated from area and yield responses is specified as (Ito, et al.):

$$E_{q/p} = E_{yd/p} + E_{a/p}(1 + E_{yd/a}) \tag{23}$$

where:

$E_{q/p}$ = the own-price elasticity for production

$E_{yd/p}$ = the price elasticity of yield

$E_{a/p}$ = the price elasticity of acreage

$E_{yd/a}$ = the area elasticity of yield, this term is supposed to capture the negative effect of higher acreage on yield.

Programming Approach

"Programming Models", especially linear programming models, have been used to estimate supply elasticities. This procedure involves estimating a lin r model which describes the production system of each of the reference farms by specifying a set of linear, additive production functions for each possible output that the farm can produce and the bounds on the availability of factors of production (Colman, p. 203). The system is estimated assuming an objective function, such as profit maximization or risk aversion. The endogenous variables are the output and input levels for each farm given the production technology, output and input prices as exogenous to the system.

By solving this system of production for various sets of prices, one can trace out the supply-price relationship for each commodity and for each reference farm. The market level supply-response relationship can be obtained by aggregating this supply-price function for the individual farms in the reference groups.

The criticisms to this approach have been that the programming approach is of a partial character in the sense that it traces out supply-price relationships for particular products given output and input prices.

> No attempt is made to summarize in a formal functional statement the multidimensional response surface between outputs and prices which is implied by the simulated numerical results. In fact, because of the stepped and irregular nature of response schedules derived from linear programming models, such a characterization is not practicable (Colman, p. 203).

Simulation Approach

"Simulation Models" have been used to estimate supply responses. Examples are the USDA's World Grain-Oilseeds-Livestock (GOL) Model (Rojko, et.al, 1978 and Liu and Roningen, 1985), and the International Institute for Applied System Analysis (IIASA) Model (Seeley, 1985). The simulation systems are based on country and regional models, a world market clearing model linking the country and regional models, and econometrically estimated coefficients which simulate the supply-demand quantities, prices, and policies for various commodities for several countries (Seeley, p. 1, Liu and Roningen p. 1). The mathematical relationships underlying the USDA's GOL Model are grouped into nine major components (Rojko, et al., Vol. 1, pp. 3-4):

1. Demand block - livestock
2. Supply block - livestock
3. Demand block - feed
4. Demand block - food grains
5. Supply block - crops: area, production
6. Price linkages within regions
7. Regional equilibrium
8. Price equations linking regions
9. World equilibrium equations for each commodity

The limitations of these studies have been that these models are mostly used for projection purposes and they use highly aggregated data. In some of these models supply elasticities measure the supply response to the world price of the product and therefore over- or under-estimate the supply elasticity with respect to domestic prices

depending on the price transmission elasticities. These elasticities measure the response of a country's domestic price to changes in the world price. Also, many coefficients including supply elasticities are adjusted to fit the model the best:

> In order to have a global modeling system which can be successfully solved, coefficients were sometimes changed from their originally estimated values to overcome solution problems. Estimated price elasticities which presented solution problems were generally reduced in absolute value. Also, small values were given to some low-valued current price elasticities to help speed up the solution process (Liu and Roningen, p. 22).

One should be aware of these adjustments when using the reported elasticities from the simulation models. Another ambiguity is regarding the short-run vs. long-run elasticities. It is not clear from the models whether the reported elasticities reflect only a short-run response or they are supposed to capture the long-run responses to changes in price.

Duality Approach

The "Dual" method is another approach for estimating supply responses. This approach has become popular during the last ten years.

> A reason for the increasing popularity of the use of duality in applied economic analysis is that it allows greater flexibility in the specification of factor demand and output supply response equations and permits a very close relationship between economics and practice. The use of duality allows us to side-step the problems of solving first order conditions by directly specifying suitable minimum cost function or maximum profit function rather than production or transformation functions. An advantage of starting by specifying a cost or profit function rather than the underlying transformation function is that in order to derive the estimating factor demand and output supply

> responses there is no need to solve any complex system of first order conditions. The behavioral response equations are obtained by simple differentiation of the dual function with respect to input and/or output prices. The major advantage of this is that it implies less algebraic manipulations and, more importantly, it allows us to specify more complex functional forms which impose much less restriction on the estimating equations (i.e., we do not need to impose restrictions on the values of the elasticities of substitution, separability, homotheticity, etc.) (Lopez, 1982, p. 353).

The foundations for the dual approach[5] are the indirect profit and cost functions which are obtained from profit maximization and constrained cost minimization (the primal problems).

The Profit Function Approach

From the primal solution, factor demand and product supply equations can be derived from profit maximization. Equation (24) represents the profit function for a single product (the direct profit function).

$$\pi = P \cdot Y - \Sigma_{i=1}^{n} r_i x_i \tag{24}$$

where

P = price of output

Y = the quantity of output

r_i = the price of input i

x_i = the quantity of input i

The production function is:

$$Y = f(x_1, \ldots x_n) \tag{25}$$

Duality theory uses an indirect profit function which is defined as the maximum profit associated with given output and input prices. One way to derive the indirect profit function is to obtain factor demand

and product supply functions from primal solution, that is from equation 24 (assuming one output and two inputs):

$$\frac{\partial \pi}{\partial x_1} = 0 \quad \Rightarrow x_1^* = x_1^* (P, r_1, r_2) \tag{26}$$

$$\frac{\partial \pi}{\partial x_2} = 0 \quad \Rightarrow x_2^* = x_2^* (P, r_1, r_2) \tag{27}$$

where:

x_1^* and x_2^* are profit maximizing levels of inputs.

substituting for x_1 and x_2 from (26) and (27) into (25) we obtain the profit maximizing level of output (Y^*):

$$Y^* = f(P, r_1, r_2) \tag{28}$$

substituting (26), (27) and (28) into (24) gives:

$$\tilde{\pi} = P \cdot Y^*(P, r_1, r_2) - r_1 x_1^*(P, r_1, r_2) - r_2 x_2^*(P, r_1, r_2)$$

or

$$\tilde{\pi} = \tilde{\pi}(P, r_1, r_2) \tag{29}$$

Equation (29) is an indirect profit function. Note that this profit function shows profit as a function of prices only and not quantities.[6] The advantage of estimating an indirect profit function that is a function of prices (and quantities of fixed factors of production) only over estimating a production function (or revenue functions) that expresses quantity of output as a function of quantities of all inputs, is that no endogenous variable (output or input levels) is included in the indirect profit function as explanatory variable and therefore simultaneous equation problems are avoided in the econometric estimates (Lopez, 1984).

This becomes especially important when estimating output elasticities with respect to the fixed factors of production. The reduced form elasticities obtained from an indirect profit function (the duality approach) reflect the output supply response of a profit-maximizing, price taking firm assuming prices of variable factors and quantities of other fixed factors remaining constant. However, unlike the production function elasticities, they do allow for the adjustment of the quantities of variable factors to the fixed factor increase. As the quantity of a fixed factor (such as capital) increases, the marginal productivity of all variable factors is expected to rise. This increase in the marginal productivity will shift the factor demand curves to the right, and as a result the profit maximizing firm will employ more of the variable factors. Under these conditions the mutatis mutandis elasticities obtained from the duality approach seem to be more appropriate in policy analysis than the ceteris paribus elasticities obtained from a direct product function (Lau and Yotopoulos, p. 17).[7]

An important concept in duality is the Envelope Theorem.[8] A very important result of the Envelope Theorem (sometimes referred to as Hotelling's Lemma) is that by taking partial derivatives of the indirect profit functions with respect to the price of output and the prices of inputs we obtain the output supply and input demand equations, that is:

$$\frac{\partial \tilde{\pi}}{\partial P} = Y^*(P, r_1, r_2) \tag{30}$$

$$\frac{\partial \tilde{\pi}}{\partial r_i} = -X_i^*(P, r_1, r_2) \tag{31}$$

Equation (30) represents an output supply equation while (31) represents input demand equations.

> The convenience of duality should be apparent. If we know the indirect profit function we can get the unconditional factor demand and product supply functions by simple partial differentiation - quite an analytical advantage, indeed (Beattie and Taylor, p. 226).

The following example is given for further clarification of the duality approach. This example is from Lau and Yotopoulos (1972). Assume a firm's production function as:

$$Y = f(x_1,\ldots,x_n;z_1,\ldots,z_m) \tag{32}$$

where:

Y = quantity of output

x = quantity of variable inputs

z = quantity of fixed inputs

Substituting (32) into (24) we will have:

$$\pi = P.f(x_1,\ldots,x_n;z_1,\ldots,z_m) - \Sigma_{i=1}^{n} r_i\ x_i \tag{33}$$

where:

π = profit defined as current revenues less current total variable costs

P = unit price of output

r_i = unit price of the ith variable input.

Dividing both sides of equation (33) by P (unit price of output) we will have:

$$\pi' = \frac{\pi}{P} = f(x_1,\ldots,x_n;z_1,\ldots,z_m) - \Sigma_{i=1}^{n} r_i'\ x_i \tag{34}$$

where

$\frac{\pi}{P} = \pi'$ is defined as the Unit-Output-Price (UOP) profit

$r_i' = \frac{r_i}{P}$ is the normalized price of the ith input.

Let us re-write equations (26) and (27) as:

$$x_i^* = f_i(r', z), \quad i=1,\ldots,n \tag{35}$$

where:

x_i^* = the optimal quantities of variable input i

r' = the vector of normalized price of variable inputs

z = the vector of fixed inputs.

By substituting (35) into (33) we will have:

$$\tilde{\pi} = P.[f(x_1^*,\ldots,x_n^*;z_1,\ldots,z_m) - \Sigma_{i=1}^n r_i' x_i^*] \tag{36}$$

Equation (36) gives the maximized value of the profit for each set of values for P, r_i', and z.

Rewriting (36) as a function of r' and z (from 35)

$$\tilde{\pi} = P.G^*(r_1',\ldots,r_n';z_1,\ldots,z_m) \tag{37}$$

The UOP profit function is therefore given by

$$\frac{\tilde{\pi}}{P} = \tilde{\pi}' = G^*(r_1',\ldots,r_n';z_1,\ldots,z_m) \tag{38}$$

From $\tilde{\pi}'$ (the UOP profit function) one can always find $\tilde{\pi}$ and visa versa. It is known that the UOP production function is decreasing and convex in the normalized prices of variable inputs and increasing in quantities of fixed inputs and in the money price of the output.

From the Envelope Theorem:

$$x_i^* = -\frac{\partial\tilde{\pi}'(r',z)}{\partial r_i'} \qquad i=1,\ldots,n \tag{39}$$

$$Y^* = \tilde{\pi}'(r',z) - \Sigma_{i=1}^n \frac{\partial\tilde{\pi}'(r',z)}{\partial r_i'} \cdot r_i' \tag{40}$$

where: Y^* is the supply function.

For empirical estimation of derived input demand functions (equation 39) and the UOP (sometimes referred to as normalized) profit function (equation 38, or alternatively the supply function, equation 40), they must be estimated jointly because of the existence of parameters that are common to both equations. In most empirical studies a method developed by Zellner is used which imposes the restriction of equality of parameters in these equations.

The advantages of working with the UOP profit function instead of the traditional production function can be summarized in the following (Lau and Yotopoulos, pp. 12-13):

1. The input demand and output supply functions (equations 39 and 40) can be directly derived from an <u>arbitrary</u> normalized indirect profit function (UOP profit function) which is decreasing and convex in the normalized variable input prices and increasing in the fixed factors of production. Hence, explicit specification of the production function (equation 32) is not needed. And therefore, without solving for first order conditions for a profit-maximizing firm ($P.\frac{\partial f}{\partial x_i} = r_i$ or $MP_i = r'_i$) the input demand functions can be derived. This would provide a great amount of flexibility in empirical analysis.

2. By the duality approach, because the derived factor demand and output supply functions are obtained from a profit function, the assumptions of profit maximization and competitive markets are assured.

3. As was mentioned before, the simultaneous equation bias is avoided because the profit, output supply, and input demand functions

are explicitly written as functions of exogenous variables (output and variable input prices and quantities of fixed factors) which are considered to be determined independently of the firm's behavior.

The indirect profit functions associated with various single-output, multi-input production functions (Generalized Cobb-Douglas, Quadratic, CES) are given in Appendix I.

The Cost Function Approach

This approach has been used to measure factor demand elasticities, elasticities of substitution and technical change in agriculture (Lopez, 1982, p. 354).

In this method an indirect cost function is defined as the minimum cost required to produce a given level of output at given factor prices. Equation (41) represents an indirect cost function:

$$\tilde{c} = \tilde{c}(r_1,\ldots,r_n,y) \tag{41}$$

Another important result of the Envelope Theorem (usually is referred to as Shephard's Lemma) is that by partial differentiating of the indirect cost function (equation 41) with respect to input prices we obtain the input demand functions, that is:

$$\frac{\partial\tilde{c}}{\partial r_i} = X_i^c(r_1,\ldots,r_n,y) \tag{42}$$

where x_i^c is the conditional factor demand equation (conditional on the level of output), also:

$$\frac{\partial\tilde{c}}{\partial y} = MC(r_1,\ldots,r_n,y) \tag{43}$$

which is the marginal cost function. By equating (43) to price we

obtain the product supply equation:

$$Y^* = Y^*(P, r_1, \ldots, r_n) \tag{44}$$

The indirect cost functions associated with various single-output, multi-input production functions (Cobb-Douglas, Quadratic, CES) are given in Appendix I.

An important limitation of the cost function approach of the dual method is that:

> ...it assumes that output levels are not affected by factor price changes and, thus, the indirect effect of factor price changes (via output levels) on factor demands are ignored. Moreover, the inclusion of output levels as explanatory variables may lead to simultaneous equation biases if output levels are not indeed exogenous. The profit function approach allows one to overcome most of these problems although at the cost of requiring a stronger behavioral assumption. The profit maximization assumption may be substantially more difficult to support in agriculture than simple cost minimization because of risk related problems which are mainly related to the variability of output yields and price rather than to costs of production (Lopez, 1982, pp. 356-357).

Limitations of the application of the duality approach (indirect profit or cost functions) are:

1. The duality approach is more of a micro-firm level approach and it should be applied to a profit maximizing individual firm's data. However, many of the empirical estimations in agricultural economics have applied the duality approach to aggregate level data in order to derive output supply and input demand functions for a country or region. The appropriateness of the results is therefore questionable.

2. In most cases, it is difficult to explicitly determine whether the estimated elasticities from the dual method are short-run or long-run elasticities. One approach used in this study to

distinguish short- and long-run elasticities has been to verify whether the indirect profit or cost functions include fixed factors of production. If they do, then it is assumed that the estimated elasticities are short-run. On the other hand, if the indirect profit or cost functions do not include any fixed inputs, then the estimated elasticities are assumed to be long-run.

3. The dual approach assumes a profit maximizing or cost minimizing production unit. As a result, this approach may not be the appropriate method to be applied to the developing countries subsistence farmers. These farmers may not necessarily be profit maximizers or cost minimizers, but only risk minimizers.

4. Although very important in decision making regarding annual or prennial crop production, price expectations have not yet been incorporated into the dual approach. It may be more appropriate to include expected prices rather than current prices in the indirect profit function.

An Explanation of the Marketed Surplus

Before concluding this chapter, given the important policy implications that this component has, an explanation of the marketed surplus is necessary. In many developing countries, the policy makers are not only interested in agricultural output responses to changes in price, but also in the response of the marketed portion of total output to this price change.

Marketed surplus determines the supply to urban and other rural areas and is obtained by subtracting from total production the quantity of on-farm consumption. A policy that increases output

prices can have two opposite effects on the marketed surplus: an income effect and a direct price effect. As output prices increase, farmer's income would increase and that would result in an increase in the on-farm consumption of the product and a reduction in the marketed surplus as a result. However, a price increase would also have a positive effect on output and therefore on the marketed surplus. The positive demand response to a price change can partly offset the production response which would lower the net responsiveness of the marketed surplus to a price change (Scandizzo and Bruce, p. 67). In other words one would expect a lower price elasticity of marketed surplus than that of output.

On the contrary, some have argued that the magnitude of the own price marketed surplus elasticity may be a good deal higher than the own price output elasticity (Strauss, 1983, p. 48). This argument is based on the assumption that the total own price elasticity of consumption is negative and therefore, a price increase would reduce quantity of consumption which will reinforce the effect of increased production and would therefore increase the marketed surplus elasticity. However, this argument does not consider the income effect of a price increase on consumption which if large enough may cause a negative elasticity for marketed surplus. For many low income households the estimates indicate a positive on-farm consumption elasticity with respect to the crop price.

In the next section a literature review of own-price supply elasticity estimates for various countries and several agricultural commodities will be given.

III. A LITERATURE REVIEW OF THE PRICE ELASTICITY ESTIMATES OF SUPPLY

This section reviews agricultural own-price supply elasticities for various commodities and regions from the published literature, including an explanation of the methodology and criticisms to each study. The review covers aggregate farm output as well as individual annual cash and subsistence crops and prennial crops. The studies are classified into three categories: the studies pertaining to the U.S., the studies covering other developed countries, and the literature related to the developing countries.

The United States

Aggregate Farm Output

Griliches (1959) estimates supply responses for U.S. aggregate output from estimated input demand elasticities. In Griliches's model, supply elasticity is expressed as a weighted average of all the elasticities of demand for individual inputs with respect to the price of the output (equation 21). The weights are the share of each factor in total costs or revenue. The assumptions of the model are given and fixed input prices implying an infinitely elastic supply of factors.

By calculating input demand elasticities and their distributive shares for various time periods in the 1911-1957 period and for cross-section data for various states, Griliches then calculates the short-run and long-run aggregate farm supply elasticities as shown in Table 1, Appendix II. Estimates in columns (1) and (2) in Table 1 are obtained by two different estimates for weights in the output elasticity formula.

Limitations of the estimates (Griliches, 1959, p. 320):

1. These estimates are the result of a set of "illustrative" calculations because of the lack of necessary information. Although all the figures are of the right order of magnitude, some are based on very little evidence.

2. These results may overestimate supply responses because they are based on the assumption of constant factor prices (except land). Therefore these estimates are not "total" or "absolute " price supply elasticity but "partial" or "relative" price supply elasticity. Partial price supply elasticity represents the elasticity of the aggregate farm supply function with respect to product prices holding factor prices constant, or with respect to relative (real) price of products. One should consider the partial nature of these elasticities while comparing them with estimates from other studies. Griliches (1959) shows that the "total" supply elasticity with respect to the absolute price of products will be lower than the supply elasticity with respect to the "real" price of products.

> I do not feel that this reservation is very important in a full employment economy, but it could result in a reduction of about one-half in the estimated elasticities (Griliches, 1959, p. 321).

Griliches (1960) estimated supply elasticity for aggregate U.S. farm output by direct estimation of the supply function using a distributed lag model, and assuming a Cobb-Douglas type aggregate farm production function. In Griliches model, supply of farm products was expressed as a function of relative prices, weather, the state of technology, and lagged output. The relative price variable is the "real" price of farm products index which is measured by the index of prices received relative to the index of prices paid for production

items, wages, taxes, and interest. The lagged farm output is used to incorporate the fact that farmers may respond only slowly to changes in relative prices and other variables. A trend variable is included to measure the effect of technological changes on output.

The supply elasticities are estimated not only for aggregate output but for the sub-aggregates: "all crops" and "livestock and livestock products." The analysis of the sub-aggregates covers the period 1911-58, whereas the aggregate output analysis is restricted to 1920-57 period. In the analysis of "livestock and livestock products" the weather variable is not included and the price of feed is treated separately. The short-run and long-run supply elasticity estimates are presented in Table 2, Appendix II.

Also estimated are the supply elasticities for an earlier and for a more recent sub-period within the entire period under study. The results indicate a short-run supply elasticity for the more recent period of 0.17 for aggregate farm output and 0.16 for all crops, while an elasticity of 0.4 for the earlier sub-period for livestock and livestock products. For "all crops" there is no significant price response during the earlier sub-period.

Limitations of the estimates (Griliches, 1960):

The estimate of the long-run supply elasticity severely <u>underestimates</u> the "true" long-run supply elasticity because much of what is attributed to the technological change (the trend variable) is actually due to changes in relative prices that are not captured by the conventional price indices (Griliches, 1960, p. 238). Griliches argues that in his 1959 supply elasticity estimates which are derived from estimates of input demand elasticities (Table 1), the role of

"trend" is taken over by the price variables leading to higher elasticity estimates.

> Hence, the somewhat higher price elasticities found in the demand studies for various agricultural inputs are due mostly to a somewhat different concept of "price". Thus a large part of what appears as "trend" in this study, I believe, is really a response to a change in relative prices, a response to the fall in the price of a "constant quality unit" of purchased agricultural inputs-fertilizer, farm machinery, insecticides, and others (Griliches, 1960, p. 292).

Tweeten and Quance (1969) estimated aggregate farm output supply elasticities for the U.S. by three methods:

1. Direct least squares estimates of the aggregate supply function. In this model, index of aggregate farm output was regressed on the lagged index of the ratio of prices received by farmers for crops and livestock to prices paid by farmers for items used in production; the beginning of the year stock of productive farm assets (including real estate, machinery, feed, livestock and cash held for productive purposes); and productivity index (the ratio of farm output to all farm production inputs which is supposed to reflect changes in management and technology as well as fluctuations in productivity induced by weather). The observation period was 1921-1966, excluding 1942-1947 (Table 3, Appendix II).

Limitations of the estimates (Tweeten and Quance, p. 348):

The estimate of long-run supply elasticity is biased toward zero because of high correlation between productive assets, productivity, and lagged output (when included).

2. Aggregate supply elasticity computed from crop and livestock components. In this model, own-price supply elasticity of total farm

output with respect to product price is measured as a weighted sum of the livestock and crop supply elasticities.

$$E_{op} = E_{cp}\ C/O + E_{lp}\ L/O + E_{lc}E_{cp}\ L/O$$

where:

O = total farm output

C = crop output

L = livestock output

P = the index of prices received by farmers

E_{op} = the supply elasticity of total farm output with respect to prices received by farmers

E_{cp} = the supply elasticity of crop output with respect to prices received by farmers

E_{lp} = the supply elasticity of livestock output with respect to prices received by farmers

E_{lc} = the elasticity of livestock output with respect to crop output

The own-price supply elasticity for crops is calculated as the acreage elasticity plus the yield elasticity corrected for the negative effect of higher acreage on yields as production moves to lower yielding land (Equation 22). For livestock, as there is no empirical evidence that the increasing number of animal units depresses the yield per unit, the supply elasticity of total livestock output is the simple sum of the unit and yield components. The calculated elasticities from this method are presented in Table 4, Appendix II.

Limitations of the estimates (Tweeten & Quance, P. 349):

Because of the low reliability of some of the estimates such as E_{1c}, the elasticities must be interpreted with caution.

3. Aggregate elasticity of supply computed from farm input components. Formula 21 (explained in the previous section) is used for the estimation of own price elasticities. The results are presented in Table 5, Appendix II.

Limitations of the estimates (Tweeten and Quance, 1969, p. 351):

It is argued that these elasticity estimates apply primarily when farm prices are increasing. Supply elasticities tend to be reduced in periods of decreasing farm prices because of fixity of assets. If only operating inputs are variable when prices fall, the short-run elasticity is reduced from 0.26 to 0.18, and the long-run elasticity is reduced from 1.52 to 0.82.

Bruce L. Gardner (1979) criticizes the indirect approach for measuring supply elasticities from estimates of input demand elasticities used by Griliches, Tweeten and Quance. He argues, that in their estimates, input prices are held constant and therefore the estimates yield questionable results which tend to overstate aggregate supply elasticity. Gardner (1979) introduces a two-product, two-factor model which specifies the elasticity of product supply as a function of input supply elasticities, alternative product demand elasticity, elasticity of substitution between production inputs, relative factor intensity of the product, and relative importance of the production in its uses of resources.

The more elastic are input supply functions, the more elastic the product supply would be. The elasticity of demand for alternative product also affects the supply elasticity for the crop under study:

as the price of the crop under study goes up, the input price will increase which will lead to an increase in the price of the alternative crop. This increase in price results in a decrease in quantity demanded for the alternative product. This will release inputs for use in producing the product whose price originally rose. Therefore, he argues that the analysis of supply elasticity, based on single-product models, does not consider the substitution of resources from one commodity to another and therefore results in biased estimates.

Limitations of the estimates (Gardner, p. 475):

This model is restricted to a two-product, two-inputs framework. The other restriction is its lack of distinction between short- and long-run elasticities. It also neglects the role of uncertainty.

Antle (1984) uses duality theory (a single product translog profit function) to measure input demand and aggregate output supply elasticity for the U. S., using annual time-series data for the 1910-78 period (excluding 1919-21 and 1924-34 periods). Output supply elasticities, along with estimates of input demand elasticities, are calculated at the sample means of data. The results indicate that supply elasticities show a marked reduction in the postwar period compared to the prewar period which indicate a fundamental change in the technology structure. Antle gives the more capital intensive postwar technology as one explanation for the reduced price responsiveness. Table 6, Appendix II presents the own-price supply elasticities. Under the homotheticity and symmetry restrictions, the supply elasticities are 2.485 for the 1910-46 and 1.440 for the 1947-78 period compared to 1.349 and .427 without these restrictions.

Antle further adds that the postwar inelastic aggregate supply function estimated from the model is consistent with those of Weaver's (1983), ranging from .4 to .73, and Shumways (1983), ranging from .25 to .72.[9] Supply elasticities estimated from Antle's Model are assumed to be short-run because of the inclusion of the vector of exogenous variables in addition to the normalized input prices in the restricted normalized profit function. In addition, the conclusion of this study implies a short-run analysis as there were no sustained price changes in the 1910-46 period:

> Hayami and Ruttan argued that the historically high land/labor ratio in the United States and the scientific advances of the twentieth century led both private entrepreneurs and public institutions to develop agricultural innovations that provided substitutes for scarce labor and complements for abundant land in the form of mechanical, chemical, and biological technology (Antle, p. 414). These (Antle's) results suggest that the Hayami-Ruttan theory is best viewed as a theory of long-run behavior with possibly long lags between relative factor price trends and the creation and adoption of new techniques. When factor and product price trends change directions in relatively short periods, as they did during 1910-46, the technology may not follow the long-run trend (Antle, p. 420).

Individual Commodity Studies

Corn: Whittaker and Bancroft (1979) criticized the use of time-series observations for estimating parameters of acreage response models because of the technological advances and changes in model's coefficients that can take place during the long time periods under analyses. Instead, pooled time-series and cross-sectional data were used to estimate the parameters of a Midwest corn acreage response function. The cross-sectional data covered four Midwestern States: Indiana, Illinois, Ohio, and Iowa, and time-series

observations on these four states covered the years 1963 through 1974.

Whittaker and Bancroft's Model specifies each state's planted corn acreage as a function of the state's lagged average market price of corn, state's lagged average market price of soybeans, announced U.S. government corn diversion price times the fraction of the base corn acreage eligible for diversion (GDP), binary variable set equal to one in years in which direct support payments were included in GDP, and binary variable intercept shifters for Illinois, Ohio and Iowa. The model was estimated in a double logarithmic functional form[10] using Ordinary Least Squares Method of estimation.

The estimated own-price corn acreage elasticity was .22[11] This figure is relatively high when compared with the own-price acreage elasticity figures estimated by Penn, Houck et al., and Ryan and Abel, which are all in the range of .12 to .17. Whittaker and Bancroft give the following explanations for this difference in acreage elasticity estimates:

1. Other studies used time-series data starting in the late 1940s or early 1950s. Whittaker and Bancroft used data starting in 1963. Elasticities may not be constant over time.

2. The price variable used in other studies was weighted corn-price support rates, while Whittaker and Bancroft used lagged market price.

3. Other models were linear in prices and acreages and therefore elasticities were measured at the means; Whittaker and Bancroft used the double logarithmic functional form implying constant acreage elasticity.

Reed and Riggins (1981) investigated the gain in explanatory power which can accrue to acreage supply functions for corn in Kentucky when data are disaggregated beyond the state level. In this study an acreage supply function was fitted for corn with sub-state data. The results were then compared with those of an acreage supply function using statewide data. The acreage planted to corn in each area is specified as a function of lagged relative price of corn, lagged relative price of soybeans, lagged area of corn planted in that area, and measures of government programs for that period.

The model was applied to acres devoted to corn in Kentucky for the 1960-79 period. Kentucky was broken into 14 areas. The acreage response equation for each area was estimated using the seemingly unrelated regressions. The coefficient for lagged price of corn was significantly different from zero in five of the 14 equations. The elasticity estimates using area data are presented in Table 7, Appendix II. The statewide aggregate results for corn acreage were rather poor. Therefore, it was concluded that area equations are far superior to the statewide analysis.

Askari and Cummings (1976) report short-run own-price supply elasticities for U. S. corn ranging from 0.09 to 1.02. These estimates are by Nerlove for the 1909-1932 period, and they cover the range of short-run supply elasticities by Reed and Riggins.

Rice: Ito, Wailes, and Grant (1985) applied equation (23) to annual data for 1962 through 1981 to estimate production elasticities from yield and acreage elasticities for seven Asian countries. For

comparison, similar data for the U.S. were also reported. United States showed no yield response to a change in price in the short- or long-run, therefore the U.S. price elasticity for yield was assumed to be zero. Acreage response showed negative impact on yield in the countries with production limitation programs including the U.S. Area elasticities were less than one in the short- and long-run (Table 8, Appendix II).

Wheat: Morzuch, et al. (1980) estimated planted wheat acreage supply elasticities for each of several leading wheat-producing states using a direct supply function for the period 1948-74. In their estimations (Model A), acreage planted to wheat is specified as a function of the expected relative price (the expected price of wheat divided by an index of expected prices for competing crops), trend (to capture the effect of omitted variables that may have exerted systematic effects over time), an estimated diversion payment per bushel divided by the index of expected prices for all other crops and the upper limit on the extent of permissible land diversion. In an alternative specification (Model B), the last two variables were replaced by the acreage diverted under both the wheat and feed grains programs.

In Morzuch, et. al., the expected prices for durum wheat and for other spring wheat are measured by future prices. Since future prices are not available for a number of crops grown in these states, one period lagged prices for these crops were chosen as a proxy for the unavailable future prices. Ordinary Least Squares Method of estimation was used for spring wheat in three states and winter wheat in 10 states. Price elasticities vary considerably

among states from 0.61 to 0.95 for the three cornbelt states[11]. Under Model A, supply elasticities vary from .13 for Montana winter wheat, to .99 for South Dakota spring wheat. Under Model B, supply elasticities vary from .13 for Montana winter wheat to 1.50 for Montana spring wheat.

Supply responses tend to be more elastic in spring wheat cornbelt states than major winter wheat states. This is understandable as one might expect an inverse relationship between extent of specialization and elasticity of acreage response. The aggregate acreage supply elasticities are calculated as weighted averages of elasticities for various states, using mean acreage for individual states as weights. The results (estimates excluded Montana) are presented in Table 9, Appendix II.

Multi-Commodity Studies

Chambers and Just (1981), in an attempt to examine the dynamic effects of exchange rate fluctuations on U. S. commodity markets, estimated supply elasticities. Chambers and Just's econometric model consists of 15 equations (three are identities) which explain disappearance, inventories, exports, and production for three commodities: corn, wheat, and soybeans. The method of estimation is three-stage least squares using quarterly data for the period 1969 through 1977. Each functional relationship is assumed to be linear in parameters and each equation is estimated in per capita form to preserve the linearity of the system.

In the production equation, per capita production of each commodity is regressed on the deflated lagged average price of the commodity received by the farmer and the deflated support price for the commodity. The estimated supply elasticities are presented in Table 10, Appendix II[11].

Weaver (1983) measures supply responses for U.S. spring wheat region (North and South Dakota) using a translog expected profit function (duality theory) for the 1950-70 period. For the expected price of output, future price for harvest contracts observed at planting time, is used. It is argued that a multi-output, multi-input model, which is used in the duality approach, is attractive from its reliance on total expenditure for each input, rather than from expenditures for each input used for each output. Weaver states that in general, all outputs and all inputs are reduced when an input price increases. He further adds that elasticities of output supply with respect to prices indicate considerable short-run flexibility in output mix. The estimates of supply elasticities from Weaver's model are presented in Table 11, Appendix II[12].

Shumway (1983) uses duality theory (a normalized quadratic profit function[13]) to estimate supply relations for six Texas field crops: cotton, grain sorghum, wheat, corn, rice and hay for the 1957-79 period. Independent variables in the profit function are: expected product prices, current variable input prices, and fixed input quantities. Government policies, weather, and technological change are also assumed to be exogenous. The system of six product supply equations and two input demand equations (fertilizer and hired labor)

are the primary estimation equations which are derived from first derivatives of the normalized equadratic profit function. The method of estimation is Zellner's generalized least squares for seemingly unrelated equations which is asymptotically equivalent to maximum likelihood. Implied product supply elasticities for the last observation, 1979, are presented in Table 12, Appendix II. Because of the existence of fixed inputs in the model, a short-run analysis is assumed.

Saez and Shumway (1985) estimated output supply and input demand elasticities for various agricultural products and inputs in 10 U. S. regions during the postwar period, 1946-1979. The advantages of their study is in its comprehensiveness:

> This econometric analysis represents the most comprehensive investigation of intercommodity supply and demand relationships ever conducted on the agricultural sector. Not only were products and inputs disaggregated to a much higher degree than is typical, but all cross-price relationships were also estimated for each of 10 geographic farm production regions comprising the contiguous 48 states (Saez and Shumway, p.4).

In their study, an indirect profit function (duality approach) was used to estimate the elasticities for eight agricultural output, and six variable input categories. The exogenous variables in the model included: weather, government policy variables such as support prices and effective diversion payments, a time trend to capture the effect of technological changes, family labor, and real estate. Because of the inclusion of non-price variables (fixed factors of production), a short-run analysis is assumed.

The results indicated that a normalized quadratic profit function was superior to one of translog form "in terms of both fewer numbers

of unexpected own-price parameters and better explanatory power of the dependent variables." (Saez and Shumway, p.2). However, none of the symmetry, homogeneity, and convexity conditions of the profit function were supported by the regional-level data. These conditions are the implications of the competitive firm. The authors attributed the causes to some combination of model misspecification, aggregation problems, data inadequacies, and imperfect theory.

In general, own-price input demand parameters were more consistent with what is expected from economic theory than own-price product supply parameters. About 25 percent of the input demand functions had own-price parameter signs that were inconsistent with economic theory, while 37 percent of output supply functions had unexpected own-price parameter signs. The estimated elasticities by Saez and Shumway are summarized in Table 13, Appendix II.

U. S. price elasticities were computed as a weighted average of regional estimates. The weights were given based on the ratio of regional quantities produced or inputs demanded to U. S. quantities. The U. S. own-price parameters were more consistent with what is expected from economic theory than were most of the individual regional estimates. As it is observed from Table 13, and is expected from economic theory, the own-price U. S. supply elasticities decrease in magnitude when an upward sloping input supply curve is assumed, compared with the scenario that an infinitely elastic supply curve is considered.

Saez and Shumway further compare their estimates with those of others (Saez and Shumway, p. 87). Their estimates of .02 for the U.S.

feed grains own-price supply elasticity is much lower than those estimated by others. Askari and Cummings (1976) report U. S. own-price supply elasticities for individual feed grains ranging from +.09 to +1.32[14] and Shumway and Green report estimates of elasticities ranging from -.22 to +1.10. For food grains, Saez and Shumway study reports an own-price elasticity of +.01, while Askari and Cummings report estimates of own price supply elasticities for various food grains ranging from +.08 to +.93 and Shumway and Green estimates from -.63 to +.90. For oilcrops Saez and Shumway report an own-price output supply elasticity of -.01 while prior estimates range from +.62 to 1.40. Saez and Shumway's own-price output elasticity estimates for tobacco is -.11, and for hay is +.39, vegetable-fruit-sugar crop is -.20, while Shumway and Green report a +.13 elasticity for sugar, a +.74 elasticity for tobacco and +.48 for hay. For cotton, Askari and Cummings report elasticities ranging from +.20 to +.67, while Saez and Shumway report an elasticity of +.30 for cotton. For livestock, Saez and Shumway report an output elasticity estimate of -.04, while Ospina and Shumway report estimates ranging from -.17 to +.14 (Saez and Shumway, p. 87). In general the elasticities reported in Saez and Shumway are lower than those reported in previous studies.

Askari and Cummings (1976) report own-price supply elasticities for several commodities and for various countries. Most of these elasticities were collected from studies that have used Nerlovian type supply models. The reported elasticities for the U. S. are summarized in Table 14, Appendix II.

Multi-Country Studies

There are several simulation models that include many countries or regions of the world. The USDA's Grain-Oilseed-Livestock (GOL) Model is one example. This model has two versions: the 1978 version by Rojko, et. al. and the 1985 version by Liu and Roningen.

The purpose of the 1978 GOL Model was to project key economic variables in 1985. It is composed of 930 equations that cover 28 major world countries and regions, and 14 separate commodities. The deriving part of the model is composed of the following exogenous variables: population growth, income growth, policy variables, agricultural productivity growth rates, and other supply and demand shifters. The responding part is composed of the following endogenous variables: production, consumption, trade, stocks, and prices for grains, oilseeds, and livestock commodities. The responding part of the model is solved for the given levels of deriving variables. The three year average 1969/70 to 1971/72 was used as base for projections to 1985.

Because of its size, the model could not be a product of a direct statistical fit. Instead, the parameters of the model were synthesized from either statistical analysis or the judgement of experts and adjusted when necessary to reflect relationships among variables (Rojko, et. al., No. 146, p. 4). The direct- and cross-price elasticities and income elasticities were arrived at in the course of research, derived from published and unpublished USDA studies or from studies outside USDA (Rojko, et. al., No. 146, p. 106 and No. 151, p. 15). The supply elasticities used in the 1978 GOL

productivity induced by weather). The observation period was 1921-1966, excluding 1942-1947 (Table 3, Appendix II).

Limitations of the estimates (Tweeten and Quance, p. 348):

The estimate of long-run supply elasticity is biased toward zero because of high correlation between productive assets, productivity, and lagged output (when included).

2. Aggregate supply elasticity computed from crop and livestock components. In this model, own-price supply elasticity of total farm

Model reflect the full effect of a price change on production over a number of successive years, and therefore measure long-run elasticities. The own-price supply elasticities for the U. S. are presented in Table 15, Appendix II.

The 1985 GOL Model is an annual simulation model designed to provide mid- to long-term projections of world food supply and demand under alternative world economic assumptions (Liu and Roningen, p.1). This model consists of 27 country and regional models and 20 major agricultural commodities. The estimated coefficients are based on time-series data from 1960 to 1980. The GOL Model consists of a set of linked country and regional models which are solved simultaneously to clear the world markets, so that total world exports equal world imports for each commodity (Liu and Roningen, p. 1). The own- and cross-price elasticities were used to calculate the world market clearing price for each commodity.

The supply equation of the model specifies total quantity supplied as a function of current and lagged real prices (trade prices of representative commodities deflated by the consumer price index of industrial countries), current and lagged cross commodity real prices, a trend, and a supply shift variable. Although the lagged value of the dependent variable is not included in the supply equation, these elasticities are assumed to be long-run elasticities. This is because the econometric model is built to capture the long-run adjustments to the exogenous shocks to the model (Roningen, Personal Communication). Estimates for U.S. supply elasticities with respect to world trade prices from the 1985 GOL model are shown in Table 16, Appendix II.

The elasticities are quite different (much smaller) than those reported in the original version (1978) of the GOL Model (Table 15, Appendix II).

Limitations of the supply elasticity estimates from the 1985 GOL model are:

1) The reported supply elasticities are adjusted from the obtained estimates so that they fit the model the best. In some cases these elasticities may be quite different from the actual estimated figures.

2) The price elasticity estimates measure supply responses to world price changes and not to domestic prices. So these elasticities may over- or under-estimate the supply elasticities with respect to domestic prices if the domestic price changes do not equate world price changes.

3) What is defined as quantity supplied is actually production plus beginning stocks. So we must view these estimates with great caution.

Sarris and Freebairn (1983) estimated a wheat cournot oligopoly type model to show that the interaction of national policies can lead to instability of both international and domestic price. The model is composed of 21 countries or regions. The supply elasticities used in the model are those reported in the 1978 model but were updated by econometric studies reported in the journals over the last five years prior to the study. Because the supply elasticities are short-run, the GOL elasticities which are essentially long-run elasticities were divided by four where it was necessary to use them. The reported short-run wheat own-price supply elasticity in Sarris and Freebairn

study was .20 for the U.S. The 1978 GOL Model reports U. S. wheat supply elasticity as 2.55, while the 1985 version of the GOL Model reports .25 for the elasticity figure. Note that both of these estimates are for the long-run.

Rodney Tyers (1984) estimated own- and cross-price supply responses in various countries and for five commodity markets with production uncertainty. The international markets are fully distinguished from the corresponding domestic markets through the use of empirically-based price transmission equations[15]. The multi-market structure and endogenous trade policy and stock-holding behaviors are considered as special features of the model used in this study. By excluding one or more of these features, six versions of the model were estimated to examine the relative significance of each of the features (Tyers, p. 29).

The model simulates the international markets for rice, wheat, coarse grains, the meat of ruminants (cattle and sheep) and the meat of non-ruminants (pigs and poultry). In this simulation model the world is disaggregated into 24 countries and country groups, and the econometric analysis is for the period of 1960-80 or a shorter period where data are unavailable. The FAO Production and Trade Year Books and the USDA provided the data for econometric estimations. Structurally, the model is simply a set of expressions for quantities consumed, produced, and stored, each of which is a function of known past prices and endogenous current prices. The model also includes equations for trade and price transmission for each of the five commodity groups and for each country or region. In any year, given a

particular set of random production disturbances, the model solves for that set of domestic and international prices which clears all markets to within acceptable tolerances (Walrasian adjustment). The solution procedure is conventionally iterative, but it is not based on a standard software package (Tyers, p. 8).

A Nerlovian partial adjustment model, linear in logs of production and producer prices is used to represent the production behavior. The following supply function was specified in the model:

$$q_t = C + aq_{t-1} + \Sigma_i b_i P_{i,t-1} + e_t$$

where:

q_t is the deviation between the logs of actual production and price-constant trend production[16].

$P_{i,t}$ is the log of the deflated producer price of commodity i.

Where superior estimates of the short- and long-run supply elasticities could be identified from the literature, these were used to replace the original estimates in Tyers Model (Tyers p. 5 and pp. 54-56). Table 17, Appendix II represents the supply elasticity estimates chosen for use in Tyers Model.

Summary of Supply Elasticity Estimates for the United States

The summary of the own-price supply elasticities for the United States for each commodity or commodity group is presented in Appendix III. As it is apparent from this appendix, own-price supply elasticities vary significantly from one study to another. For all the commodities that were included in the two versions of the GOL Model, the 1978 version (Rojko, et. al.) gave the largest long-run elasticities (except for livestock products), while the .985 version (Liu and Roningen) gave the smallest long-run elasticities.

For the majority of the products whose elasticities were estimated by the duality approach (indirect profit function) as well as by other methods, the duality approach gave the largest short-run elasticities[17]. However, for some commodities, elasticities estimated by this method were among the smallest short-run elasticities as well. For example, for coarse grains, the indirect profit function estimated by Weaver gave the largest own-price supply elasticity (.64 to .74) while the indirect profit function estimated by Saez and Shumway gave the smallest elasticity (.01 for the cornbelt states and .02 for the U.S.).

For aggregate farm output and for crops, Griliches (1960) Model generated the smallest long-run elasticities (.15 and .23 respectively), while the Tweeten and Quance Model generated the largest estimates (1.79 and 1.56 respectively). As explained before, Griliches estimates severely underestimate the true long-run supply elasticities. As it is argued, the included trend variable captures changes in relative prices that are not captured by the conventional

price indices.

It is expected that individual crops have a higher own-price supply response than aggregate farm output. This is because it is more plausible to switch land and other resources from one crop to another, than between agriculture and non-agricultural sectors as prices change. The elasticity estimates for the U.S. presented in Appendix III support this. Excluding the relatively high supply elasticity estimated for the 1910-46 period by Antle, aggregate output elasticities for the U.S. range from .08 to .43 in the short-run and .15 to 1.79 in the long-run. Individual crops show higher supply elasticities than aggregate output. For wheat, the supply elasticities range from .45 to .52 in the short-run and .25 to 2.55 in the long-run; for corn, the range is .34 to .56 in the short-run and .09 to 2.40 in the long-run; for soybeans and other oilcrops, elasticities vary from .01 to .64 in the short-run and from .10 to 3.27 in the long-run.

In order to rank the individual crops in terms of the magnitude of their own-price supply elasticities, one has to compare elasticities for various crops from the same study. According to the 1978 GOL estimates, oilseeds have the highest elasticity, while wheat and coarse grains rank second and third. The 1985 GOL estimates, however, rank wheat, other oilseeds (other than soybeans) and cotton as having equal and the highest elasticities compared to other crops, while rice, soybeans, corn and other coarse grains rank second, third, and fourth, respectively. Chambers and Just also show soybeans as having the largest elasticity, while corn and wheat are ranked second and third. The rankings of agricultural products for the United

States by the magnitude of their supply elasticities from various studies are given in Table A.

Table A. Ranking of Agricultural Commodities By the Magnitude of Their Own-Price Supply Elasticities From Various Models, United States, Derived from Appendix III.

Model	Own-Price Supply Elasticities					
	Largest					Smallest
1978 GOL Model	((3.27))[1] Oilseeds >	((2.55)) Wheat >	((2.40)) Coarse Grains			
1985 GOL Model	((.25)) Other oilseeds =	((.25)) Wheat =	((.25) Cotton >	((.16)) Rice >	((.10)) Soybeans >	((.09)) Corn & Other Coarse Grains
Chambers & Just Model	(.64)[2] Soybeans >	(.55) Corn >	(.50) Wheat			

[1]The figures in double parentheses represent elasticities with respect to world prices.

[2]The figures in single parentheses represent elasticities with respect to domestic prices.

Canada

Lopez (1984) used a two-output, four-input profit function to estimate a system of factor demand and output supply responses for Canadian agriculture using 1971 cross-section census data for the 240 agricultural census divisions in Canada. The advantages of using an indirect profit function (duality approach), as Lopez argues, are the simplicity of estimation and that there is no need to use endogenous variables (output or input levels) as explanatory variables.

The profit function in Lopez's model is of a Generalized Leontief specification and is applied to two outputs (crops and animal products) and four inputs (land and structures, hired labor, operator and family labor and farm capital). The profit function is specified as a function of input and output prices, an index of farm operator's education and regional dummy variables to capture the effects of climate and soil differences. The net output supply equations can be obtained by simple differentiation of the profit function. The estimated own-price output elasticities are, in general, less than one. Table 18, Appendix II presents own- and cross-price elasticities estimated from Lopez's model. The estimates illustrate that crop production is more responsive to the prices of operator and family labor, land and structures, animal products, and farm capital than to its own price. However, animal production is much more responsive to its own price than to the prices of crops and factors of production.

Because all the four input prices are included in the profit function and there are no fixed factors of production in the model, we

take these elasticities to be long-run in nature. This interpretation is supported in the paper:

> Three issues concerning the appropriateness of the cross-sectional data and interpretations of the results are worthwhile to consider: (a) enough systematic price variability appears to exist across the country to permit a meaningful estimation of supply and demand responses; (b) observed relative price variability in 1970 corresponds reasonably well with similar price data for the previous years, thus indicating that the 1970 relative price variability approximately reflects normal or long-run relative prices across the regions; (c) this allows one to interpret the results as long-run in nature (Lopez, 1984, p. 362).

Also calculated from the model are compensated output supply elasticities (Table 19, Appendix II) which are supply elasticities assuming that all inputs remain fixed when output price changes. This is a measure of trade-offs along the production possibility frontier. We assume these elasticities represent the lower limit on the short-run elasticities.

Estimates of own-price supply responses for Canada from the 1978 and 1985 versions of the GOL Model are presented in Tables 20 and 21, Appendix II respectively. By comparing the figures in these tables and Table 18, (Appendix II) we can see that, the elasticity estimates for various crops from the two versions of the GOL Model are much higher than the estimates from the Lopez model. However, for livestock products, the 1985 version of the GOL model reports elasticities that are lower than the estimates from the Lopez model. The study by Sarris and Freebairn (1983) which was explained before, reports the short-run wheat supply elasticity for Canada as being equal to .17. Tyers (1983) reports elasticities for crops and livestock products for Canada (Table 22, Appendix II). The long-run

estimates for crop elasticities from Tyers are very consistent with the estimates from the 1978 GOL Model (Table 20, Appendix II).

Seeley (1985) reports the supply, demand, and net trade elasticities from the International Institute for Applied System Analysis (IIASA) Model. This model is a simulation system that is based on econometrically estimated coefficients and simulates the supply-demand quantities, prices, and policies for 21 countries or regions and 10 commodity groups, including non-agricultural commodities (Seeley, p. 1). The system has an annual solution through two steps: In the first step, inputs (capital, labor, land, and fertilizer) are optimally allocated among various commodities by a mathematical programming model which maximizes expected net revenue. In the second step, the system takes the supply as given and determines its demand and government policies. The system reaches a general equilibrium in the sense that world markets are cleared. The simulation base is in 1985 and the model determines elasticities and trade responses through 1994.

The reported elasticities are with respect to the world prices and measure the supply response to a sustained price change in two, four, six, and ten years. These elasticities which were estimated using the coefficients obtained from historical data, along with price transmission elasticities are presented in Table 23, Appendix II. Price transmission elasticity is defined as the percentage change in domestic price to a one percent change in the world price:

$$E_{pt} = \frac{\%\Delta P_d}{\%\Delta P_I}$$

where:

E_{pt} = the price transmission elasticity.

$\%\Delta P_d$ = percentage change in the domestic price.

$\%\Delta P_I$ = percentage change in the world (international) price.

By dividing own-price supply elasticity with respect to world prices by the price transmission elasticity, own-price supply elasticity with respect to domestic price is calculated:

$$\frac{\%\Delta Q_s}{\%\Delta P_d} = \frac{(\%\Delta Q_s/\%\Delta P_I)}{(\%\Delta P_d/\%\Delta P_I)}$$

where:

$\frac{\%\Delta Q_s}{\%\Delta P_d}$ = percentage change in quantity supplied divided by percentage change in domestic price (own-price supply elasticity with respect to domestic price).

$\frac{\%\Delta Q_s}{\%\Delta P_I}$ = percentage change in quantity supplied divided by percentage change in international price (own-price supply elasticity with respect to world price).

$\frac{\%\Delta P_d}{\%\Delta P_I}$ = price transmission elasticity.

The calculated supply elasticities with respect to domestic price are presented in Table 24, Appendix II. The two-year elasticities are taken to be short-run, while the ten-year elasticities are taken to be long-run. By comparing the long-run elasticities in Table 24 with the 1978 GOL elasticities which are also long-run in nature (Table 20), we can see that the 1978 GOL estimates for crops are much higher than the

estimates in the IIASA model as reported by Seeley. One factor that may explain the relatively low values of supply elasticities for crops in the IIASA model compared to the 1978 GOL estimates, is the upward bias in estimates for price transmission elasticities. For a given supply elasticity with respect to the world price, the higher the price transmission elasticity, the lower the supply elasticity with respect to the domestic price. Another factor that may have caused the difference in the elasticity estimates from the IIASA model and the 1978 GOL model, is the product aggregation. The IIASA system has more aggregated products (especially animal products) than the GOL Model which has a larger distinct commodity list (Seeley, p. 27).

In response to Seeley's criticisms to the IIASA Model, Frohberg and Kromer (1985) estimated own- and cross-price supply elasticities with respect to domestic prices using a revised version of the IIASA Model[18]. The parameters used in their model were based on the 1961-76 data. The elasticities were calculated once assuming constant levels of agricultural and non-agricultural inputs and another time assuming variable inputs. In the latter case, the transformation function between all agricultural and non-agricultural goods changes in each year.

Frohberg and Kromer report the supply response in one as well as two years (1984 and 1985) to a once-and-for-all sustained price change; therefore, these elasticities are assumed to be short-run in nature. The included commodities or commodity categories are: wheat, rice, coarse grains, bovine and ovine meats, dairy products, other animal products, protein feed, other food, non-food agricultural

products, and non-agricultural products. The elasticities reported in Frohberg and Kromer are presented in Table 25, Appendix II. The two-year supply responses assuming variable inputs in Frohberg and Kromer can be compared with the short-run supply elasticities from Seeley which are also two-year responses assuming variable inputs (Table 24). For crops and livestock products (except for dairy), the estimated elasticities from Frohberg and Kromer are much higher than those reported in Seeley.

Askari and Cummings (1976) report Canadian own-price supply responses for wheat, barley and pork from various studies. The reported elasticities are summarized in Table 26, Appendix II. The range of elasticities for wheat in Askari and Cummings covers the long-run elasticities from Rojko, et. al. (the 1978 GOL Model) and short-run elasticities from Seeley. For animal products, the range of elasticities in Askari and Cummings is consistent with the elasticities from Tyers and Seeley (for the short-run).

Summary of Own-Price Supply Elasticity Estimates for Canada

All the own-price supply elasticities for Canada, which are explained in this study, are presented in Appendix IV. From this appendix, it is observed that elasticities vary significantly from one study to another. This is true in spite of the fact that most studies have used a direct supply function and cover the period 1960 to 1976 or 1960 to 1980. For crop products, the study by Lopez which utilizes an indirect profit function (the duality approach) gives the lowest

supply elasticities. Frohberg and Kromer (the revised IIASA Model), give the largest short-run supply elasticities for crops (food grains, feed grains and oilseeds) while Rojko, et. al. (the 1978 GOL Model) give the largest long-run elasticities.[19]

By comparing the short-run elasticities from the two versions of the IIASA Model (Seeley, and Frohberg and Kromer) in Appendix IV, for all crops and livestock products (except for dairy), the elasticity figures illustrate that Frohberg and Kromer report much higher elasticities for the short-run than Seeley. Also between the two versions of the GOL Model (1978 version by Rojko, et. al. and 1985 version by Liu and Roningen), the 1978 version reports much higher long-run elasticities than the 1985 version which reported the smallest long-run elasticities among all other estimates.

One should, however, note that the elasticities from the 1985 GOL Model are with respect to world prices, while the elasticities from the 1978 GOL Model are with respect to domestic supply prices. A less than one price transmission elasticity will cause the world price supply elasticity to be less than domestic price supply elasticity.

The aggregate crop elasticity estimated by Lopez (1984) is low relative to the supply elasticities estimated for individual crops. This is not surprising, since it is generally easier to shift resources from the production of one crop to another than it is to shift resources from the production of agricultural goods to non-agricultural goods. Hence, the aggregate crop elasticity estimate is expected to be lower than the supply elasticity estimates for single crops.

Comparing the individual crop supply elasticities in Canada,

according to the two versions of the GOL Model, oilseeds have the largest own-price supply elasticities among all other crops, while according to the IIASA versions they have the smallest elasticities. Based on the GOL and Tyer Models, coarse grains have higher elasticities than wheat but the opposite is true from the IIASA Model estimates: wheat has a higher elasticity than coarse grains. The rankings of individual products by the magnitude of their supply elasticities are presented in Table B.

Finally, the output supply elasticities with respect to output and input prices from the Lopez (1984) study (Table 18, Appendix II) show that crop output is more responsive to input prices (except for hired labor) than to its own price. Therefore, policies directed toward decreasing input prices are expected to be more successful in increasing output than those aimed at increasing output prices. However, for animal products, output shows to give a higher response to output price than to input prices. Therefore, policies aimed at supporting output prices are more successful than those directed toward input subsidies.

Table B. Ranking of Agricultural Commodities By the Magnitude of Their Own-Price Supply Elasticities From Various Models, Canada, Derived from Appendix IV.

Model	Own-Price Supply Elasticities		
	Largest		Smallest
GOL Models[1]	(1.20) Oilseeds >	(.70) Coarse Grains >	(.65) Wheat
IIASA Model	(.38) Wheat >	(.37) Coarse Grains >	(.14) Protein Feeds
Tyers Model	(.68) Coarse Grains >	(.53) Wheat	

[1]The elasticity figures are from the 1978 version.

Other Developed Countries

The study by Bale and Lutz (1981) attempts to estimate the effect of agricultural price distortions on output, consumption, and rural employment for nine developed and developing countries based on the 1976 data. The partial equilibrium comparative static analysis in the Marshallian economic surplus framework is used for the study. The supply elasticity estimates applied to Bale and Lutz's model are derived from the estimates reported in the 1978 GOL Model ($\pm$.5 times the point estimates given in the 1978 GOL Model). The elasticities reported in Bale and Lutz for developed countries are presented in Table 27, Appendix II.

The own-price supply elasticities for developed countries as reported in the studies by Rojko, et. al. (the 1978 GOL Model), Liu and Roningen (the 1985 GOL Model), Sarris and Freebairn (1983), Tyers (1983), Seeley (IIASA Model, 1984 version), Frohberg and Kromer (IIASA Model, 1985 version), and Askari and Cumming (1976) are presented in Appendix II, Tables 28, 29, 30, 31, 32, 34, and 35, respectively. The information in all the above mentioned tables are compiled in Appendix V. Table 32, Appendix II presents supply elasticities with respect to world prices and price transmission elasticities from the IIASA Model (Sealey 1985). By dividing these world price supply elasticities by price transmission elasticities, supply elasticities in Table 32, Appendix II are transformed into elasticities with respect to domestic prices. Table 33, Appendix II presents the supply elasticities with respect to domestic prices, calculated from the IIASA model elasticities.

Summary of Own-Price Supply Elasticity Estimates for Other Developed Countries

By comparing the information in Appendix V one can see that the elasticity estimates for the same region and the same commodity vary significantly from one study to the other. For short run elasticities in all of the developed countries, and for almost all of the reported commodities, Frohberg and Kromer's version of the IIASA Model gave the largest estimates (this comparison does not include the estimates reported in Askari and Cummings). For long-run elasticities the 1978 version of the GOL Model (Rojko, et. al.) reported much larger elasticities than the 1985 version (Liu and Roningen)[20]. However, recall that the latter study reports elasticities with respect to world prices while the domestic prices are the relevant price variables in the other studies. The long-run elasticity estimates reported in Askari and Cummings (Table 35, Appendix II) for ruminant and non-ruminant meats are mostly greater than one, while all of the other reported studies in this research give long-run elasticities of less than one for all meats.

By comparing supply elasticity estimates for crops versus livestock products in developed countries (Appendix V), it is hard to conclude whether or not livestock products have higher supply elasticities than crops. In Western Europe, Australia and New Zealand, from elasticity figures it appears that crops have higher elasticities than livestock products. However, in Japan, the opposite is true: livestock products on an average have higher elasticities than crops.

Among individual crops in the Western European countries, wheat has the highest elasticity according to the two versions of the GOL Model and the Seeley version of the IIASA Model. According to all the studies, oilseeds and protein meal have the lowest supply elasticity. Rice has a lower elasticity than wheat and coarse grains according to the two versions of the GOL Model and Tyers. Table C ranks commodities according to their supply elasticity estimates from various models.

In Japan, based on the studies by Tyers, Bale and Lutz, the 1978 GOL and the IIASA Models, rice has the smallest elasticity. Also, according to the 1978 GOL and the IIASA Models, wheat has a higher elasticity than coarse grains. The ranking of individual commodity supply elasticities for Japan is presented in Table D.

A comparison of the supply elasticities for the same crop among the developed countries illustrates the diversity of the estimates. The ranking of countries by the magnitude of their supply elasticities differs significantly from one study to another for the same commodity. For coarse grains, wheat and rice, the 1978 GOL Model gives estimates for the U.S. that are greater than Western European countries and for Western European countries that are greater than Japan. The same statistics are quite different in the 1985 version of the GOL Model. The estimates from this version of the model for coarse grains indicate a higher supply response for Japan than for Canada which in turn has a higher supply elasticity than Western Europe. The estimate of the supply elasticity for the U.S. for coarse grains is the lowest among all other developed countries from the 1985

Table C. Ranking of Agricultural Commodities By the Magnitude of Their Own-Price Supply Elasticities From Various Models, Western European Countries, Derived from Appendix V.

Model	Own-Price Supply Elasticities			
	Largest			Smallest
GOL Model	(.95) Wheat >	(.91) Coarse Grains >	(.40) Rice >	(.20) Oilseeds
Tyers Model	(.91) Coarse Grains >	(.90) Wheat >	(.40) Rice	
IIASA-Seeley Model	(2.89) Wheat >	(1.37) Coarse Grains		
IIASA-Frohberg & Kromer Model	(1.49) Rice >	(1.09) Wheat >	(.93) Coarse Grains >	(.04) Protein Feed

Table D. Ranking of Agricultural Commodities By the Magnitude of Their Own-Price Supply Elasticities From Various Models, Japan, Derived from Appendix V.

Model	Own-Price Supply Elasticities			
	Largest			Smallest
1978 GOL Model	(.43)[1] Oilseeds >	(.30) Wheat >	(.25) Coarse Grains >	(.16) Rice
1985 GOL Model	((.30))[2] Coarse Grains >	((.25)) Other Oilseeds >	((.15)) Rice >	((.08)) Wheat
IIASA-Frohberg & Kromer Model	(.44) Wheat >	(.38) Coarse Grains >	(.35) Protein Feed >	(.31) Rice
Tyers Model	(.60) Wheat =	(.60) Coarse Grains >	(.50) Rice	
Bale & Lutz Model	(.80 to 2.41) Wheat >	(.08 to .24) Rice		

[1]The figures in double parentheses represent elasticities with respect to world prices.

[2]The figures in single parentheses represent elasticities with respect to domestic prices.

version of the GOL Model. The supply elasticity estimates for coarse grains, wheat and rice are larger for Western European countries than for Canada and Japan in all of the other studies. The following table (Table E) gives the supply elasticity estimates for various commodities ranked by countries according to various studies.

Table E. Ranking of Countries By the Magnitude of Their Own-Price Supply Elasticities By Commodity, Developed Countries, Derived from Appendix III - V.

Commodity/Model	Own-Price Supply Elasticities				
	Largest				Smallest
Coarse Grains					
1978 COL Model	((2.40))[1] U.S. >	(.35 - .91)[2] W. Europe >	(.81) Australia & New Zealand >	(.70) Canada >	(.25) Japan
1985 COL Model	((.30)) Japan >	((.25)) Canada >	((.16 - .25)) W. Europe >	((.16)) Australia & New Zealand >	((.09)) U.S.
Tyers Model	(.91) W. Europe >	(.75) U.S. >	(.68) Canada >	(.60) Australia	
IIASA-Beeley Model	(1.37) W. Europe >	(.48) Australia >	(.37) Canada		
IIASA-Frohberg & Kromer Model	(.93) W. Europe >	(.84) Australia >	(.78) Canada	(.38) Japan	
Wheat					
1978 COL Model	((2.55)) U.S. >	(.85 - .95) W. Europe >	(.65) Canada >	(.55) Australia & New Zealand >	(.30) Japan
1985 COL Model	((.25)) U.S. =	((.25)) W. Europe >	((.08)) Japan =	((.08)) Australia & New Zealand >	((.06)) Canada
Tyers Model	(.90) W. Europe =	(.90) Australia	(.80) U.S. >	(.60) Japan >	(.53) Canada
IIASA-Beeley Model	(2.89) W. Europe >	(.51) Australia >	(.38) Canada		
IIASA-Frohberg & Kromer Model	(1.09) W. Europe >	(.80) Canada >	(.64) Australia >	(.44) Japan	
Corn					
1985 COL Model	((.29)) Japan >	((.23)) W. Europe			
Rice					
1978 COL Model	((.90)) U.S. >	(.30 - .40) W. Europe >	(.16) Japan =	(.16) Australia & New Zealand	
1985 COL Model	((.25)) W. Europe >	((.16)) U.S. >	((.15)) Japan >	((.10)) Australia & New Zealand	
Tyers Model	(.75) U.S. >	(.50) Japan >	(.40) W. Europe >	(.30) Australia	
IIASA-Frohberg & Kromer Model	(1.49) W. Europe >	(.94) Australia >	(.31) Japan		
Oilseeds					
1978 COL Model	((3.27)) U.S. >	(1.20) Canada >	(.45) Australia & New Zealand >	(.43) Japan >	(.02-.20) W. Europe
1985 COL Model (other than soybeans)	((.25)) W. Europe =	((.25)) Japan =	((.25)) U.S. >	((.09)) Canada	
IIASA-Frohberg & Kromer	(.40) Canada >	(.35) Japan >	(.04) EC	(.00) Australia	
Sugar					
1985 COL Model	((.25)) Japan >	((.13)) EC >	((09)) Australia & New Zealand =	((.09)) Other W. Europe >	((.07)) Canada
Bale & Lutz Model	(.81 - 2.44) France >	(.43 - 1.30) W. Germany >	(.22 - .66) United Kingdom >	(.21 - .64) Japan	
Cotton					
1985 COL Model	((.27)) Japan >	((.25)) Other W. Europe =	((.25)) U.S. >	((.12)) EC - 10 >	((.05)) Canada

[1] The figures in double parentheses represent elasticities with respect to world prices.

[2] The figures in single parentheses represent elasticities with respect to domestic prices.

Asian Developing Countries

India, Total Output

Lau and Yotopoulos use an indirect profit function (duality approach) to estimate output supply and input demand elasticities from cross-sectional data obtained from the Indian Ministry of Food and Agriculture. A CES (Constant Elasticity of Substitution) production function was fitted directly and since the elasticity of substitution was found to be not significantly different from one, the Cobb-Douglas production function was adopted. Labor was considered as the variable input while land and capital were considered as the fixed factors of production.

The final estimating equations consisted of:

$$\ln \pi^* = \alpha_o + \Sigma_{i=1}^{4} \delta_i^* D_i + \alpha_1^* \ln W + B_1^* \ln K + B_2^* \ln T \qquad (1)$$

$$\frac{-wL}{\pi^*} = \alpha_1^* \qquad (2)$$

where:

π^* = profit (current revenues less current variable costs) in rupees per farm

W = money wage rate in rupees per day

D_i = regional dummy variable with D_1, D_2, D_3, D_4 taking the value of one for only West Bengal, Madras, Madhya Pradesh, and Uttar Pradesh, respectively. Since it is assumed that prices of output differ only across states, the state dummy variables are supposed to capture the effect of differences due to prices as well as interstate differences in the efficiency parameter.

L = labor in days per year per farm

K = interest on fixed capital per farm

T = cultivable land in acres per farm

The farm decision variables (the endogenous variables) are the quantities of output and labor input, while the prices of output and variable inputs and the quantities of fixed inputs are assumed to be predetermined (exogenous variables) and not subject to change by any action of the farm in the short-run. Because profit is defined as current revenues less current variable costs, an alternative set of jointly dependent variables are profits and total labor costs. That is, the left-hand side variables in the equations (1) and (2) are the dependent variables while the right-hand side variables are the predetermined variables.

Although the estimated coefficients obtained by Ordinary Least Squares Method of estimation applied to each equation separately are consistent, they will be inefficient because α^*_1 appears in both of equations (1) and (2). Therefore, Zellner's Method of estimation which imposes known constraints of the coefficients is used. This method provides asymptotically efficient estimates of the coefficients.

Three sets of estimates are obtained with imposing the following restrictions:

1. The two equations were estimated <u>Unrestricted</u>.

2. The restriction that $\alpha^*_{1,1} = \alpha^*_{1,2}$ from equations (1) and (2) was imposed.

3. The restriction that $B_1 + B_2 = 1$, which assumes

constant returns to scale, along with the restriction that $\alpha^*_{1,1} = \alpha^*_{1,2}$ was imposed.

The null hypothesis that α^*_1 from both equations are equal and the hypothesis of constant returns to scale could not be rejected. From the estimated parameters of the model, indirect estimates of the own-price input demand elasticities and output supply elasticity were obtained. All the calculated elasticities were greater than one. The estimated elasticities are presented in Table 36, Appendix II. These elasticities are assumed to represent short-run elasticities because of the existence of fixed factors of production.

The results from the Lau and Yotopaulos study indicate that the own-price supply elasticity is positive, statistically significant and greater than one. An important implication of the estimated elasticities is that if the goal of the policy-maker is to increase output and/or increase labor employment, decreasing the wage rate will have the exact same effect on output and employment as increasing the output price by the same percentage.

Bapna (1980) used a Nerlovian type supply function to estimate supply elasticities for the Ajmer district of India. Six estimates of the aggregate supply elasticities were obtained using different price expectation formation. The low estimates are in the range of 0.20 to 0.25, while the high estimates are in the range of 0.5 to 0.6. Bapna rejects the latter set of supply elasticities on the ground that they are too high.

Ajay Chhibber (1982) provided an alternative to the Nerlovian type farmers' expectations models and estimated agricultural output

supply response for India. Chhibber argues that the Nerlovian type models underestimate the true supply elasticities. This is because they use time series data which are subject to transient fluctuations and to which farmers may not respond to as much as they would to permanent price changes. Chhibber's model consists of the following equations:

$$Q = f(Q_{t-1}, G, R \text{ or } I, Y_{m,t-1}) \quad (1)$$

$$Q_d = f(P, Y) \quad (2)$$

$$Y = f(P, Q, Y_{m,t-1}) \quad (3)$$

where: Q is the index of agricultural production

G is the percentage of area irrigated by government canals

R is the rainfall index

I is the percentage of area irrigated (total)

Y_m is the index of manufactures output

P is the ratio of agricultural to manufactured prices

Y is the index of GDP at manufactured goods prices

As observed in Equation 1, output in Chhibber's Model is not a function of prices. Furthermore, the irrigated area is included to represent all other non-price supply shifters such as technological improvements, credit availability and fertilizer use. This is because data on credit use or data on the provision of credit by the government were difficult to obtain for a time-series analysis. Also, Indian time-series data indicate severe multicollinearity between irrigation, fertilizer and area under high yielding varieties. The

adoption of modern technologies and fertilizer use were shown to be highly dependent on the availability of assured water supply (irrigated area).

In one version (Case I), the net irrigated area by government canals and in another version (Case II) total irrigated area was used in Equation 1. The former version represents the upper limit to the price supply elasticity, while the latter estimate represents the lower limit to the aggregate supply elasticity. Equations 1 through 3 were estimated using Three Stage Least Squares estimation technique applied to data from 1960/61 through 1977/78. In this study, in addition to the estimates from the above model, estimates using the Nerlovian adaptive expectations model and the rational expectations model were also presented for comparison. The results are summarized in Table 36A, Appendix II.

The figures in Table 36A show that supply elasticities estimated from the Chhibber's model are larger than estimates from both the Nerlovian adaptive expectations and the rational expectations models. These elasticity estimates, therefore, give support to the criticism that the Nerlovian type models underestimate the true supply elasticities. In Chhibber's model, supply is not a function of observed prices which may be viewed as transient. Furthermore, Chhibber's supply elasticity estimates are below the estimates obtained from cross-country data (in the range of 1.5). It is argued that the estimates based on cross-country data overestimate the true supply elasticities because of the differences in technological and economical development stages across regions or countries.

No conclusion can be derived from this study on whether the government of India should concentrate on non-price policy variables rather than output prices to increase agricultural production. The output supply elasticities with respect to non-price shifters are almost twice as large as the elasticities with respect to the price shifter when total irrigated area is used as a non-price supply shifter. However, when area irrigated by government canals is used in the supply equation, the non-price output elasticity is less than the own-price supply elasticity.

India, Wheat

Sidhu and Baanante (1979) use a normalized (by the price of output) restricted profit function (duality approach) to estimate input demand and output supply elasticities for the Mexican wheat varieties in the Indian Punjab. Wheat production is assumed to follow a Cobb-Douglas production function; labor, chemical fertilizer, and irrigation water are included as variable inputs while land, capital, and education are included as fixed factors of production. Dummy variables are included for farm sizes: one dummy takes the value of one if the wheat area is greater than 10 acres while the other dummy variable takes the value of one if the wheat area is less than 10 acres.

The indirect profit function and the variable input demand equations were estimated using two methods of estimation: the Ordinary Least Squares applied to individual equations and Zellner's asymptotically efficient method for simultaneous estimation of the

equations. The 1970-71 cross-sectional data were used in both estimations. Output supply elasticities with respect to price and non-price variables, estimated from this study are presented in Table 36-B, Appendix II. Because of the inclusion of fixed factors of production, we interpret these elasticities as short-run.

The results from this study suggest a relatively elastic response of output supply function and fertilizer and other variable input demand functions to changes in wheat price compared to variable input price.

> The impact on fertilizer use and wheat output of a 1% decrease in fertilizer price is not symmetric with a 1% increase in wheat price. Wheat price appears to be a much more powerful policy instrument than fertilizer price to influence fertilizer use, output supply, and returns to fixed-farm resource (Sidhu and Baanante, 1979, p.461).

The results also indicate that one other significant contribute to agricultural production in Punjab is the education of farm people in that area.

> The role and significance of productive value of education should again be pointed out. The indicated shift in output supply and factor demand functions, resulting from a small amount of education of about 2.6 years of schooling per family is 3%. This, however, is not a total measure of the productive value of education in agricultural production since wheat is only one of the several farm enterprises on Punjab farms (Sidhu and Baanante, 1979 pp. 460-61).

Another important implication of this study is that there is no significant difference in the efficiency (technical and price) parameters of small and large farms. That is, both farm sizes maximize profits, and that there exists constant returns to scale in wheat production in the Punjab area of India.

Furthermore, strong support is given for the approach used in this study which uses a normalized profit function and other factor demand functions for deriving policy implications from empirical applications of farm-level data (Sidhu and Baanante, 1979, p. 461). One reason for this support is that in the duality approach, the output supply and input demand elasticities with respect to the fixed factors of production (land, capital assets, and education) give the resp[illegible] to exogenous changes in these factors, allowing output and variable inputs to adjust optimally although the prices of output and variable inputs are held constant.[21] As a result, the magnitude of these reduced form elasticities are much larger than the production function elasticities and therefore the elasticities obtained from dual approach are more meaningful and relevant measures of the effect of policy changes (Sidhu and Baanante, 1979, p. 460).

Sidhu and Baanante (1981) used a normalized restricted translog profit function to estimate input demand and output supply functions of Indian Punjab farms producing Mexican wheat varieties. The model was applied to 1970-71 cross-sectional data. The use of a translog function is supported because it allows more flexibility than a Cobb-Douglas profit function.

> While the empirical results for the specification employed are plausible, they also demonstrate in this case a lack of support for the hypothesis of the Cobb-Douglas form of the profit function. Of particular importance is the result that the flexibility afforded by the translog formulation allowed the exogenous variables to produce different impacts across input demand functions of labor, fertilizer, and animal power. This is much more natural as compared to the symmetric impacts produced in the case of the Cobb-Douglas formulation (Sidhu and Baanante, 1981, p. 245).

The profit function used in this study is normalized by the price of wheat. The variable inputs are: labor, chemical fertilizer, and animal power, while the quantity of capital equipment and machinery used for wheat production, land, soil (PH) of farmland, soil organic carbon content of land, and P_2O_5 and K_2O in the soil, average number of years of schooling per family member, and area-weighted average number of irrigations per hectar are included as fixed factors of production. The model consisting of the normalized restricted translog function and derived factor demand equations are estimated jointly by the restricted generalized least squares which is an asymptotically efficient method of estimation. The calculated elasticities which are evaluated at simple averages of factor shares in total profits and at geometric means of the variable input prices and of levels of fixed inputs, are presented in Table 37, Appendix II. These elasticities are estimated assuming both a translog and a Cobb-Douglas form profit function. The cross-price elasticities indicate that the price of wheat has a more significant impact on quantities of wheat supplied and input demanded than prices of variable inputs. Futhermore, the test for the Cobb-Douglas specification was rejected. Therefore, for the data and model specification in this analysis, the translog form of the profit function appeared to be more suitable (Sidhu and Baanante, 1981, p. 241).

The effect of education, land and irrigation on output supply is quite significant when a translog profit function is estimated. The elasticity of wheat supply with respect to the level of education, quantity of land, and the amount of irrigation is .0874, .6951, and .5641 respectively. These elasticity figures support the importance

of non-price variables on output supply.

> The influence of expansion in education of the farm family is quite important. It increases demand for all variable inputs but, more importantly, for fertilizer and animal power. It also influences wheat supply significantly. Exogenous increases in land quantities also increase wheat supply and demand for all variable inputs of production (Sidhu and Baanante, 1981, p. 244).

de Janvry and Kumar (1981), in an attempt to analyze marketed surplus response to factor price changes, derived output supply and input demand elasticities for Mexican wheat and hybrid bajra in Delhi Union Territory of India. An indirect normalized (by the price of output) profit function obtained from a Cobb-Douglas production function is used to estimate output supply and input demand functions. Fertilizer and labor are included as variable factors of production, while land and capital are included as fixed factors of production. Detailed information was collected on randomly selected farms from two villages of the Delhi Union Territory between 1968-69 and 1975-76 (de Janvry and Kumar, p. 6). Wheat farms were classified into small (less than 7.5 acres) and large (larger than 7.5 acres) farms.

The three equations: the normalized profit function, and the two variable input demand equations for labor and fertilizer were estimated simultaneously by Zellner's Method of estimation for small and large farms. The imposed restriction was the equality of coefficients that appeared in the profit function and input demand equations.

Because all of the area planted in wheat is irrigated, inclusion of a weather index as well as year dummy variables in the profit function proved to always be insignificant (de Janvry and Kumar, p.

7). The calculated elasticities from this study were consistent with the elasticities reported in Askari and Cummings (1977), Table 38, Appendix II.

An important result of this study is that the price elasticities of output supply and derived input demand functions are the same for small and large farms. This indicates an identical pattern of production response to price movements in small and large farms (de Janvry and Kumar, p. 7). By looking at output supply and input demand elasticities with respect to output and input prices (Table 39, Appendix II), it can be concluded that output price has a higher impact on production than input prices and output price has a slightly higher impact on input utilization than input prices. Therefore, ceteris paribus, policies aiming at output price will have a higher impact on output and employment than policies subsidizing inputs.

India, Rice

Kalirajan and Flinn used a normalized restricted profit function derived from a Cobb-Douglas form production function to explore the allocative efficiency and supply response of farmers producing modern varieties of rice in the kharif season for the irrigated rice of Coimbatore District of India.

Two types of rice varieties were examined: one was EMV (Exotic Modern Variety) IR20. This variety which was bred and named by the International Rice Research Institute in the Philippines resistant to tungo virus and its vector, the green leaf-hopper. The other type studied was the locally-bred varieties (LBV) which were bred at the Aduthurai and Coimbatore Paddy Breeding Stations. These varieties are resistant to brown plant-hopper and insects indigenous in Southern

India. Data from May 1977 to April 1978, from 91 sample farmers for the Kharif rice crop in Coimbatore District was used. This area is irrigated and is considered as one of India's most progressive and favorable rice growing areas.

The model consisted of the following five equations: the restricted normalized (by price received per kg. of paddy) profit function and the four variable input demand equations:

$$\ln \pi^* = \ln A^* + B_1^* \ln W + B_2^* \ln F + B_3^* \ln P + B_4^* \ln B + \delta_1^* \ln L + \delta_2^* \ln C \quad (1)$$

$$\frac{-WX_1}{\pi^*} = B_1^* \quad (2)$$

$$\frac{-FX_2}{\pi^*} = B_2^* \quad (3)$$

$$\frac{-PX_3}{\pi^*} = B_3^* \quad (4)$$

$$\frac{-BX_4}{\pi^*} = B_4^* \quad (5)$$

where:

π^* = the normalized restricted profit (current revenues less current variable costs) from the rice crop

W = the normalized wage

F = the normalized price of fertilizer per kg

P = the normalized price of pesticide per kg

B = the normalized cost per bullock day

L = the area grown in rice (acres)

C = the capital flow calculated as the sum of depreciation, maintenance, and opportunity cost of capital stock.

The variable factors of production are labor (X_1), fertilizer (X_2), pesticides (X_3), and bullock (X_4), while land and capital are the fixed factors.

Equations 1 through 5 were estimated jointly by the Zellner Method imposing the condition that the B_i's are equal in both the profit function and the relevant factor demand function. The assumption of profit maximization by farmers was tested for both rice varieties. This assumption could not be rejected by farmers growing LBVs; that is, farmers growing LBVs are judged to be allocatively efficient. However, in the case of EMV this assumption was rejected for pesticides implying that farmers were not equating marginal value product and marginal cost of pesticides with IR20. The main reason for this inefficiency is that the IR20 which is bred in the Philippines is not as resistant as the locally bred varieties to the brown plant hopper found in Coimbatore area of India.

In general, it is assumed that the sample farmers in the irrigated area of Coimbatore are profit maximizers with respect to the Kharif rice crop. The factors that give support to this assumption are that production risk and price risk are minimized in this area. This area's assured and well-controlled supply of irrigation water for two rice crops a year, a low climate risk because of lack of droughts or floods, and an active co-operative movement that distributes inputs are factors that contribute to production risk minimization. Also,

price risk is minimized because this region is a substantial rice importer and thus farmers have a ready market for paddy. Additionally, price expectations are based on well established and known marketing and transport costs and on market prices.

The estimated rice output supply and input demand elasticities are summarized in Table 40, Appendix II. From the elasticity estimates in Table 40, it appears that EMV shows a higher own-price supply response than the LBV. Another important implication is that a one percent increase in rice output price has a higher impact on output than a one percent decrease in the normalized price of any of the variable inputs. Therefore, policy-makers can have a larger impact on output supply and input utilization through aiming at supporting output prices than subsidizing input costs. This conclusion is consistent with the studies by de Janvry and Kumar, and Sidhu and Baanante.

Among all input prices and quantities of fixed inputs, the normalized prices of fertilizer and labor and the quantity of land appear to have the highest impact on output in both varieties. The elasticities calculated from direct estimation of production function also show that quantities of fertilizer, labor, and land have the highest impact on rice output than any other factor.

Developing Countries, Rice

The study by Ito, et al. (1985) gives estimates of rice supply elasticities for various Asian countries. Unlike the study by Kalirajan and Flinn, the reported figures show inelastic supply elasticities for both the short- and long-run for India as well as many other Asian rice producing countries (Table 41, Appendix II). In this study, equation (23) was used to estimate supply elasticities. In the supply equations, government prices were used for Burma, India, Indonesia, Japan, Pakistan, the Philippines, and Taiwan, while market prices were used for Bangladesh, South Korea, and Thailand.

The first column of Table 41 represents yield elasticity with respect to price of rice. Burma, Pakistan and Thailand show no yield response to price. South Korea, and the Philippines show a relatively high yield response to price. The negative effect of acreage on yield appears only in the country with production control programs: Taiwan. Thailand is the only country that has an area elasticity greater than one, and thus an own-price production elasticity greater than one in the long-run. After Thailand, Pakistan has a relatively high area elasticity. In terms of production responses, South Korea and the Philippines show relatively high elasticities that have resulted because of their relatively high yield elasticities.

The time period that it takes for the full impact of a price change to take place (the adjustment period), varied significantly from one country to another. This adjustment period took anywhere from one year in Burma, Indonesia, and the Philippines, to about five years in Thailand.

Sri Lanka, Rice

The study by Bogahawatte (1983) suggests an inelastic own-price supply response for rice in Sri Lanka, a country that relies on rice imports to feed its population. The model in this study consists of yield and acreage equations; total production of paddy rice is then calculated as a multiple of yield and acreage:

$$Q = Y.A$$

$$Y = f(IR, R, R_{t-1}, MV, CR, CI, P_{t-1})$$

$$A = f(IR, R, R_{t-1}, MV, CR, CI, A_{t-1}, GPS)$$

where:

Q = total production of paddy in metric tons (MT)

Y = yield of paddy in kilogram per hectare

A = area planted to rice in hectares

IR = the proportion of paddy area under irrigation

R = the amount of rainfall

MV = the proportion of paddy under local hybrid varieties

CR = the amount of agricultural credit given for paddy in rupees per hectare

CI = the proportion of paddy under crop insurance

GPS = the Ratio of guaranteed price of paddy to average weighted guaranteed price of subsidiary food crops.

$P_{t-1} = \frac{GPS_{t-1}}{P_f}$ where: P_f is the average price of NPK fertilizers.

This model was estimated for the wet and dry zones of the island for two seasons: Maha and Yala.[22] Zellner's seemingly unrelated

regression procedure was applied to data from 1955 through 1979. The supply elasticities are summarized in Table 42, Appendix II. These elasticities are assumed to be short-run because of the exclusion of the lagged dependent variable in the yield equation. Although in the area equation lagged dependent variable is included, the elasticities are not divided by the adjustment coefficient and therefore they are assumed to represent short-run elasticities.

The results suggest relatively low yield and area elasticities, implying a relatively small incentive to increase paddy production (especially paddy acreage) in response to an increase in the government's guaranteed price.

> The regression results suggest that the guaranteed price scheme provides only a small incentive to paddy production. Irrigation is a major contributory factor to rice production in the dry zone. The modern varieties and agricultural credit significantly affect yields. Rainfall and cultivated acreage in the previous season affect the current rice area... The policy of the government should be to maintain the rice imports at its original level and increase domestic production through producer incentives such as provision of credit, farm inputs, etc. The increase in the world price of rice brings about a direct impact on the consumption sectors of the rice economy through reduction in rice imports. However its effect on domestic production appears to be low (Bogahawatte, p. 25).

Through simulation, the long-run effects of a world price increase on rice production was obtained which appeared to be low.

Indonesia, Rice

Pitt (1983) criticizes the previous work on input demand elasticities, such as the study of Sidhu and Baanante (1981), because of their failure to account for the seed switching possibility.

> These and other studies neglect the possibility that cultivators can respond to price changes not only by adjusting their use of variable inputs but also by switching to different seed varieties (Pitt, p. 502).

The fertilizer demand models that do not consider this seed switching activity will therefore underestimate input demand response to price as the response is higher if seed variety is allowed to vary. Furthermore, because these models only consider the response of one kind of variety to changes in price, they selectively eliminate the farmers who have switched varieties and therefore the least squares estimation may be selectively biased.

In Pitt's study, simple two-stage estimation procedures which adjust for selectivity bias are applied to data pertaining to Javanese paddy cultivators of traditional (TV) as well as high yielding varieties (HYV). Pitt's model assumes profit maximization in the simultaneous determination of seed variety and fertilizer demand. A translog (transcendental logarithmic) profit function is used to derive the equations that estimate fertilizer demand elasticities. Data pertain to 616 individual farm plots of wet rice on the island of Java, Indonesia, in 1971. The included variables are land (plot area in hectare), irrigation (the quality-weighted index of irrigation applied), the money price of rice, and the money price of urea fertilizer (very little factory fertilizer other than urea was used).

The change in the probability of planting HYV rice in response to changes in the exogenous variables are presented in Table 42A, Appendix II. From the figures in this table, one can conclude that seed selection is quite responsive to the fertilizer/rice price ratio. Also, improvements in irrigation quality will induce substantial adoption of HYV variety (Pitt, p. 506). The calculated price elasticity of demand for fertilizer, allowing for seed switching, in HYV of rice is -1.561 and the TV is -0.400. The total elasticity in the absence of seed switching is -1.042, while adjusting for the seed switching activity increases the elasticity to -1.155.

Although this paper does not report any own-price supply elasticities per se, it was included in this manuscript because of its consideration of seed switching activity which will affect the own-price supply elasticities.

Nainggolan and Suprapto (1984), estimated short- and long-run rice output elasticity for Java, Indonesia. Total output supply elasticity was calculated as the summation of acreage and yield elasticities. Rice acreage and yield models were specified as Nerlovian-type models and were applied to time-series data from 1968 to 1977. Ordinary Least Squares Method of estimation was applied to each equation individually.

Rice acreage was specified as a function of lagged deflated (by general price index) price of rice, weather (measured by rainfall), and lagged acreage. Yield per hectare was specified as a function of lagged deflated price of rice, current acreage, weather, and lagged yield per hectare. The results from acreage equation were not satisfactory: none of the coefficients turned out to be significantly

different from zero and the R^2 was relatively low (.57). Therefore it was concluded that price increases do not encourage expansion in rice acreage. However, the coefficients for lagged rice price and the weather variable turned out to be significantly different from zero in the yield equation and R^2 was equal to .92 for this equation.

In summary, the price variable had a significant effect on rice yields, but not on acreage. Two reasons were given for these results (Nainggolan and Suprapto, p. 5):

1. The majority of rice farmers in Java are small holders with average of 0.1 hectares of land.

2. Most of the BIMAS and INMAS activities have been centered in Java.

Therefore land is a major constraint for rice production, and thus price incentives would not increase acreage while they would encourage the expansion of use of other inputs such as fertilizer, improved seeds, pesticides, and irrigation which would all lead to an increase in yields. Short- and long-run elasticities from this study are reported in Table 42B, Appendix II.

India, Sugarcane

In a study of the determinants of sugarcane acreage fluctuations in various regions of Uttar Pradesh, Lal and Singh emphasize the importance of sugarcane and sugar industry as a source of income and employment in this state. Uttar Pradesh accounted for about 40 percent of sugarcane production during the 1977-78 period.

Lal and Singh applied a Nerlovian adjustment lag model to data

from 1950-51 to 1974-75:

$$\log Y_t = \log a + b_1 \log Y_{t-1} + b_2 \log Z_{t-1} + b_3 \log P^g_{t-1} + b_4 \log W_t + b_5 \log D_{t-1} + b_6 \log I_t + b_7 \log P_{yt} + b_8 \log V_{yt} + \log V_t$$

where:

Y_t and Y_{t-1} = current and lagged sugarcane acreage in thousand hectares.

Z_{t-1} = relative yield of cane to wheat, lagged one period.

P^g_{t-1} = gur price deflated by wheat price, lagged one year.

W_t = rainfall during sowing months (October - February) in millimeters.

D_{t-1} = percent cane acreage infested with pests and diseases.

I_t = irrigated area in thousand hectares during growing season.

P_{yt} = price risk measured by standard deviation of sugarcane prices over the three preceding years

V_{yt} = yield risk represented by the standard deviation of cane yields over the three preceding years.

V_t = random error.

The model was estimated using Ordinary Least Squares method of

estimation. The Durbin 'h' statistics did not indicate the presence of serial correlation. The relative gur price was found to be a better variable in explaining acreage fluctuations than relative sugarcane price. Lal and Singh give the reason:

> The gur sector accounts for a greater part of the sugarcane acreage and output in Uttar Pradesh, and since the cultivator converts cane into gur himself, the price of gur appears to be a more relevant decision variable (Lal and Singh, p. 104).

The elasticity estimates (Table 43, Appendix II) show a very el stic long-run supply response with respect to lagged gur/wheat relative price for Western region and Uttar Pradesh as a whole. The adjustment coefficient was found to be the highest for the central region which implies that the acreage adjustments were made more rapidly in this region. Futhermore, the response of the farmers in the eastern, central, and the western regions to the risk of price fluctuations were found to be negative and statistically different from zero. However, although negative, the regression coefficient of the yield risk variable was not significantly different from zero for all the regions and the state as a whole.

Pakistan, Various Agricultural Products

Tweeten (1985)used a Nerlovian-type direct supply function to estimate own- and cross-price elasticities for several agricultural products in Pakistan. A typical supply response equation used by Tweeten is presented below:

$$O_i = F\ [W(P_i/PP),\ I,\ HYV]$$

where:

O_i = output (production of commodity i)

$W(P_i/PP)$ = a declining weighted average of past real prices of commodity i (prices received to prices paid by farmers)

I = irrigated area or water supply

HYV = high-yielding varieties as a measure of technology

In addition to the direct estimation of the supply function, total output elasticities were also calculated as a summation of yield and acreage elasticities. Ordinary least squares method of estimation was used for most of the crops and it was applied to data from 1962/63 to 1982/83. Because of the autoregression of residuals in equations for rice, wheat, and livestock, autoregressive least squares method of estimation was also used for these crops. However, the estimates from the latter method did not significantly differ from the OLS results. The price coefficients in rice and wheat equations were not significantly different from zero.

The estimated elasticities from this study and from other studies (consensus judgments) are presented in Table 44, Appendix II. Not all the cross-price elasticities were available from other studies or could be estimated directly from econometric estimates because of multi-collinearity among the variables and unavailability of data. Therefore, economic theory was used to derive the cross-price elasticities. The procedure is explained in Tweeten, 1985, Appendix A. The results of Tweeten's study indicate that in the short-run for cotton grown in Pakistan and Punjab, yield is more responsive than

area to price. For sugarcane, area elasticities are considerably larger than yield elasticities in the long-run. In addition, supply responses are much greater in Punjab than in Sind, both in the short- and long-run (Tweeten, 1985, p. 10). However, for wheat, both area and yield elasticities are much larger in Sind than in Punjab or Pakistan as a whole. Tweeten's elasticity estimates (Tables 44) suggest that wheat supply is less responsive to price than is the supply of other major crops (Tweeten, 1985, p. 11).

Because of data unavailability aggregate output supply elasticities were not calculated for individual provinces but only for Pakistan as a whole. The estimated elasticities for aggregate output are smaller than individual commodity elasticity estimates. The explanation is given as:

> Resources can be shifted from one commodity to another when the price of only one commodity is changed. When all prices increase, however, the aggregate output response is restricted by more modest percentage changes possible in total resources (Tweeten, 1985, p.11).

From the consensus estimates it appears that in the short-run output prices have a higher impact on output supply of individual crops than input prices. In the long-run, however, this is not the case for many of the studied crops. The reduction of prices paid by farmers by a certain percentage has a higher impact on cotton, sugar, rice, and miscellaneous crops output supply than the increase in the respective output prices by the same percentage.

Taiwan, Agricultural Output

Yotopoulos, Lau and Lin (1976) extend an earlier study by Lau and

Yotopoulos (1972) to an analysis of farm household in Taiwan. The study uses a normalized restricted profit function (duality approach) of a Cobb-Douglas form applied to cross-sectional data on about 400 farm households grouped according to five sizes of operation. The data were collected for 1967 and 1968. Four variable inputs: labor, animal labor, mechanical labor, and fertilizer and two fixed factors: land and fixed assets were included in the model. All the input prices and the profit were normalized by the price of output. Dummy variables corresponding to agricultural regions were also included.

The normalized restricted profit function and the four sets of input demand equations were estimated by Zellner's Method which is asymptotically efficient. As was mentioned before, OLS applied to each of the equations separately, although consistent, will not necessarily be efficient. The estimation results indicate that the null hypothesis of equality of the coefficients appearing in both the profit function and input demand equations could not be rejected. This implies that the hypothesis of profit maximization cannot be rejected.

> Thus, the agricultural households in Taiwan may therefore be regarded as efficient producers at least within their own environment (Yotopoulos, Lau and Lin, 1976, p. 339).

Indirect estimates of the production elasticities were derived using the parameters of the estimated model. These indirect estimates represent production elasticities of the Cobb-Douglas production function that underlies the normalized restricted profit function. These estimates were compared with direct production elasticities obtained from estimating the production function in this study and

other studies. The direct and indirect elasticities figures are quite different from one another. One should note that indirect estimates are consistent and asymptotically efficient, while the direct estimates are generally inconsistent because of the existence of simultaneous bias. The indirect elasticity estimates from this study indicate that labor and land are by far the two most important factors in output. Production elasticity with respect to labor is .44, and with respect to land is .41. Next to labor and land, fertilizer is the most important factor with an elasticity of 0.10. Own- and cross-price elasticities derived from this study are presented in Table 45, Appendix II. Because of the existence of the fixed factors of production, these elasticities are assumed to be short-run in nature.

As it is shown in Table 45, own-price elasticities are all greater than one implying elastic own-price output supply and input demand functions. Moreover, in the output supply and input demand functions, the price of output has a larger impact than any other variable. Therefore, Taiwanese government output price support programs will have a greater effect on output supply and employment of inputs than input subsidy programs.

The own-price supply elasticities for India, Egypt, Indonesia, Sri Lanka, Pakistan and Taiwan from the above explained studies as well as the estimates from the two versions of the GOL Model and the IIASA Model, and the study by Tyers are reported in Appendix VI.

Latin American Developing Countries

Colombia, Various Agricultural Products

Norton (1985) tests the price-responsiveness hypothesis for various agricultural products in Colombia, using time-series data on production and prices. The analyzed commodities are: cotton, corn, sorghum, barley and rice. The results of this study suggest that the production of most of the examined crops (except for rice) were price-responsive (Norton, p. 52).

For Cotton, the most important explanatory variables in the area planted equation are: lagged cotton price, the price of cotton relative to the price of rice, and the price of cotton relative to the rural wage rate. In the area planted equation for corn, the main explanatory variables are the lagged ratio of barley to corn price, and the lagged real rural wage rate deflated by consumer price index.

For sorghum, the dependent variable is the physical production of sorghum. Lagged price ratio of sorghum to cotton and the lagged real price of sorghum are the main explanatory variables in the equation. For barley too, the dependent variable is the physical production level. The explanatory variables are the price ratios of barley to potatoes, lagged one to four years. For most equations data from 1958 through 1984 were used.

For rice, neither area planted nor the production level was found to be price responsive. Historically, rice has responded to increases in the irrigated area, and therefore year-to-year fluctuations in its relative price have not affected its attractiveness for irrigated farmers (Norton, p. 55).

African Developing Countries

Egypt, Rice

de Janvry, Siam and Gad (1983) measured the price elasticity of marketed surplus for rice in Egypt. Emperical results from this study are based on two three-year periods: 1975-78 and 1978-81. The results indicate that marketed surplus elasticity is higher with respect to free-market price than to quota price. Moreover, the results show that increasing the quota for forced deliveries actually reduces marketed surplus as long as free sales exist. That is:

> Egyptian food security in rice for the urban and landless populations is not significantly improved by forced deliveries (de Janvry, Siam, and Gad, p. 499).

Another important finding from this study is that the elasticity of marketed surplus with respect to price changes is positive and high on all farm sizes. The output supply elasticities used in this study were obtained from Cuddihy and Von Braun and were taken to be the same for all farms because of homogenous economic behavior and physical constraints across farms. The elasticity of output supply with respect to price of rice in Egypt was assumed to be .32. This is interpreted as a long-run supply elasticity because in the paper it is mentioned that short-run effects assume zero output response.

Sierra Leone, Various Agricultural Products

John Strauss (1984), in an attempt to measure the marketed surplus elasticities in Sierra Leone for various agricultural products, estimated a production and a demand model. The included

commodities were rice, root crops and other cereals, oils and fats, fish and animal products, and miscellaneous foods. The data were from a cross-section survey of 138 households in rural Sierra Leone, for the 1974-75 cropping year (May-April). The sample was divided into three expenditure groups: those with annual per capita expenditures in 1974-75 U.S. dollars of $54, $88, and $136 respectively for the low, middle and high[23] expenditure groups.

It is assumed that the household behaves as if it maximizes its profit subject to its production function and then maximizes utility subject to its full income and time constraints. The demand and production sides can be estimated separately with the assumption that the stochastic disturbances of the two sides are independent. The demand side uses a quadratic-expenditure system with quadratic engel curves; the production side assumes a constant elasticity of transformation function to specify output and a Cobb-Douglas function to specify inputs. Since price data were available and because estimating the production side directly would result in simultaneity bias[24], duality approach was used to estimate the output supply and input demand elasticities.

The calculated own-price output supply elasticities from the constant elasticity of transformation/Cobb-Douglas System, calculated at sample mean values, are reported in Table 46, Appendix II. These elasticities are assumed to be short-run because of the existence of fixed factors of production, such as land. The calculated marketed surplus elasticities are much larger compared to output-supply elasticities. This is possible if production is much larger than surplus. Strauss states that the marketed surplus elasticities for rice is consistent with previous studies.

Limitations of the study:

The results of this study suggest relatively low own-price supply elasticities for agricultural products, especially for cash crops such as oils and fats. However, it is discussed that the estimated own-price supply elasticities are biased towards zero. The failure to correct for land quality is given as one reason for this downward bias. The price effect on output will be biased downward if one considers that higher quality of land is associated with more output and therefore lower prices. Two other factors that may have contributed to the low price supply elasticities for oils and fats are:

1. Palm products produced by the sample households are entirely from wild trees. Therefore, the major response to price changes can only come from varying picking and processing labor.

2. The elasticities are calculated by averaging the exogenous variables over numerous households, only some of which are major oil and fat producers with higher than reported supply elasticities.

Nigeria, Cocoa

Oni and Olayemi (1974) estimated acreage elasticity for cocoa in Western Nigeria. As it is the case for most supply response models applied to perennial crops, a Nerlovian-type model was used. Ordinary Least Squares multiple regression technique was applied to annual data from 1937 through 1958 for six provinces: Indo, Ibadan, Oyo, Abeokuta, Ijebu, and Colony, as well as the state aggregate.

It is assumed that farmers allocate their resources to new cocoa planting such that they maximize the present value of the expected

flow of revenues minus the present value of the expected flow of future costs. The present value of the expected flow of revenues and costs depends on expected prices, input costs, and revenues. It is further assumed that the average future cocoa price expected by the farmer for the bearing crops (after the gestation period is over) is equal to the lagged observed price (P_{t-1}). This assumption about the expected future price, has been referred to as a "Naive Nerlovian Model" in the literature. Also, new planting decisions are not only based on future expected prices and economic outlook, but on the extent that previous desired adjustments were achieved. The real producer price lagged two periods (P_{t-2}) is included to represent this adjustment. Prices of competing crops such as palm oil and palm kernel were also included. The substitute crop price was included only in the aggregate model because of the absence of sub-regional data on this variable.

Another important factor that influences the new planting decision is the area available for cocoa expansion. This variable is calculated as the maximum area that can be put under cultivation minus total existing cocoa acreage. It is expected that, as the existing cocoa acreage becomes larger, the farmers' acreage response declines because of the limited management capacity and suitable land. Also, the age of the existing trees is an important factor in acreage response. As the existing trees get older and their yield decline, it is expected that farmers would undertake more cocoa planting. On the other hand, the proportion of the trees that are bearing affects the farmer's ability to finance new plantings. Additionally, the limited management capacity available for the new crop should also be taken

into account. To represent the age factor in this study, the percentage of cocoa trees that were over 10 years old was included. A time trend was also included to capture the effect of the technological developments.

The model performed fairly well for Western Nigeria and all the provinces except for the Colony Province. The poor results for the Colony Province may be because of the fact that in this province cocoa is not an important crop.

The supply elasticities (presented in Table 47, Appendix II) suggest that the farmers response to prices varies significantly (from 0.46 to 5.74) from one province to another depending on the prevailing sociological conditions and the inherent characteristics of the farmers in each area. These elasticities can be regarded as long-run elasticities because of the inclusion of prices lagged one and two periods. The fact that these elasticities were used for cocoa planting projections for the 1969/70 season, choosing 1947 as the base year, also supports the long-run nature of these elasticities.

Ghana, Cocoa

Bateman (1965) used a Nerlovian type supply function to explain the supply of Ghanaian Cocoa. The model was based on the assumption that the farmer maximizes the present discounted value of the future stream of net returns from his investment in cocoa. The acreage supply equation specifies the number of acres planted in year t (X_t) as a function of the discounted value of the expected real producer price of cocoa ($\tilde{P}_t$), and the discounted value of the expected real

producer price of coffee ($\tilde{C}_t$) which is included as a substitute crop in production, and lagged acreage under cocoa. It is further assumed that the price expectations follow the usual Nerlovian Model, and that the factor that causes a change in the farmer's price expectations from one year to the next is the change in real producer prices (Bateman, p. 387). Based on these assumptions, the acreage response equation was specified as:

$$X_t = a_0 + a_1 P_t + a_2 C_t + a_3 X_{t-1} + V_t$$

However, since the data for area planted to cocoa were not available, the annual amount of cocoa harvested was used as the dependent variable.

$$\Delta Q_t = b_2 a_0 + b_1 a_1 P_{t-k} + (b_2 - b_1) a_1 P_{t-s} + b_1 a_2 C_{t-k} + (b_2 - b_1) a_2 C_{t-s} + C\Delta R_{t-1} + d\Delta H_{t-1} + U_t$$

where:

k = the age at which cocoa trees first begin to bear; it is also assumed that this is the year in which the first significant increase in yield occurs[25]

s = the year in which the second distinct increase in yield occurs

b_1 = output per acre attained after the first increase in yield

b_2 = output per acre after the yield plateau is reached

P_t = the real cocoa price paid to producers in year t

C_t = the real producer price of coffee in year t, measured by the world price of coffee

R_{t-1} = the influence of rainfall during the formative stages (March-June). The lag occurs because the crop year begins in October and extends to the following September

H_{t-1} = the humidity variable which affects yield through black pod and other fungi diseases.

This equation was estimated using OLS Estimation Method applied to data covering 1946-62 period. The cocoa growing area of Ghana was divided into five main regions: Central, Western, Volta, Eastern, and Ashanti. Because of soil and climatic differences the Ashanti region was further divided into three areas: Old Ashanti, Sunyani, and Goaso. The estimation results indicated that in most regions the coefficient of cocoa price was significantly different from zero at 5 percent level. Furthermore, the results illustrated the importance of cocoa and coffee prices, rainfall and to a much lesser extent, humidity for cocoa output in Ghana. Supply responses to cocoa prices in each region are represented in Table 48, Appendix II. The supply elasticities differ significantly from one region to the other. The differences among regional output responses to lagged cocoa and coffee prices is attributed to the differences in soil and age structure of the trees in these regions.

It must be added that, the current cocoa producer price at the time of harvesting was initially included in the estimated equation to capture its effect on farmer's decision on harvesting. The coefficient was not significantly different from zero and therefore it was eliminated from the equation. The insignificant coefficient for the current price variable suggests that harvesting is not influenced

by current producer prices. This is perhaps because the producer price has always covered the costs of harvesting and transportation (Bateman, p. 392).

Kenya, Tanzania, Senegal; Major Crops

Estimates of short-run supply elasticities for major crops in Kenya, Tanzania and Senegal are given in USDA, Report No. 194 (1983). For Kenya and Tanzania the model was divided into supply and demand equations and a government behavior model with government announced producer and consumer prices, net imports and increase in government-held stocks as endogenous variables. The exogenous variables in the government behavior model are self-sufficiency price, world price, P. L. 480 imports, unanticipated demand, and the change in government-held foreign exchange reserves. The supply equation is a Nerlovian partial adjustment model.

For Kenya and Tanzania, the total quantity produced of each crop was specified as a linear function of the current-year government-announced real producer price for quantities of the crop delivered to the government marketing boards, lagged index of real producer price of the export crops (coffee, tea and cotton), a time trend, and the lagged endogenous variable (total quantity produced) of the crop. Producer prices were deflated by fertilizer price. The analysis was based on data from 1964 to 1979 for Kenya, and 1964 to 1978 for Tanzania. The own-price supply elasticities are presented in Appendix II, Tables 49 and 50. From the estimation results, wheat supply appears to be very responsive to government-announced producer prices in Kenya and Tanzania.

For Senegal, an econometric model for the rice sector was developed to investigate the effects of certain government agricultural and food policies on the Senegalese economy. The model was divided into three sections: production, consumption, and imports (USDA, 1983, p. 51). The production section was divided into separate regressions for changes in cultivated rice areas and average rice yields.

Area planted to rice in Senegal was found to be very responsive to real producer price of rice. An increase (decrease) of 1 percent in real producer price of rice resulted in about 3 percent increase (decrease) in rice area (USDA, Report No., 194, p. 51). Therefore, should the Tanzanian government reverse the steady decline in the real producer price of rice, a significant increase in rice area would be expected (USDA, p. 51). Yields were found to be greatly influenced by the price of fertilizer relative to the price of rice and by the amount of rainfall. Furthermore, the findings indicate a positive effect on yields as rice area increases. That is, the expansion in rice area has tended to bring in better quality land (USDA, p. 52). Appendix VI includes the own-price supply elasticities for African countries.

Summary of Own-Price Supply Elasticity Estimates for Developing Countries

Similar to the developed countries, estimates of supply elasticities for the same crop in the same country vary significantly from one study to another. Duality approach gave the largest

short-run elasticity estimates for aggregate farm output and rice in the developing countries. For coarse grains, meat and dairy, however, the revised version of the IIASA Model by Frohberg and Kromer gave the largest short-run elasticity estimates.

In order to compare the aggregate output elasticity with individual crop elasticities, it is more appropriate to compare the relevant elasticities from the same study. Tweeten (1985) estimated aggregate output elasticity as well as elasticities for cotton, sugarcane, rice, and wheat for Pakistan (Table 44, Appendix II and Appendix VI). A lower supply elasticity is expected for aggregate farm output than for individual crops. This is because, as it was discussed earlier, it is generally easier to shift resources from the production of one crop to another than it is from the production of agricultural goods to non-agricultural products. The own-price supply elasticities obtained from the direct estimation of the supply function and the consensus judgments in the study by Tweeten (1985) indicate that the aggregate output elasticity is lower than the supply elasticities for rice, sugarcane, and cotton, but higher than the elasticity estimate for wheat.

The ranking of individual products according to the responsiveness to their own-price also varies from one study to another for the same country. Among individual crops in India, according to the 1978 GOL Model and the study by Tyers, wheat has the largest supply elasticity and coarse grains have the lowest. The results are not the same as other studies. Based on the 1985 GOL Model, cotton has the largest elasticity estimate while rice has the

lowest. Among all the elasticities estimated by the direct supply function, sugarcane has the largest estimate, while rice and wheat have the lowest.

For Pakistan, based on the study by Tyers, coarse grains have the largest own-price supply elasticity and rice has the smallest. But, according to Bale and Lutz, cotton has the largest supply elasticity and maize has the smallest. Tweeten's study indicates that cotton has the largest own-price supply elasticity while wheat has the lowest in Pakistan.

In Taiwan, according to the study by Tyers, coarse grains have a higher supply elasticity than wheat in the long-run. However, the opposite is true for the short-run. Wheat has a larger elasticity than coarse grains.

In Indonesia, according to the 1978 GOL Model, oilseeds have the highest supply elasticity and coarse grains have the lowest. But, based on the 1985 GOL Model, cotton has the largest own-price supply elasticity, while wheat has the smallest. In Egypt, according to the revised version of the IIASA Model (Frohberg and Kromer), protein feed has the lowest own-price supply elasticity and rice has the highest. However, based on the 1985 GOL Model, sugar has the lowest supply elasticity, while wheat has the largest. Bale and Lutz gave the lowest supply elasticity for cotton and the highest for rice. The ranking of individual commodities by the magnitude of their own-price supply elasticities are presented in Table F for several developing countries.

Table F. Ranking of Agricultural Commodities by the Magnitude of Their Own-Price Supply Elasticities From Various Models, for Several Developing Countries, Derived from Appendix VI.

Country/Model	Own-Price Supply Elasticity					
	Largest					Smallest
India						
1978 GOL Model	(.38)[1] Wheat >	(.35) Oilseeds >	(.32) Rice >	(.21) Coarse Grains		
1985 GOL Model	((.25))[2] Cotton >	((.15)) Coarse Grains =	((.15)) Wheat =	((.15)) Oilseeds =	((.15)) Sugar >	((.13)) Rice
Tyers Model	(.41) Wheat >	(.29) Rice >	(.21) Coarse Grains			
Direct Supply Function	(1.21) Sugarcane >	(1.08) Cotton >	(.85) Groundnuts >	(.56) Maize >	(.22) Rice >	(.10) Wheat
Pakistan						
Tyers Model	(.19) Coarse Grains >	(.15) Wheat >	(.07) Rice			
Bale & Lutz Model	(.82 - 2.47) Cotton >	(.17 - .53) Wheat >	(.15 - .45) Rice >	(.10 - .30) Maize		
Tweeten Model	(.88 - 1.03) Cotton >	(.44 - .94) Sugarcane >	(.45 - .66) Rice >	(.27 - .40) Wheat		
Taiwan						
Tyers Model	Long-run:	(.50) Coarse Grains >	(.45) Wheat			
	Short-run:	(.30) Wheat >	(.25) Coarse Grains			
Indonesia						
1978 GOL Model	(.32) Oilseeds >	(.30) Rice >	(.19) Coarse Grains			
1985 GOL Model	((.25)) Cotton >	((.15)) Oilseeds >	((.12)) Rice >	((.09)) Sugar >	((.05)) Wheat	
Egypt						
IIASA-Frohberg & Kromer Model	(2.03) Rice >	(1.25) Wheat >	(.65) Coarse Grains >	(.13) Protein Feed		
1985 GOL Model	((.39)) Wheat >	((.25)) Maize >	((.18)) Cotton >	((.16)) Sugar		
Bale & Lutz Model	(.25 - .75) Rice >	(.12 - .37) Wheat >	(.06 - .18) Maize >	(.05 - .15) Cotton		

[1]The figures in single parentheses represent elasticities with respect to domestic prices

[2]The figures in double parentheses represent elasticities with respect to world prices

It is expected that the supply responsiveness to price fluctuations will increase with the degree of commercialization (Sobhan, p. 12). That is, we would expect that commercial crops such as cotton, sugarcane, coffee and cocoa to have higher own-price supply elasticities than subsistence food crops such as wheat and rice.

From the studies that are summarized in Appendix VI, the weight of the evidence indicates that cash crops have larger own-price supply elasticities than subsistence crops. In Nigeria, the elasticities collected from the studies by Behrman, Oni and Olayemi, and Frohberg and Kromer show much larger elasticities for cocoa than cotton in the long-run and for cotton than oilseeds, coarse grains and wheat in the short-run. For Africa in general, the supply elasticity for coffee estimated by Bacha is much larger than the long-run elasticity estimates for oilseeds, coarse grains, rice, wheat and maize reported in the 1985 GOL Model for Subsaharan Africa. For Thailand, the Bale and Lutz estimates of supply elasticities for rubber and sugarcane are higher than their estimated elasticity for rice. On the other hand, the 1985 GOL Model reports a higher elasticity estimate for maize than rice and sugarcane.

The ranking of commodities in Table F, gives support to the argument that in many of the developing countries, cash crops have larger supply elasticities than subsistence food crops. For India, according to the 1985 GOL Model the elasticity for cotton is larger than wheat and rice. And based on the models that have used the direct estimation of the supply function, sugarcane and cotton show much higher supply response to price than maize, rice and wheat.

Similarly, the supply elasticity estimates by Bale and Lutz, and Tweeten for Pakistan and the reported elasticities in the 1978 and 1985 versions of the GOL Model for Indonesia (Table F) show that cash crops are more price responsive than subsistence crops.

Policy analysts may be interested in knowing which countries have higher supply elasticities relative to other countries. In other words, whether supply is more responsive to price in higher income developing countries with more commercial agriculture, compared to the lower income developing countries. The ranking of the developing countries according to the magnitude of their supply elasticities is given in Table G.

The majority of the studies in Appendix VI (Table G) rank Turkey, Egypt, Taiwan and South Korea as countries with relatively high own-price supply elasticities (relative to other developing countries). While the supply elasticity estimates for Bangladesh, Pakistan, Sri Lanka, Burma and Indonesia place these countries at the lower end of supply elasticities. For some commodities, according to some studies, India has been ranked as a country with relatively high supply elasticities, while for other commodities it has been ranked as a country with relatively low supply response to own-price.

Empirical estimates of supply elasticities with respect to output and input prices indicate that crop output is much more responsive to output prices than to input prices. The estimated own- and input-price output supply elasticities by Sidhu and Baanante (1979 and 1981, Tables 36-B and 37, Appendix II), de Janvry and Kumar, (Table 39), and Kalirajan and Flinn (Table 40) for India, by Tweeten (Table

Table G. Ranking of Countries and Regions by the Magnitude of Their Own-Price Supply Elasticities, By Commodity, Developing Countries, Derived from Appendix VI.

Commodity/Model	Own-Price Supply Elasticity					
	Largest					Smallest
Coarse Grains						
1978 COL Model	(.21)[1] India >	(.20) Thailand >	(.19) Indonesia >	(.12 - .14) North Africa & the Middle East		
Tyers Model	(.65) South Korea =	(.65) Malaysia >	(.50) Taiwan >	(.40) Philippines >	(.35) Burma >	(.22) Thailand =
	(.22) Indonesia >	(.21) India >	(.20) Sri Lanka >	(.19) Pakistan >	(.04) Bangladesh	
IIASA-Frohberg & Kromer Model	(.83) Turkey >	(.65) Egypt >	(.17) Pakistan >	(.03) Nigeria		
Wheat						
1978 COL Model	(.38) India >	(.15 - .25) North Africa & the Middle East				
1985 COL Model	((.25))[2] Egypt >	((.15)) India >	((.05)) Indonesia =	((.05)) North Africa & the Middle East		
Tyers Model	(.45) Taiwan =	(.45) South Korea >	(.41) India >	(.31) Burma >	(.15) Pakistan	
IIASA - Seeley	(.76) Egypt >	(.58) Turkey >	(.51) Pakistan >	((.09)) India		
IIASA-Frohberg & Kromer Model	(1.25) Egypt >	(.82) Turkey >	(.21) Pakistan			
Corn						
1985 COL Model	((.33)) Thailand >	((.25)) Egypt				
Hale & Lutz Model	(.10 - .30) Thailand =	(.10 - .30) Pakistan >	(.06 - .18) Egypt			
Direct Estimation of Supply Function	(.41 - 14.17) Thailand >	(.42 - 1.14) Philippines >	(.56) India =	(.56) Sudan >	(.09) Egypt	
Rice						
1978 COL Model	(.32) India >	(.30) Indonesia >	(.15) Thailand			
1985 COL Model	((.24)) Thailand >	((.13)) India >	((.12)) Indonesia			
Tyers Model	(.74) Bangladesh >	(.38) Malaysia >	(.32) Sri Lanka >	(.30) Indonesia >	(.29) India >	(.26) Philippines >
	(.20) Burma >	(.14) Taiwan =	(.14) South Korea >	(.08) Thailand >	(.07) Pakistan	
IIASA-Frohberg & Kromer Model	(2.03) Egypt >	(.93) Pakistan >	(.57) Turkey			
Ito, et. al. Model	(1.62) Thailand >	(.47) Philippines >	(.39) Pakistan >	(.34) Indonesia >	(.22) India >	(.17) Taiwan >
	(.07) Bangladesh >	(.04) Burma				
Oilseeds						
1978 COL Model	(.35) India >	(.32) Indonesia				
1985 COL Model	((.15)) India =	((.15)) Indonesia				
IIASA-Frohberg & Kromer Model	(.13) Egypt >	(.04) Nigeria				
Sugar						
1985 COL Model	((.16)) Egypt >	((.15)) India >	((.14)) Thailand >	((.09)) Indonesia		
Direct Estimation of Supply Function	(.70 - 2.21) India >	(.44 - .94) Pakistan >	(.13 - .16) Philippines			
Cotton						
1985 COL Model	((.25)) India =	((.25)) Indonesia =	((.25)) Thailand			
Direct Estimation of Supply Function	(1.08 - 1.62) India >	(.50) Sudan >	(.28) Nigeria >	(-.08) Egypt		

[1]The figures in single parentheses represent elasticities with respect to domestic prices

[2]The figures in double parentheses represent elasticities with respect to world prices

44) for Pakistan and by Yotopoulos, Lau and Lin (Table 45) for Taiwan support this argument. Thus, in these developing countries, policies directed toward increasing output prices are expected to be more successful in increasing output than those that decrease input prices.

Although the weight of the evidence indicates the significant effect of prices on output supply, the role of non-price variables should not be ignored. Non-price variables such as credit availability, irrigation, fertilizer, education and technological improvements increase the level of output supply for a given price by shifting the supply curve to the right.

Chhibber's estimates of output supply elasticities with respect to non-price shifters in India are almost twice as large as the elasticities with respect to price when total irrigated area is used as a non-price supply shifter (Table 36-A, Appendix II). However, when area irrigated by government canals is used as a supply shifter, the non-price output elasticity is less than the own-price supply elasticity.

The studies by Sidhu and Baanante (1979 and 1981, Tables 36-B and 37, Appendix II) show the significant impact of non-price variables such as education and land quantity on output supply. Bogahawatte's estimates (Table 42, Appendix II) suggest that irrigation, modern varieties, and agricultural credit are major contributory factors to rice production in Sri Lanka, while supply response to an increase in the government's guaranteed price is low.

Finally, the supply elasticity estimates by Sidhu and Baanante (1979) and de Janvry and Kumar for small and large farms in India

suggest that there exists constant returns to scale in wheat production and that there is identical pattern of production response to price movements in small and large farms (de Janvry and Kumar, p. 7).

A Comparison of Supply Responses

Between Developed and

Developing Countries

Willis Pete -on (1979) estimated long-run supply elasticities for fifty-thre. developed as well as developing countries. Cross-sectional data for two, three-year periods (1962-64 and 1968-70) were used for the estimations. A log-linear supply function of the following specification was fitted for this purpose:

$$Q = AP^{x} W^{B} T^{\delta} e^{u}$$

where:

Q is total agricultural output in quantities of wheat units per hectare of agricultural land

A is the constant term

P is "real" domestic prices received for all farm products in each country during each three-year period in terms of kilograms of commercial fertilizer that could be purchased with 100 kilograms of wheat equivalents

W is a weather variable approximated by the long-run average annual precipitation of each country in the sample

T is a technology variable approximated by the number of agricultural research publications for each country in the sample.

The above equation was estimated using both Ordinary Least Squares (OLS) and Instrumental Variable (Durbin) techniques. The latter method of estimation was used in order to guard against the

possibility of bias in the coefficients because of measurement errors as well as simultaneous equation bias (Peterson, p. 16). Since the results indicated that the set of coefficients was not significantly different between the two time periods, all the observations were pooled into a single regression. The supply equation was also estimated without the research variable (T). The results are presented in Table 51, Appendix II.

Own-price supply elasticities estimated by Peterson (Table 51) suggest a highly elastic supply function for the world. These estimates are substantially larger than the U.S. aggregate output supply elasticity estimated by Griliches (1960) but in the same range as those estimated by Tweeten and Quance and Griliches (1959). It is observed that the inclusion of the research variable reduces the supply elasticity estimates. This is perhaps because of the positive correlation between price and the research variable.

Another important finding of this study is that real prices of agricultural commodities received by farmers in the LDCs have been lower than those in the developed nations. Governments of the LDCs have kept the real prices of agricultural products artificially low for various reasons:

a) to collect government revenue by imposing export taxes

b) to control inflation

c) to protect local industries, to conserve on foreign exchange, and to collect additional taxes by imposing tariffs, quotas, and embargoes on inputs used in agriculture and consumer goods purchased by farm people.

All the above listed factors have contributed to a decrease in real farm prices in LDCs. In addition, foreign food assistance programs such as P. L. 480 to these countries have contributed to lowering farm prices in developing countries.

Finally, the data used in this study were partitioned between DCs and LDCs to test the hypothesis that the peasant farmers in the LDCs are less responsive to price than their commercial counterparts in the developed countries. The F tests showed no significant difference in the supply elasticities between the two groups of countries.

> In fact, the observed difference in the supply elasticity ran in the direction of a larger elasticity for the LDCs, although the difference was not statistically significant at the conventional levels. At least it seems fairly safe to say that the estimated supply elasticity definitely is not smaller in the LDCs than in the DCs, and may even be larger (Peterson, p. 18).

Limitations to the estimates:

It is argued that the supply elasticities obtained from cross-sectional data overestimate the true supply elasticities because of the difficulties of incorporating structural differences among countries which are at different stages of development. It is expected that the omission of non-price constraints would lead to an overestimation of the true supply elasticity with respect to own-price. From Table 51, Appendix II, it is observed that the own-price supply elasticity in Peterson's study decreases from 1.66 to 1.27 with the inclusion of research expenditure as a shift variable. The magnitude of elasticity is further reduced to .97 with the introduction of an irrigation variable.

In order to derive unbiased estimates of the aggregate supply

responsiveness of farmers, all other constraints such as the availability of credit and fertilizer must also be included in the supply equation (Chhibber, p. 6).

> Otherwise it is dangerous to derive strong policy conclusions on the need for higher farm prices to stimulate agricultural growth from estimates which do not take account of fundamental structural differences between countries (Chhibber, pp. 6-7).

Are the Developed Countries Producers More Price Responsive Than the Developing Countries Farmers?

Although Peterson's study showed that there is no significant difference between supply elasticities of developed and developing countries, many of the studies that are reviewed in this manuscript do not give the same results. The ranking of countries (developed and developing) according to the magnitude of their supply elasticities is given in Table H.

The majority of the studies (Table H) rank developed countries as having higher own-price supply elasticities than developing countries. For aggregate farm output according to the models that have used the duality approach and for coarse grains, wheat, corn, and sugar, according to the 1978 GOL Model and the studies by Tyers, Frohberg and Kromer, and Bale and Lutz, the estimates of own-price supply elasticities are larger for the developed countries than the majority of the developing countries. However, for rice, oilseeds and cotton, it is not apparent that the farmers in the developed countries are more responsive to price changes than the peasant farmers in the developing countries (Table H).

Table H. Ranking of Countries by the Magnitude of Their Own-Price Supply Elasticities, by Commodities, Developed and Developing Countries, Derived from Appendices III - VI.

Commodity/Model	Own-Price Supply Elasticity					
	Largest					Smallest
Aggregate Farm Output						
Duality Approach	(1.35)[1] U.S. >	(1.25) Taiwan >	(1.17) India			
Course Grains						
1978 GOL Model	((2.40))[2] U.S. >	(.35 - .91) EEC >	(.81) Australia & New Zealand >	(.70) Canada >	(.49) Other Western Europe >	(.25) Japan >
	(.21) India >	(.20) Thailand >	(.19) Indonesia >	(.12 - .14) North Africa and the Middle East		
1985 GOL Model	((.30)) Japan >	((.25)) Canada =	((.25)) North Africa and the Middle East >	((.18 - .25)) Western Europe >	((.21)) East Asia >	((.16)) Australia & New Zealan
	((.15)) India >	((.09)) U.S.				
Tyers Model	(.91) Western Europe >	(.75) U.S. >	(.68) Canada >	(.65) South Korea =	(.65) Malaysia >	(.60) Australia .
	(.50) Taiwan >	(.40) Philippines >	(.35) Burma >	(.22) Thailand =	(.22) Indonesia >	(.21) India
	(.20) Sri Lanka >	(.19) Pakistan >	(.04) Bangladesh			
IIASA-Frohberg & Kromar Model	(.93) Western Europe >	(.84) Australia . >	(.83) Turkey >	(.78) Canada >	(.65) Egypt >	(.38) Japan >
	(.17) Pakistan >	(.03) Nigeria				
Wheat						
1978 GOL Model	((2.55)) U.S. >	(.85 - .95) Western Europe >	(.65) Canada >	(.55) Australia & New Zealand >	(.38) India >	(.30) Japan >
	(.15 - .25) North Africa & the Middle East					
1985 GOL Model	((.39)) Egypt >	((.25)) U.S. =	((.25)) Western Europe >	((.15)) India >	((.08)) Japan =	((.08)) Australia & New Zealan
	((.06)) Canada >	(.05) Indonesia =	((.05)) North Africa & the Middle East			
Tyers Model	(.[illegible]) Western Europe =	(.90) Australia >	(.80) U.S. >	(.60) Japan >	(.53) Canada >	(.45) Taiwan =
	(.45) South Korea >	(.41) India >	(.31) Burma >	(.15) Pakistan		
IIASA-Seeley Model	(2.39) Western Europe >	(.76) Egypt >	(.58) Turkey >	(.51) Pakistan =	(.51) Australia >	(.38) Canada >
	((.09)) India					
IIASA-Frohberg & Kromer Model	(1.25) Egypt >	(1.09) Western Europe >	(.82) Turkey >	(.80) Canada >	(.64) Australia >	(.44) Japan >
	(.21) Pakistan >	(-.79) Nigeria				
Bale & Lutz Model	(.80 - 2.41) Japan >	(.47 - 1.42) Western Europe >	(.17 - .53) Pakistan >	(.12 - .37) Egypt		
Corn						
1985 GOL Model	((.33)) Thailand >	((.29)) Japan >	((.25)) EC - 10 =	((.25)) South Africa =	((.25)) Egypt >	((.23)) Other Western Europe
Bale & Lutz Model	(.45 - 1.35) United Kingdom >	(.17 - .53) West Germany =	(.17 - .52) France >	(.10 - .30) Thailand =	(.10 - .30) Pakistan >	(.06 - .18) Egypt
Rice						
1978 GOL Model	((.90)) U.S. >	(.30 - .40) Western Europe >	(.32) India >	(.30) Indonesia >	(.16) Japan =	(.16) Australia & New Zealan
	(.15) Thailand					
1985 GOL Model	((.23)) Western Europe >	((.24)) Thailand >	((.16)) U.S. >	((.15)) Japan >	((.13)) India >	((.12)) Indonesia >
	((.10)) Australia & New Zealand					
Tyers Model	(.75) U.S. >	(.74) Bangladesh >	(.50) Japan >	(.40) Western Europe >	(.38) Malaysia >	(.32) Sri Lanka >
	(.30) Australia =	(.30) Indonesia >	(.29) India >	(.26) Philippines >	(.20) Burma >	(.14) Taiwan =
	(.14) South Korea >	(.08) Thailand >	(.07) Pakistan			

Table H Continued

Table H. Ranking of Countries by the Magnitude of Their Own-Price Supply Elasticities, by Commodities, Developed and Developing Countries, Derived from Appendices III - VI[1]. Continued.

Commodity/Model	Own-Price Supply Elasticity					
	Largest					Smallest
IIASA-Frohberg & Kromer Model	(2.03) Egypt >	(1.49) Western Europe >	(.94) Australia & New Zealand >	(.93) Pakistan >	(.57) Turkey >	(.31) Japan
Ito, et. al. Model	(1.62) Thailand >	(.50) Japan >	(.47) Philippines >	(.39) Pakistan >	(.34) Indonesia >	(.31) U.S. >
	(.22) India >	(.17) Taiwan >	(.07) Bangladesh >	(.04) Burma		
Oilseeds						
1978 GOL Model	((3.27)) U.S. >	(1.20) Canada >	(.45) Australia & New Zealand >	(.43) Japan >	(.35) India >	(.32) Indonesia >
	(.20) Other Western Europe >	(.10) South Africa >	(.02) EC - 3			
1985 GOL Model	((.25 - .25)) EC - 10 >	((.10 - .25)) U.S. >	((.14 - .23)) Other Western Europe >	((.09 - .25)) Canada >	((.06 - .25)) Japan >	((.15)) India =
	((.15)) Indonesia					
IIASA-Frohberg & Kromer Model	(.40) Canada >	(.35) Japan >	(.13) Egypt >	(.04) EC =	(.04) Nigeria >	(.00) Australia
Sugar						
1985 GOL Model	((.25)) Japan >	((.16)) Egypt >	((.15)) India >	((.14)) Thailand >	((.13)) EC - 10 >	((.09)) Indonesia =
	((.09)) Other Western Europe =	((.09)) Australia & New Zealand >	((.07)) Canada			
Bale & Lutz Model	(.81 - 2.44) France >	(.43 - 1.30) West Germany >	(.22 - .66) United Kingdom >	(.21 - .64) Japan >	(.08 - .24) Thailand	
Cotton						
1985 GOL Model	((.27)) Japan >	((.25)) U.S. =	((.25)) Other Western Europe =	((.25)) Indonesia =	((.25)) Thailand =	((.25)) North Africa & the Middle East >
	((.12)) EC - 10 >	((.05)) Canada				

[1]The figures in single parentheses represent elasticities with respect to domestic prices

[2]The figures in double parentheses represent elasticities with respect to world prices

IV. SUMMARY AND CONCLUSIONS

The study of agricultural supply responses has been of great interest to the policy makers of developed and developing countries. The effect of price support policies can not be determined without an understanding of price elasticities of supply.

This manuscript summarizes the agricultural price supply responses in developed and developing countries. The various methods that have been used in estimating supply elasticities are explained and a literature review of the studies that have estimated price elasticities of supply is presented. The studies cover the United States, Canada, other developed countries, and the developing countries. The elasticity estimates from the reviewed studies are summarized in Appendices III - VI.

While it is recognized that some studies are better than others due to different theoretical and methodological approaches, the existing literature has provided a wide range of estimates for supply elasticities. A comparison of the supply elasticities for the same crop in a given country, estimated by various studies, illustrates the diversity of the estimates. Due to the valid differences in econometrics or in methodology and theory, it is difficult, if not impossible to rank all of the supply elasticities reviewed in this manuscript by the quality of estimates. Therefore, the "weight of the evidence" is used as an evaluation criteria.

Some of the reasons for the diversity of estimates are explained in the following paragraphs. For example, Nerlovian type supply

models are likely to underestimate the own-price short-run and long-run supply elasticities. Errors in the independent variables, misspecification errors (e.g. exclusion of the technology variable from the supply equation), and failure to include all relevant past prices in the price expectation variable are given as some of the reasons for this downward bias.

The supply elasticity estimates may also differ from one study to another depending on the type of data (time series or cross-sectional) utilized. It is argued that estimates based on cross-sectional data overestimate the true supply elasticities if there are differences in technological and economical development stages across regions. However, the studies that utilize time-series data may underestimate the true supply elasticities. Time series data are subject to transient fluctuations to which farmers may not respond so much as they would to permanent price changes (Chhibber).

Moreover, what is included as price data may not be the same across studies. Some estimates are based on nominal prices while others are based on real prices. Even what is considered to be "real prices" may not be a homogenous variable across studies. Some studies may use the price of one input, such as fertilizer, as a deflator, while the others may use an aggregate input price index to deflate nominal prices. The supply elasticity estimates, therefore, may differ significantly from one study to another depending on the data that have been used to represent the price variable. Also, it is important to differentiate between elasticities with respect to domestic prices and elasticities with respect to world prices.

A summary of issues of interest to policy analysts explained in this manuscript is presented below.

Aggregate Output Supply Elasticity Compared to Individual Crop Elasticities

It is expected that individual crops have a higher own-price supply response than aggregate farm output. This is because it is generally easier to shift resources from the production of one crop to another than it is to shift resources from the production of agricultural goods to non-agricultural goods. A comparison of the supply elasticities for aggregate farm output and for individual crops in the same country gives support to this hypothesis.

A Comparison of the Elasticities of Cash Crops and Subsistence Crops

This study also ranks individual commodities according to the magnitude of their supply elasticities (Tables A, B,C, D and F in the text). It is expected that the supply responsiveness to price fluctuations will increase with the degree of commercialization. By reviewing the elasticity estimates for developing countries (Appendix VI), the weight of the evidence indicates that cash crops such as cotton, sugarcane, coffee and cocoa have larger own-price supply elasticities than subsistence food crops such as wheat and rice.

A Comparison of Supply Responses Between Developed and Developing Countries

In this study, a ranking of developed and developing countries is given by the magnitude of their own-price supply elasticities for given crops. The results are summarized in Tables E and G for developed and developing countries respectively. Among developing nations, the majority of the studies rank Turkey, Egypt, Taiwan and South Korea as countries with relatively high own-price supply elasticities, while Bangladesh, Pakistan, Sri Lanka, Burma and Indonesia are ranked as countries with relatively low supply elasticities. The elasticities of supply are also compared among developed and developing countries for specific commodities (Table H). The majority of the studies, for the majority of commodities, rank developed countries as having larger own-price supply elasticities than developing countries. This conclusion is consistent with the general belief that the commercial producers in developed nations are more price responsive than peasant farmers in developing countries.

The Effect of Output Price Support Programs Versus Input Subsidies on Production

Empirical estimates of supply elasticities in India, Pakistan and Taiwan indicate that crop output is much more responsive to output prices than to input prices. Therefore, policies directed toward increasing output prices are expected to be more successful in

increasing output than those that decrease input prices. However, the same conclusion can not be derived for crops in Canada. Based on a study by Lopez (1984), crop output is more responsive to input prices than to its own price, while animal products have a higher response to output price than to input prices.

The Importance of Non-Price Variables in Output Expansion

Non-price variables such as credit availability, irrigation, fertilizer usage, education, and technological improvements play an important role in increasing output. For a given level of output and input prices, an increase in non-price variables increases output by shifting the supply curve to the right. Many of the studies reviewed in this manuscript give support to the importance of non-price variables and the fact that they should be used along with price variables to increase output.

Supply Responses to Price Fluctuations In Small Versus Large Farms

It is generally expected that supply elasticity estimates for larger commercial farms are higher than the estimates for relatively small farms. However, the supply elasticity estimates for India do not support this. The supply response estimates by Sidhu and Baanante (1979), and de Janvry and Kumar for small and large farms in India

suggest constant returns to scale in wheat production.

Conclusions

The estimates of supply elasticities could be used to determine the effect of government farm policies on quantity produced. Along with demand elasticities, they can be used to determine the appropriate policies for different objectives. For example, if the goal is self sufficiency, supply and demand elasticities could determine the price level that will move the economy toward agricultural self-sufficiency.

Classical welfare analysis is another important role for supply and demand elasticities. The net gain or losses to society from a trade (import or export) tax or subsidy is a function of supply and demand elasticities. For example, in a small country case, an import tax will increase producers surplus and government revenue, while it decreases consumers surplus through increasing domestic prices. The magnitude of the gain in producers surplus and government revenue relative to the size of the loss in consumer surplus depends on demand and supply elasticities.

Footnotes

[1]The elasticity of expectation is the ratio of the proportional rise in expected future price of x to the proportional rise in its current price.

[2]In some studies a short-run supply elasticity is defined as the supply response evolving over two years.

[3]This method is called the weighted average of input demand elasticities with respect to the output price because input demand elasticities are weighted by the respective distributive share of each input (the share of each input in total costs or revenues). It can be shown that the elasticity of output with respect to each input (E_{Qi}) is equal to the distributive share of that input (Griliches, 1959, p. 319):

$$E_{Qi} = \frac{\partial Q}{\partial X_i} \cdot \frac{X_i}{Q} \qquad (21a)$$

where:

Q = total output

X_i = the quantity demanded of input i.

$\frac{\partial Q}{\partial X_i}$ = the marginal productivity of input i.

Assuming perfect markets, the value of marginal product of input i will equal its price. That is:

$$P_Q \cdot \frac{Q}{X_i} = P_i \qquad (21b)$$

where:

P_Q = the price of output

$P_Q \cdot \frac{\partial Q}{\partial X_i}$ = the value of marginal product of input;

P_i = the price of input i.

Dividing both sides of equation (21b) by P_o, we will have:

$$\frac{\partial Q}{\partial X_i} = \frac{P_i}{P_Q} \qquad (21c)$$

Substituting for $\frac{\partial Q}{\partial X_i}$ from (21c) into (21a) we will have:

$$E_{Qi} = \frac{P_i \cdot X_i}{P_Q \cdot Q} \qquad (21d)$$

where:

$P_i \cdot X_i$ = the total cost of purchasing input i

$P_Q \cdot Q$ = total value of output.

[4]This method requires comprehensive data on production inputs used to produce the commodity in question (Tweeten, July, 1985).

[5]The following discussion on dual analysis (the profit function approach and the cost function approaches) is paraphrased from Beattie and Taylor, Chapter 6.

[6]Note that equations (26) and (27) imply that the inputs are used up to the point that the Marginal Value Product (MVP) of the last unit of the input equals its price. This is the basic principle behind the derivation of a conventional input demand curve. Also by taking partial derivative of equation (24) with respect to the quantity of output one can derive the output supply curve which is the marginal cost curve above the minimum of average cost. Therefore, output supply and input demand price elasticities derived from indirect profit function (duality method) should result in the same estimates as those derived from the direct functions (direct estimates of the output supply and input demand functions). The advantages of duality method over the conventional derivation of output supply and input demand functions will be discussed later in this section.

[7]Mutatis Mutandis elasticities allow for the necessary changes in the quantities of variable inputs to be made, while Ceteris Paribus elasticities assume quantities of all other factors of production to be constant.

[8]For explanation of envelope theorem refer to Beattie and Taylor, pp. 227-236.

[9]The studies by Weaver and Shumway will be explained later in this section.

[10]The double logarithmic functional form was used so that the estimated acreage price elasticities would be constant across states (Whittaker and Bancroft, p. 551).

[11]It was not specified in this study whether the elasticity estimates are short- or long-run. However, since, the model did not include the lagged dependent variable as an explanatory variable, it is concluded that these estimates are short-run.

[12]Although it is not explicitly specified whether these elasticities are short- or long-run, it is assumed these are short-run elasticities for the following reasons:

1. Fixed factors of production (land and pre-season precipitation) are included in the model.
2. The implications which are derived from the results apply to the short-run, as mentioned in the text.

[13]The translog function is used for tests that cannot be performed with the normalized quadratic function.

[14]The supply elasticities reported in Askari and Cummings (1976) for the U. S. is summarized in Table 14.

[15]In this model, short-run price transmission elasticities are econometrically based, while the long-run transmission elasticities are set at unity (Tyers, p. 6).

[16]To estimate the price-constant production growth rates (trends in production due to non-price factors such as technological changes), geometric time trends were fitted to production and price data. These estimates were then combined with a prior estimates of long-run supply elasticities to estimate price-constant components of production growth (Tyers, p. 55).

[17]Since almost all of the studies that have utilized the duality approach include fixed factors of production, no long-run elasticities were available from this approach for comparison.

[18]Seeley used the May 1984 version of the IIASA Model, while Frohberg and Kromer used the March 1985 version. Within the ten months from May 1984 to March 1985, while the structural form of the model remained the same, revisions were made on the coefficients.

[19]For wheat the study by Schmitz reported in Askari and Cummings, gives a larger elasticity than Rojko, et. al.

[20]The exception is for coarse grains in Japan.

[21]Mutatis mutandis as opposed to ceteris paribus.

[22]Maha season refers to the paddy crop which is sown in the months of July to November and harvested in February to March of the following year. Yala season refers to the crop which is sown in the months April to June and harvested in August to September.

[23]The high expenditure group in rural Sierra Leone is quite poor compared to those living in urban Sierra Leone and other countries.

[24]This bias, as was explained before, is as a result of endogenous output (and inputs) appearing as right-hand side variables.

[25]The yield pattern of cocoa indicates two major yield increases. For the first k years of tree's life, output is zero but then output per tree increases significantly in the kth year. After this initial increase, yield per tree stays constant for three or four years and then each tree experiences another rapid yield increase. This high yields continues for about 40 years after planting (Bateman, p. 388). In most of the studied cocoa growing regions in Ghana, the lag between planting and initial bearing was eight years with the second increase in the 12th year.

APPENDIX I.
INDIRECT COST AND PROFIT FUNCTIONS ASSOCIATED WITH VARIOUS PRODUCTION FUNCTIONS

Appendix I. Indirect Cost and Profit Functions Associated with Various Production Functions.

Production Function		*Indirect Cost Function*
Generalized Cobb–Douglas[a]	$y = Ax_1^{b_1}x_2^{b_2}$	$\hat{c} = [yA^{-1}r_1^{b_1}r_2^{b_2}]^{1/a}\left[\left(\frac{b_1}{b_2}\right)^{b_2/a} + \left(\frac{b_2}{b_1}\right)^{b_1/a}\right]$
Quadratic[b,c]	$y = a_0 + a_1x_1 + a_2x_2 + \frac{1}{2}b_1x_1^2 + \frac{1}{2}b_2x_2^2 + b_3x_1x_2$	$\hat{c} = 2(y - \gamma_0)^{1/2}(\beta_1r_1^2 + \beta_2r_2^2 + \beta_3r_1r_2)^{1/2}$ for $y > \gamma_0$
CES	$y = A[bx_1^{-\varrho} + (1 - b)x_2^{-\varrho}]^{-\nu/\varrho}$	$\hat{c} = y^{1/\nu}A^{-1/\nu}[b^{1/(1+\varrho)}r_1^{\varrho/(1+\varrho)} + (1 - b)^{1/(1+\varrho)}r_2^{\varrho/(1+\varrho)}]^{(1+\varrho)/\varrho}$
Transcendental	$y = Ax_1^{b_1}e^{b_1x_1}x_2^{b_2}e^{b_2x_2}$	Mathematically intractable

Production Function	*Indirect Profit Function*
Generalized Cobb–Douglas[a]	$\hat{\pi} = (1 - a)[pAr_1^{-b_1}r_2^{-b_2}b_1^{b_1}b_2^{b_2}]^{1/(1-a)}$
Quadratic[b]	$\hat{\pi} = p\gamma_0 - \eta_1r_1 - \eta_2r_2 - \frac{\beta_1r_1^2}{2p} - \frac{\beta_2r_2^2}{2p} - \frac{\beta_3r_1r_2}{p}$
CES	$\hat{\pi} = p^{1/(1-\nu)}\nu^{\nu/(1-\nu)}(1 - \nu)A^{1/(1-\nu)}[b^{1/(1+\varrho)}r_1^{\varrho/(1+\varrho)} + (1 - b)^{1/(1+\varrho)}r_2^{\varrho/(1+\varrho)}]^{-\nu(1+\varrho)/\varrho(1-\nu)}$
Transcendental	Mathematically intractable

[a] $a = b_1 + b_2$.

[b] Let $A = b_1b_2 - b_3^2$. Then $\beta_1 = b_2/A$; $\beta_2 = b_1/A$; $\beta_3 = -b_3/A$; $\gamma_0 = a_0 - (b_1a_2^2 + b_2a_1^2 - 2a_1a_2b_3)/A$; $\eta_1 = -a_1\beta_1 - a_2\beta_3$; and $\eta_2 = -a_1\beta_3 - a_2\beta_2$

[c] The indirect cost equation was obtained by integrating the inverse of the product supply equation from γ_0 to y. Note that conditional factor demand equations, which are practically impossible to obtain as relatively simple expressions using the direct (primal) approach, can be obtained by this circuitous route.

Source: Beattie and Taylor, p. 248.

APPENDIX II.
INDIVIDUAL COUNTRY
SUPPLY ELASTICITY TABLES

Table 1. Implied Own-Price Supply Elasticities, Aggregate Farm Output, U.S., 1911-1957, Estimated From a Weighted Average of Input Demand Elasticities, Griliches (1959)

	(1)	(2)
Short-run	.28	.30
Long-run	1.20	1.32

Table 2. Own-Price Supply Elasticities, Farm Output, U.S., 1920-57 (Aggregate Farm Output) and 1911-1958 (Sub-aggregates), Estimated From a Direct Supply Function, Griliches (1960).

	Aggregate Farm Output	All Crops	Livestock and Livestock Products
Short-run	0.10	0.16	0.2 to 0.3
Long-run	0.15	0.23	0.70

Table 3. Own-Price Supply Elasticities, Aggregate Farm Output, U. S., 1921-66, Estimated From a Direct Supply Function, Tweeten and Quance (1969).

	1921-66 (Entire Period, Excluding 1942-47)	1921-41 (PreWar)	1948-66 (PostWar)
Short-run	0.155	.08	0.16
Long-run	0.19	0.31	0.31

Table 4. Own-Price Supply Elasticities, Farm Output, U.S., 1921-1966, Estimated From Crop and Livestock Components, Tweeten and Quance (1969).

	Aggregate Supply Elasticity	Crops[1]	Livestock
Short-run	0.25	.17	.38
Long-run	1.79	1.56	2.90

[1]The computed acreage and yield elasticities for the short-run are .04 and .15 respectively, while the long-run acreage and yield elasticities are .10 and 1.50, respectively.

Table 5. Own-Price Supply Elasticities, Aggregate Farm Output, U.S., 1921-1966, Estimated From a Weighted Average of Input Demand Elasticities, Tweeten and Quance (1969).

Short-Run	0.26
Long-run	1.52

Table 6. Own-Price Supply Elasticities, Aggregate Farm Output, U.S., 1910-1978, Estimated From a Translog Profit Function, Antle (1984).

Period	Elasticity
1910-46	1.349
1947-78	0.427

Table 7. Own-Price Planted Acreages Elasticities, Corn, Kentucky, 1960-1979, Estimated From a Direct Supply Function Applied to Sub-State Data, Reed and Riggins (1981).

Short-run	.34 to .56
Long-run[a]	.93 to 2.07

[a]Long-run elasticities are calculated by dividing each elasticity by the adjustment coefficient. This coefficient is derived from the coefficient of lagged acreage variable.

Table 8. Own-Price Supply Elasticities, Rice, U.S., 1962-81, Estimated From Yield and Acreage Elasticities, Ito, Wailes, and Grant (1985).

	Yield (Eyd/p)	Acreage Effect on Yield (Eyd/a)	Area Harvest (Ea/p)	Production (Eq/p)
Short-run	0	-.156	.125	.110
Long-run	0	-.156	.369	.311

Table 9. Own-Price Supply Elasticities, Wheat Acreage, U.S., 1948-74, Estimated From a Direct Supply Function, Morzuch, et.al. (1980).

Commodity	Model A[a]	Model B[a]
Spring Wheat	0.77	0.90
Winter Wheat	0.45	0.32
All Wheat Combines	0.52	0.46

[a]Models A and B are explained in the text, p. 40.

Table 10. Own-Price Per Capita Supply Elasticities, Wheat, Corn, Soybeans, U. S., 1969-1977, Estimated From a Direct Supply Function, Chambers and Just (1981).

Commodity	Elasticity with Respect to Deflated Lagged Average Price	Elasticity with Respect to Support Price
Wheat	.498	.487
Corn	.555	.443
Soybeans	.641	.358

Table 11. Own-Price Supply Elasticities, Agricultural Products, U. S., (North and South Dakota), 1950-70, Estimated From a Translog Profit Function, Weaver (1983).

Commodities	North Dakota	South Dakota
Food Grains	.400	.789
Feed Grains	.735	.638
Livestock	.555	1.011

Table 12. Implied Own-Price Supply Elasticities, Texas Field Crops, U. S., 1957-79, Estimated From a Normalized Quadratic Profit Function, Shumway (1983).

Cotton	.25
Sorghum	.62
Wheat	.43
Corn	.07
Rice	.72
Hay	.10

Table 13. Own-Price Output Supply and Input Demand Elasticities (Estimated at 1978 Prices), Various Agricultural Outputs and Inputs, U. S., 1946-1979, Estimated From A Normalized Quadratic Profit Function, Saez and Shumway (1985).

Output/ Input	REGION											
	North East	Lake States	Corn Belt	Northern Plains	Appa-lachia	South East	Delta States	Texas Oklahoma	Mountain	Pacific	U. S.[1]	U.S.[2]
LIVSTK	-0.456	-0.329	0.006	0.432	0.122	0.101	0.154	-0.199	0.419	-0.253	-0.020	-0.040
FEEDGR	0.135	0.022	0.011	0.098	0.242	0.265	-4.351	-0.030	-0.137	0.219	0.032	0.016
FOODGR	0.282	0.004	0.628	-0.098	b/	a/	0.014	0.057	0.008	0.223	0.048	0.008
COTTON	c/	c/	1.494	c/	-0.018	-0.185	0.456	0.377	0.596	0.405	0.404	0.302
OILCROP	a/	0.220	0.053	0.545	-0.033	0.011	-0.365	0.019	a/	a/	0.016	-0.006
HAYFOR	2.343	1.438	3.052	-3.248	-0.097	0.224	-0.580	0.338	0.222	0.741	0.587	0.388
TOBACCO	-0.531	a/	a/	c/	-0.302	1.351	c/	c/	c/	c/	-0.042	-0.107
VEGFRT	-0.271	-0.167	0.190	0.264	0.196	-0.356	-0.732	0.134	-0.112	-0.160	-0.184	-0.201
AGRCHEM	0.240	-0.027	-0.373	0.011	-0.056	-0.057	-0.237	-0.353	-0.329	-0.477	-0.427	—
FSL	-1.066	0.068	0.250	-0.415	-0.521	-0.195	-0.101	0.151	-0.288	-0.268	-0.182	—
MPMCH	-0.132	0.140	-0.134	0.055	0.163	0.578	-0.001	0.535	-0.023	0.398	0.111	—
TXINT	-0.008	0.075	-0.126	-0.192	-0.307	-0.105	-0.061	-0.069	0.210	0.000	-0.068	—
HLABOR	-0.320	-0.148	-0.086	-0.340	-0.306	-0.892	-1.394	-0.883	-0.209	-0.839	-0.543	—
MISCEL	-0.084	-0.466	0.794	-1.217	-0.954	-0.850	-2.164	-1.692	0.420	-0.287	-0.480	—

a/ Product was included with vegetable-fruit-sugar crops, due to its small share in the region.
b/ Food Grains were aggregated with Feed Grains; the former represents a small share in the region.
c/ Commodity is not produced in the region.

[1] Assuming exogenous input prices (infinitely elastic input supply curve).

[2] Calculated after adjusting for upward-sloping input supply functions.

Row Codes: LIVSTK is livestock quantity, FEEDGR is feed grains quantity, FOODGR is food grains quantity, COTTON is cotton quantity, OILCROP is oil crops quantity, HAYFOR is hay-forage quantity, VEGFRT is vegetable-fruit-sugar crops quantity, TOBACCO is tobacco quantity, AGRCHEM is agricultural chemicals quantity, FSL is feed-seed-livestock purchases quantity, MPMCH is mechanical power-machinery quantity, TXINT is taxes-interest quantity, HLABOR is hired labor quantity, and MISCEL is miscellaneous input quantity.

Table 14. Own-Price Supply Elasticities, Various Aricultural Commodities, U. S., Estimated From Direct Supply Functions, By Various Authors, Reported in Askari and Cummings (1976).

Crop	Region	Period	Author	Short-Run Elasticity	Long-Run Elasticity
Wheat	United States (17 States)	1867 - 1914	Fisher and Temin	0.11[a]	0.80[a]
		1874	Cooley and DeCanio	0.12[a]	0.18[a]
		1914	Cooley and DeCanio	0.08[a]	0.11
	United States	1909-32	Nerlove	0.47 to 0.93	—
Barley		1909-32	Brandow	1.32	—
Maize		1909-32	Nerlove	0.09 to 1.02	—
Lima Beans		b	Nerlove and Addison	0.10	1.70
Snap Beans		b	Nerlove and Addison	0.15	c
Peas		b	Nerlove and Addison	0.31	4.40
Soybeans	United States	1946-66	Houk and Subotnik	0.84	—
	(Lake States)	1946-66	Houk and Subotnik	0.91	—
	(Corn Belt)	1946-66	Houk and Subotnik	0.50	—
	(Plains States)	1946-66	Houk and Subotnik	2.10	—
	(Delta States)	1946-66	Houk and Subotnik	0.75	—
	(Atlantic States)	1946-66	Houk and Subotnik	1.70 to 3.30	—
Cotton	(10 States)	1883 - 1914	DeCanio	0.13 to 0.34	0.23 to 0.85
	(10 States)	1874	Cooley and DeCanio	0.08 to 0.29	0.12 to 0.60
	(10 States)	1914	Cooley and DeCanio	0.06 to 0.33	0.08 to 0.60
	(Southeast)	1905-32	Brennan	0.33	—
	(Delta)	1905-32	Brennan	0.31	—
	(Southwest)	1905-32	Brennan	0.37	—
	United States	1909-932	Nerlove	0.20 to 0.67	—
Eggs		1927-57	Jones	0.42	1.35
Milk		1931-54	Halvorson	0.03[d]	—
		1931-54	Halvorson	0.14[e]	—
		1927-57	Halvorson	0.13 to 0.17	0.40 to 0.44
		1941-57	Halvorson	0.18 to 0.31	0.15 to 0.89
		1958-68	Prato	0	—
Wool		1948-65	Witherell	0.14 to 0.15	0.32 to 0.35
Pork		1924-37	Dean and Heady	0.46[f]	—
		1924-37	Dean and Heady	0.28[g]	—
		1937-56[h]	Dean and Heady	0.60[f]	—
		1938-56[h]	Dean and Heady	0.30[g]	—
		1961-72	Meilke, Zwart, and Martin	0.24	0.48

[a]Median value

[b]Nerlove - Addison time periods variously begin between 1919 and 1929, and all end in 1[illegible]

[c]Infinite value indicated

[d]Summer production

[e]Winter production

[f]Spring farrowing

[g]Fall farrowing

[h]Omitting 1942 to 1944

Table 15. Own-Price Supply Elasticities, Agricultural Products, U.S., 1976, Calculated From Area and Yield Elasticities as Reported in the 1978 GOL Model, Rojko, et.al. (1978).

	Area Elasticity With Respect to (Own) Price	Yield Elasticity With Respect to (Own) Price	Total Supply Elasticity
Wheat	2.5	.05	2.55
Rice	.8	.10	.90
Coarse grains	2.3	.10	2.40
Oil seeds	3.25	.02	3.27
Beef	--	--	.30
Pork	--	--	.50
Poultry	--	--	.90
Milk	--	--	.40
Cheese	--	--	.60

[1]These elasticities are with respect to trade prices.

Table 16. Own-Price Supply Elasticities, Agricultural Products, U.S., 1960-80, Estimated From a Direct Supply Function as Reported in the 1985 GOL Model, Liu and Roningen (1985).[1]

	Current Supply (Own) Price Elasticity	Lagged Supply (Own) Price Elasticity	Total Supply[2] (Own) Price Elasticity
Wheat	.05	.20	.25
Corn	.05	.04	.09
Coarse Grains (other than corn)	.05	.04	.09
Rice	.05	.11	.16
Soybeans	05	.05	.10
Other Oilseeds	.05	.20	.25
Beef and Veal	.06	-.05	.01
Pork	-.05	.10	.05
Mutton and Lamb	-.02	.07	.05
Poultry - Meat	.08	.16	.24
Poultry - Eggs	.06	.02	.08
Dairy - Butter	.05	--	.05
Dairy - Cheese	.05	.17	.22
Dairy - Other Products	.05	--	.05
Cotton	.05	.20	.25
Sugar	.05	.02	.07

[1] These elasticities are with respect to world trade prices.

[2] Total supply elasticity is calculated as the summation of current price and lagged price supply elasticities.

Table 17. Own-Price Supply Elasticities, Agricultural Products, U. S., 1960-80, Estimated From a Direct Supply Function or Gathered From Elasticities Reported in the Literature, Tyers (1983).

	Rice	Wheat	Coarse Grains	Ruminant Meat	Non-Ruminant Meat
Short-Run	.35	.45	.40	.13[a]	.33[a]
Long-Run	.75	.80	.75	.50	.81

[a]Short-run supply elasticities are the summation of elasticities with respect to one- and two-period lagged prices.

Table 18. Own- and Cross-Price Output Supply and Input Demand Elasticities, Agricultural Products and Inputs, Canada, 1971 Cross-Section Data, Estimated From a Generalized Leontief Profit Function, Lopez (1984)[1].

	Price of					
	Crops	Animal Products	Land and Structure	Hired Labor	Operator and Family Labor	Farm Capital
Crop Products	.012	.023	.059	-.002	-.072	-.022
Animal Products	.012	.472	-.050	-.240	-.102	-.091
Land and Structures	-.212	.335	-.362	.255	-.051	.035
Hired Labor	.009	1.264	.260	-1.240	-.268	-.025
Operator and Family Labor	.026	.069	-.005	-.026	-.065	.002
Farm Capital	.154	1.36	.078	-.054	.037	-1.575

[1]Elasticities are evaluated at mean values of prices and quantities.

Table 19. Own-Price Compensated Output Supply Elasticities, Agricultural Products, Canada, 1971 Cross-Section Data, Lopez (1984)

Crop Products	.007
Animal Products	.098

Table 20. Own-Price Supply Elasticities, Agricultural Products, Canada, 1976, Calculated From Area and Yield Elasticities, Reported in the 1978 GOL Model, Rojko, et.al. (1978).

	Area Elasticity With Respect To (Own) Price	Yields Elasticity With Respect To (Own) Price	Total Supply Elasticity
Wheat	.50	.15	.65
Coarse Grains	.55	.15	.70
Oilseeds	1.00	.20	1.20
Beef	--	--	.40
Pork	--	--	.60
Poultry	--	--	.70
Milk	--	--	.30
Cheese	--	--	.60

[1]These elasticities are with respect to domestic price.

Table 21. Own-Price Supply Elasticities, Agricultural Products, Canada, 1960-80, Estimated From a Direct Supply Function as Reported in the 1985 GOL Model, Liu and Roningen (1985).[1]

	Current Supply (Own) Price Elasticity	Lagged Supply (Own) Price Elasticity	Total Supply (Own) Price Elasticity
Beef	.12	.04	.16
Pork	.05	.28	.33
Mutton and Lamb	.05	.30	.35
Poultry and Meat	.05	.00	.05
Wheat	.05	.01	.06
Corn	NA*	NA*	NA*
Coarse Grains (other than corn)	.05	.20	.25
Soybeans	.05	.20	.25
Other Oilseeds	.05	.04	.09
Dairy - Cheese	.05	.10	.15
Dairy - Other Products	.70	--	.70
Cotton	.05	--	.05
Sugar	.05	.02	.07

NA*: Not available.

[1]These elasticities are with respect to world prices.

Table 22. Own-Price Supply Elasticities, Agricultural Products, Canada, 1960-80, Estimated From a Direct Supply Function or Gathered From Elasticities Reported in the Literature, Tyers (1983).

	Wheat	Coarse Grains	Ruminant Meat	Non-Ruminant Meat
Short-Run	.33	.52	.17[a]	.31
Long-Run	.53	.68	.40	.84

[a]Short-run supply elasticities are the summation of elasticities with respect to one- and two-period lagged prices.

Table 23. Own-Price Supply and Price Transmission Elasticities, Agricultural Output, Canada, 1961-76, Reported in the IIASA Model, Seeley (1985).

Product	Elasticities with Respect to World Price				Supply Price Transmission Elasticity	
	2 Years	4 Years	6 Years	10 Years	2 Years	10 Years
Wheat	.50	.57	.51	.43	1.12	1.12
Coarse Grains	.25	.34	.35	.37	1.00	1.00
Protein Feed	.18	.28	.32	.34	1.51	2.37
Ruminant Meat	.23	.27	.30	.34	.64	.54
Dairy	.05	.07	.08	.08	.11	.09
Other Animal Products	.13	.19	.19	.21	.41	.25

Table 24. Calculated Own-Price Supply Elasticities with Respect to Domestic Prices, Agricultural Output, Canada, 1961-76, Calculated From The World Price Supply Elasticities and Price Transmission Elasticities Reported in the IIASA Model, Seeley (1985).

Product	Elasticity with Respect to Domestic Price	
	Short-Run	Long-Run
Wheat	.45	.38
Coarse Grains	.25	.37
Protein Feed	.12	.14
Ruminant Meat	.36	.63
Dairy	.45	.89
Other Animal Products	.32	.84

Table 25. Own-Price Supply Elasticities, Agricultural Output, Canada, 1961-76, Estimated From the Revised IIASA Model, Frohberg and Kromer (1985).[1]

Product	Inputs Constant[2] 1 Year	Inputs Constant[3] 2 Years	Inputs Variable 1 Year	Inputs Variable 2 Years
Wheat	.695	.635	.856	.798
Rice	-.175	-.176	-.169	-.168
Coarse Grains	.822	.776	.814	.779
Bovine and Ovine Meats	.274	.269	.438	.455
Dairy Products	-.064	-.064	-.059	-.058
Other Animal Products	.356	.353	.593	.624
Protein Feed	.408	.349	.410	.395
Other Food	.399	.385	.497	.499
Non-Food Agriculture	.218	.214	.256	.258
Non-Agriculture	.0	.0	.009	.010

[1] These elasticities are point elasticities.

[2] "1 year" refers to the supply response after one year.

[3] "2 years" refers to the supply response after two years.

Table 26. Own-Price Supply Elasticities, Various Agricultural Products, Canada, Estimated From Direct Supply Functions, By Various Authors, Reported in Askari and Cummings (1976).

Product	Region	Period	Author	Short-Run Elasticity	Long-Run Elasticity
Wheat	Canada	1947-66	Schmitz	.42 to .75	.62 to 1.30
Barley	Canada	1947-66	Schmitz	0	0
Flaxseed	Canada	1947-66	Schmitz	.08 to .19	--
Pork	Canada, (Eastern Provinces)	1961-72	Meilke, Zwart, & Martin	.38	1.12
Pork	Canada, (Western Provinces)	1961-72	Meilke, Zwart, & Martin	.16	.79

Table 27. Own-Price Supply Elasticities, Agricultural Products, Developed Countries, 1976, Derived From the Elasticities Reported in the 1978 GOL Model, Bale and Lutz (1981).

	France		W. Germany		United Kingdom		Japan	
	Range of Supply Elasticities							
	Low	High	Low	High	Low	High	Low	High
Wheat	.42	1.28	.42	1.28	.47	1.42	.80	2.41
Rice	--	--	--	--	--	--	.08	.24
Maize	.17	.52	.17	.53	.45	1.35	--	--
Barley	.42	1.28	.42	1.28	.47	1.42	.80	2.41
Sugar	.81	2.44	.43	1.30	.22	.66	.21	.64
Beef	.20	.60	.20	.60	.20	.60	.33	.99

Table 28. Own-Price Supply Elasticities, Agricultural Products, Developed Countries, 1976, Calculated From Area and Yield Elasticities as Reported in the 1978 GOL Model, Rojko, et. al. (1978).

	EC-6	EC-3	Other Western Europe	Japan	Australia & New Zealand	South Africa
Wheat	.95	.85	.50	.30	.55	.55
Rice	.40	--	.30	.16	.20	--
Coarse Grains	.91	.35	.49	.25	.81	(.60)[1]
Oilseeds	--	.02	.20	.43	.45	(.10)[1]
Beef	.40	.40	.40	.50	.40	--
Pork	.70	.70	.50	.70	.30	--
Poultry	.70	.70	.60	.70	--	--
Mutton	.30	.30	.30	--	.20	--
Milk	.35	.35	.30	.80	.40	--
Cheese	.40	.40	.50	--	1.00	--

[1] The use of parentheses in the table indicates trade prices; the absence of parentheses indicates supply prices.

Table 29. Own-Price Supply Elasticities, Agricultural Products, Developed Countries, 1960-80, Estimated From a Direct Supply Function as Reported in the 1985 GOL Model, Liu and Roningen (1985)[1]

	EC-10	Other Western Europe	Japan	Australia & New Zealand	South Africa
Beef & Veal	.07	.01	.08	.34	--
Pork	.07	.06	.25	--	--
Mutton & Lamb	.33	.01	.35	.07	.44
Poultry-Meat	.16	.39	.45	--	.35
Poultry-Eggs	.14	.19	.36	.25	.35
Wheat	.25	.25	.08	.08	--
Corn	.25	.23	.29	--	.25
Coarse Grains other than corn	.16	.25	.30	.16	--
Rice	.25	.09	.15	.10	.05
Soybeans	.25	.14	.06	--	--
Other oilseeds	.25	.23	.25	--	--
Soymeal	--	--	--	--	--
Soyoil	--	--	--	.05	--
Other Meals	--	--	--	--	--
Other Oils	--	--	--	.70	--
Dairy-Butter	.18	.05	--	.05	--
Dairy-Cheese	.23	.33	.35	.05	--
Dairy-Other Products	.40	.22	.05	.53	--
Cotton	.12	.25	.27	--	--
Sugar	.13	.09	.25	.09	.15

[1] These elasticities are with respect to world (trade) prices. Total supply elasticity is calculated as the summation of current- and lagged-price supply elasticities.

Table 30. Own-Price Supply Elasticities, Wheat, Developed Countries, 1976, Derived Elasticities From the 1978 GOL Model, Sarris and Freebairn (1983).

	EC-9	Other Western Europe	Japan	South Africa	Australia
			Short-Run Supply Elasticity		
Wheat	.35	.35	.10	.12	.10

Table 31. Own-Price Supply Elasticities, Agricultural Products, Developed Countries, 1960-80, Estimated From a Direct Supply Function or Gathered From Elasticities Reported in the Literature, Tyers (1983).

	European Community		Japan		Australia	
	Short-Run	Long-Run	Short-Run	Long-Run	Short-Run	Long-Run
Wheat	.30	.90	.30	.60	.31	.90
Rice	.20	.40	.20	.50	.18	.30
Coarse Grains	.40	.91	.30	.60	.20	.60
Ruminant Meat	.23[a]	.70	.40[a]	.80	.18[a]	.36
Non-Ruminant Meat	.33[a]	1.00	.23[a]	.69	.10[a]	.30

[a]Short-Run supply elasticities are the summation of elasticities with respect to one- and two-period lagged prices.

Table 32. Own-Price Supply and Price Transmission Elasticities, Agricultural Output, Developed Countries, 1961-76, Estimated From the IIASA Model, Seeley (1985).

Product	EC-9		Japan		Australia		New Zealand		EC-9		Japan		Australia		New Zealand	
	Elasticities with Respect to World Price								Supply Price Transmission Elasticities							
	2 Yrs[a]	10 Yrs[b]	2 Yrs	10 Yrs	2 Yrs	10 Yrs	2 Yrs	10 Yrs	2 Yrs	10 Yrs	2 Yrs	10 Yrs	2 Yrs	10 Yrs	2 Yrs	10 Yrs
Wheat	.41	2.60	—	—	.35	.31	—	—	.38	.90	—	—	.75	.61	—	—
Coarse Grains	.25	1.18	—	—	.41	.68	—	—	.33	.86	—	—	1.06	1.41	—	—
Protein Feed	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ruminant Meat	.04	.04	—	—	—	—	.24	.60	.15	.15	—	—	—	—	1.00	1.00
Dairy	.03	.02	.07	.07	—	—	.12	.34	.07	.05	.12	.08	—	—	—	—
Other Animal Products	.27	.20	.16	.20	—	—	.94	.94	.61	.37	.81	.52	—	—	1.00	1.00

[a]"2 Yrs" refers to the supply response after two years

[b]"10 yrs" refers to the supply response after ten years

Table 33. Calculated Own-Price Supply Elasticities With Respect to Domestic Prices, Agricultural Output, Developed Countries, 1961-76, Calculated From the World Price Supply Elasticities and Price Transmission Elasticities Reported in the IIASA Model, Seeley (1985).

Product	EC-9		Japan		Auutralia		New Zealand	
	Short-Run	Long-Run	Short-Run	Long-Run	Short-Run	Long-Run	Short-Run	Long-Run
Wheat	1.08	2.89	—	—	.47	.51	—	—
Coarse Grains	.76	1.37	—	—	.35	.48	—	—
Protein Feed	—	—	—	—	—	—	—	—
Ruminant Meat	.27	.27	—	—	—	—	.24	.60
Dairy	.43	.40	.58	.88	—	—	.12	.34
Other Animal Products	.44	.54	.20	.38	—	—	.94	.94

Table 34. Own-Price Supply Elasticities, Agricultural Output, Developed Countries, 1961-76, Estimated From the Revised IIASA Model, Frohberg and Kromer (1985).

Product	EC		Austria		Japan		Australia		EC		Austria		Japan		Australia	
	Inputs Constant								Inputs Variable							
	1 Yr[a]	2 Yrs[b]	1 Yr	2 Yrs	1 Yr	2 Yrs	1 Yr	2 Yrs	1 Yr	2 Yrs	1 Yr	2 Yrs	1 Yr	2 Yrs	1 Yr	2 Yr
Wheat	.53	.52	.80	.78	.40	.40	.48	.42	1.06	1.09	1.29	1.41	.43	.44	.69	.64
Rice	.63	.59	-.06	-.06	.23	.23	.90	.89	1.49	1.49	-.06	-.06	.29	.31	.94	.94
Coarse Grains	.43	.41	.56	.55	.38	.38	.57	.54	.90	.93	.66	.66	.38	.38	.85	.84
Bovine and Ovine Meats	.26	.26	.54	.53	.07	.06	.07	.07	.59	.62	.61	.61	.07	.07	.11	.11
Dairy Products	.35	.33	.64	.61	.78	.74	.41	.41	.79	.82	.74	.73	.77	.74	.44	.44
Other Animal Products	.40	.41	.61	.63	.20	.18	.64	.63	.63	.66	.75	.79	.22	.54	.66	.66
Protein Feed	.05	.05	.00	.00	.34	.33	.00	.00	.04	.04	.00	.00	.35	.35	.00	.00
Other Food	.41	.40	.34	.34	.29	.29	.44	.44	.75	.78	.49	.52	.34	.35	.53	.54
Non-Food Agric.	.17	.16	.07	.07	.21	.21	.06	.06	.21	.21	.07	.07	.23	.23	.10	.11
Non-Agric.	.00	.00	.00	.00	.00	.00	.00	.00	.16	.17	.07	.08	.01	.02	.00	.00

[a]"1 Yr" refers to the supply response after one year

[b]"2 Yrs" refers to the supply response after two years

Table 35. Own-Price Supply Elasticities, Agricultural Output, Developed Countries, Estimated From Direct Supply Functions, Reported in Askari and Cummings (1976).

Product	Region	Period	Author	Short-Run Elasticity	Long-Run Elasticity
Wheat	Japan	1910-41	Mangahas, Reeto	+ .01 to .26	+ .02 to 1.16
	France	1946-61	Oury	+ .63	--
	United Kingdom	1924-39	Jones	+ .33 to .41	+ .46 to .98
	United Kingdom	1955-66	Colman	+ .17	--
	United Kingdom (Spring Wheat)	1955-66	Colman	+ .41	--
	Argentina	1948-65	Freire	+ .57	--
	Australia	1947-64	Powell & Gruen	+ .18	+ .85
	New S. Wales (Old Districts)	1947-62	Duloy & Watson	+ .33 to .47	+ .66 to 1.07
	New S. Wales (New Districts)	1947-62	Duloy & Watson	+ .16 to 1.13	- .13 to .795
	New Zealand	1945-65	Guise	+ .96	+1.58
Barley	United Kingdom	1924-39	Jones	+ .57 to .63	+1.75 to 2.71
	United Kingdom	1955-66	Colman	+ .57	--
Oats	United Kingdom	1924-39	Jones	+ .11	+ .16
	United Kingdom	1955-66	Colman	+1.56	--
Feed Grains	France	1946-61	Oury	+ .77	--
	Australia	1947-64	Powell & Gruen	+ .14	+ .81
Vegetables	United Kingdom	1924-58	Jones	+ .32	+1.45
	United Kingdom	1946-57	Jones	+ .30	+ .94
Eggs	United Kingdom	1927-39	Jones	+ .28 to .57	+1.17 to 1.36
	United Kingdom	1955-63	Jones	+ .55	+1.66
	United Kingdom	1954-66	Robertson	+1.52	+2.42
Milk	Australia	1947-64	Powell & Gruen	+ .19	+ .42
	Ireland	1951-68	Buttimer & MacAirt	+ .25 to .30	--
	Ireland	1953-70	Buttimer	+ .37	--
	United Kingdom	1924-58	Jones	+ .06	+ .46
	United Kingdom	1955-64	Jones	+ .17 to .23	.27 to 1.05
	United Kingdom	1965-70	Hill	.10	--
	United Kingdom	1957-68	Gardner & Walker	.22	.66
	United Kingdom & Wales	1948-58	Gardner	.13	1.42
Beef	Australia	1947-64	Powell & Gruen	.16	--
	United Kingdom	1924-58	Jones	.10 to .38	above +1.00
	West Germany	1951-64	Jones	--	1.06
	Ireland	1953-70	Buttimer	.11	--
Lamb	Australia	1947-64	Powell & Gruen	.32	1.38
	United Kingdom	1907-58	Jones	.30	2.31
	United Kingdom	1955-64	Jones	.28 to .50	1.51 to 4.00
Pork	United Kingdom	1924-39	Jones	.65	3.61
	United Kingdom	1949-58	Jones	.40	above 2.00
	Canada (E. Provinces)	1961-72	Meilke, Zwart & Martin	.38	1.12
	Canada (W. Provinces)	1961-72	Meilke, Zwart & Martin	+ .16	+ .79
Poultry	United Kingdom	1927-39	Jones	+ .69	--
	United Kingdom	1960-64	Jones	+1.00	+2.50

Table 36. Own-Price Supply and Input Demand Elasticities, Aggregate Output and Labor, India, 1955-56 (1956-57 in Some Cases) Cross-Sectional Data, Estimated From a Cobb-Douglas Form Indirect Profit Function, Lau and Yotopoulos (1972).

Quantity	Elasticities with Respect to Price of	
	Output	Labor
Output	1.166	-1.166 (with respect to normalized wage rate)
Labor	2.166	-2.166 (with respect to nominal wage rates)

Table 36-A. Estimates of Own-Price and Non-Price Supply Elasticities, Aggregate Farm Output, India, 1960/61 - 1977/78, Estimated From Direct Supply Functions, Ajay Chhibber (1982).

Method	No. Shift Variables		With Shift Variables			
			Area Irrigated by Government Canals		Total Irrigated Area	
	S-R	L-R	S-R	L-R	S-R	L-R
	Elasticities With Respect to Price					
Nerlovian (Adaptive Expectations)	—	1.25 (3.57)*	—	.07 (.55)	—	.06 (.68)
Rational Expectations	—	—	.12 (.95)	.21 (.82)	.11 (1.22)	.18 (1.10)
Chhibber's Model	Elasticities With Respect to Price & Other Variables					
Elasticities with Respect to:						
Price	—	—	.297 (2.05)	.455 (2.21)	.198 (1.91)	.285 (2.06)
Non-Price Shifter	—	—	.274 (8.60)	.420 (5.49)	.413 (12.53)	.594 (7.93)
Rainfall	—		.79 (8.84)		.75 (11.25)	
Adjustment Coefficient (d)			.652 (7.80)		.695 (9.54)	

*Figures in parenthesis are t- values.

Table 36-B. Own- and Cross-Price Supply Elasticities of Variable Inputs and Elasticities with Respect to Fixed Inputs and Education, Wheat (Mexican Varieties), Indian Punjab, 1970-71 Cross-Sectional Data, Estimated From a Cobb-Douglas Form Indirect Profit Function, Sidhu and Baanante (1979).

		Elasticities with Respect to						
		Price of Wheat (P)	Price of Labor (P_N)	Price of Fertilizer (P_F)	Price of Irrigation (P_I)	Land (L)	Capital (K)	Education (E)
Wheat Supply	W	0.710	-0.441	-0.161	-0.108	0.744	0.256	0.030
Labor	N	1.710	-1.441	-0.161	-0.108	0.744	0.256	0.030
Fertilizer	F	1.710	-0.441	-1.161	-0.108	0.744	0.256	0.030
Irrigation	I	1.710	-0.441	-0.161	-1.108	0.744	0.256	0.030

Table 37. Derived Elasticity Estimates for Output Supply and Demand for Variable Inputs, Wheat (Mexican Variaties), Indian Punjab, 1970—71 Cross-Sectional Data, Estimated From Translog and Cobb-Douglas Form Indirect Profit Function, Sidhu and Baanante (1981)

	Price of Wheat	Price of Labor	Price of Fertilizer	Price of Animal Power	Capital	Land	Soil pH	Organic Soil Carbon	Soil (P + K)	Education	Irrigation
Derived from Parameter Estimates of the Translog Profit Function:[a]											
Wheat supply	0.6337[b]	−0.2672[c]	−0.2513[c]	−0.1151[d]	0.1933[c]	0.6951[b]	−0.8160[b]	0.0929	−0.0324	0.0874[c]	0.5641[b]
	(7.797)	(5.462)	(4.376)	(3.076)	(3.978)	(34.550)	(4.309)	(0.836)	(0.074)	(5.269)	(12.005)
Labor	1.1269[b]	−0.6954[c]	−0.2356	−0.1958[d]	0.0932	0.8311[b]	−0.4329	0.1293	−0.0175	0.0977[c]	0.8584[b]
	(31.962)	(4.511)	(1.221)	(2.800)	(0.429)	(23.790)	(0.646)	(0.668)	(0.008)	(3.667)	(11.135)
Fertilizer	2.4895	−0.5534	−1.8829[d]	−0.0531	0.1312	0.9522[b]	−0.4649	0.0112	−0.1870	0.1838[b]	0.7223[c]
	(1.311)	(1.221)	(3.387)	(0.142)	(0.595)	(21.314)	(0.525)	(0.002)	(0.667)	(8.707)	(5.256)
Animal power	0.8060[b]	−0.3249[d]	−0.0375	−0.4434[c]	−0.5219[c]	1.2407[b]	0.1946	−0.1566	0.1840	0.2381[b]	0.0076
	(43.990)	(2.800)	(0.142)	(4.439)	(4.677)	(18.115)	(0.046)	(0.299)	(0.266)	(8.327)	(0.000)
Cobb-Douglas Case:											
Wheat supply	0.783[b]	−0.402[b]	−0.173[b]	−0.208[b]	0.297[b]	0.649[b]	−0.717[b]	0.170	0.026	−0.029	0.585[b]
Labor	1.783[b]	−1.402[b]	−0.173[b]	−0.208[b]	0.297[b]	0.649[b]	−0.717[b]	0.170	0.026	−0.029	0.585[b]
Fertilizer	1.783[b]	−0.402[b]	−0.173[b]	−0.208[b]	0.297[b]	0.649[b]	−0.717[b]	0.170	0.026	−0.029	0.585[b]
Animal power	1.783[b]	−0.402[b]	−0.173[b]	−1.208[b]	0.297[b]	0.649[b]	−0.717[b]	0.170	0.026	−0.029	0.585[b]

[a] Using equations (6), (8), (11), (13), (14), (21), and (23), and simple averages of input S_i ratios. F-values in parentheses; $F_{0.10}(1, 246) = 2.71$; $F_{0.05}(1, 246) = 3.88$.
[b] Significant at 0.01 level.
[c] Significant at 0.05 level.
[d] Significant at 0.10 level.

Source: Sidhu and Baanante, 1981, p. 243.

Table 38. Own-Price Output Supply Elasticities, Wheat (Mexican Variety) and Hybrid Bajra, Delhi Union Territory of India, 1968/69 - 1975/76 (Small and Large Farms), Estimated From a Cobb-Douglas Form Indirect Profit Function, de Janvry and Kumar (1981), and Askari and Cummings (1977), Estimations Are From Direct Supply Functions.

Author	Estimates of Own-Price Supply Elasticities Short-Run	Long-Run
de Janvry and Kumar	.25 (small farms) .24 (large farms)	
Askari and Cummings	.18	.31

Table 39 Own- and Cross-Price Output Supply and Input Demand Elasticities, Wheat, Fertilizer and Labor, Delhi Union Territory of India, 1968/69 - 1975/76 (Small and Large Farms), Estimated From a Cobb-Douglas Form Indirect Profit Function, de Janvry and Kumar 1981.

Elasticities	Small Farms	Large Farms
Wheat Output Supply Response to:		
Wheat Price	.25	.24
Normalized Fertilizer Price	-.11	-.08
Normalized Wage	-.14	-.16
Fertilizer Demand to:		
Wheat Price	1.24	1.24
Normalized Fertilizer Price	-1.11	-1.08
Normalized Wage	-0.14	-0.16
Labor Demand Response to:		
Wheat Price	1.24	1.24
Normalized Fertilizer Price	-0.11	-0.08
Normalized Wage	-1.14	-1.16

Table 40. Own- and Cross-Price Elasticities, Kharif Rice Output and Variable Inputs, Coimbatore District of India, 1977/78 Cross-Sectional Data, Estimated From a Cobb-Douglas Form Indirect Profit Function, Kalirajan and Flinn (1981).

	Price of Rice	---------Normalied Price of---------- Labor	Fertilizer	Pesticide	Bullocks
(a) Exotic Modern Variety					
Rice	1.96[1]	-.57	-1.20	-.07	-.12
Labor	2.96	-1.57	-1.20	-.07	-.12
Fertilizer	2.96	-.57	-2.20	-.07	-.12
Pesticides	2.96	-.57	-1.20	-1.07	-.12
Bullocks	2.96	-.57	-1.20	-.07	-1.12
(b) Locally-Bred Variety					
Rice	1.32	-.46	-.73	-.06	-.07
Labor	2.32	-1.46	-.73	-.06	-.07
Fertilizer	2.32	-.46	-1.73	-.06	-.07
Pesticides	2.32	-.46	-.73	-1.06	-.07
Bullocks	2.32	-.46	-.73	-.06	-1.07

[1] The underlined figures represent own-price output supply and input demand elasticities.

Table 41. Own-Price Supply Elasticities, Rice, Various Developing Countries, 1962-81, Estimated From Yield and Acreage Elasticities, Ito, Wailes and Grant (1985).

Countries	Yield $E_{yd/p}$		Acreage Effect on Yield $E_{yd/a}$	Area Harvested $E_{a/p}$		Production $E_{q/p}$	
	Elasticities						
	S-R	L-R	S-R	S-R	L-R	S-R	L-R
Bangladesh	.049	.049	.0	.011	.022	.060	.072
Burma	.0	.0	.0	.043	.043	.043	.043
India	.156	.156	.0	.027	.060	.183	.216
Indonesia	.094	.269	.0	.074	.074	.168	.343
South Korea	.396	.396	.0	.051	.071	.447	.467
Pakistan	.0	.0	.0	.091	.389	.091	.389
Philippines	.197	.355	.0	.116	.116	.313	.471
Thailand	.0	.0	.0	.337	1.620	.337	1.620
Taiwan	.119	.119	-.67	.059	.1159	.138	.171

Table 42. Own-Price Yield, Area, and Total Production Elasticities, Rice, Sri Lanka, 1955-79, Estimated From Yield and Acreage Elasticities, Bogahawatte (1983).

	Yield	Area	Total[1]
Wet Zone			
Maha[2]	.3863*	.0223	.4086
Yala[3]	.4751*	.0097	.4848
Dry Zone			
Maha	.1765	.1333*	.3098
Yala	.2529	.1463	.3992

[1]Total elasticity is calculated as the summation of yield and area elasticities. However it should be noted that yield elasticities are with respect to GPS (ratio of guaranteed price of paddy to average weighted guaranteed price of subsidiary food crops), while yield elasticities are with respect to P_{t-1} (GPS_{t-1}/P_f where P_f is the average price of NPK fertilizers).

[2]Maha season refers to the paddy crop which is sown in the months of July to November and harvested in February to March of the following year.

[3]Yala season refers to the crop which is sown in the months of April to June and harvested in August to September.

*The relevant coefficient is signiciant at 5 percent level.

Table 42-A. Elasticities of the Probabilities of Planting HYVs at the Sample Means, Rice, Indonesia, 1971 Cross-Sectional Data, Estimated From a Translog Profit Function, Pitt (1983).

Exogenous Variables	Estimates
Rice Price	0.911 (4.28)[a]
Fertilizer Price	-0.911 (4.28)
Irrigation	1.457 (4.05)
Area	-0.103 (2.44)

[a]Approximate t-values are in parentheses.

Table 42-B. Own-Price Supply Elasticities, Rice, Indonesia, 1968-77, Estimated From Direct Supply Functions, Nainggolan and Suprapto (1984).

	Acreage	Yield	Total Production
Short-run	.034	.127	0.161
Long-run	.036	.128	0.164

Table 43. Acreage Elasticities With Respect to Gur/Wheat Relative Price, Sugarcane, India, Uttar Pradesh (Various Regions and the State as a Whole), 1950-51 to 1974/75, Estimated From a Nerlovian Type Direct Supply Function, Lal and Singh (1981).

Region/State	Short Run	Long-Run
Western Region	.604**	2.207
Eastern Region	.235*	0.699
Central Region	.317*	0.721
Uttar Pradesh	.415*	1.600

**Significantly different from zero at 1 per cent level.

*Significantly different from zero at 5 per cent level.

Table 44. Own-Price Supply Elasticities, Major Agricultural Crops, Pakistan (as a Whole and Punjab and Sind Provinces), 1962/63 to 1982/83, Estimated From a Nerlovian Type Direct Supply Function or From Consensus Estimates, Tweeten (1985).

Commodity and Component	Pakistan		Punjab		Sind	
	Short-Run	Long-Run	Short-Run	Long-Run	Short-run	Long-Run
Cotton						
Area (A)	.10	.54	.07	.32	.16	.32
Yield (Y)	.25	.49	.26	.52	.10	.28
Production (AY)	.35	1.03	.33	.84	.26	.60
Production (direct)	.44	.88	.44	.89	.67	1.33
Consensus judgments	.30	1.00	--	--	--	--
Sugarcane						
Area (A)	.36	.70	.25	1.51	.11	.42
Yield (Y)	.12	.24	.20	.37	.11	.19
Production (AY)	.48	.94	.45	1.88	.22	.61
Production (direct)	.44	.44	.53	.53	--	--
Consensus judgments	.30	.90	--	--	--	--
Rice						
Area (A)	.09	.43	.18	.37	.05	.09
Yield (Y)	.12	.23	.08	.15	.22	.45
Production (AY)	.21	.66	.26	.52	.27	.54
Production (direct)	.22	.45	.27	.54	.31	.62
Consensus judgments	.20	.60	--	--	--	--
Wheat						
Area (A)	.07	.27	.07	.29	.25	.59
Yield (Y)	.07	.13	.06	.12	.10	.21
Production (AY)	.14	.40	.13	.41	.35	.80
Production (direct)	.18	.27	.20	.21	.13	.34
Consensus judgments	.15	.40	--	--	--	--
Miscellaneous (other) Crops						
Area (A)	--	--	--	--	--	--
Yield (Y)	--	--	--	--	--	--
Production (AY)	--	--	--	--	--	--
Production (direct)	--	--	--	--	--	--
Consensus judgments	.15	.50	--	--	--	--
Livestock and Livestock Products						
Area (A)	--	--	--	--	--	--
Yield (Y)	--	--	--	--	--	--
Production (AY)	--	--	--	--	--	--
Production (direct)	.14	.28	--	--	--	--
Consensus judgments	.15	.50	--	--	--	--
Aggregate Output						
Area (A)	.16	.31	--	--	--	--
Yield (Y)	.23	.46	--	--	--	--
Production (AY)	.39	.77	--	--	--	--
Production (direct)	.18	.35	--	--	--	--
Consensus judgments	.15	.60	--	--	--	--

Table 45. Own- and Cross-Price Elasticities and Elasticities with Respect to the Fixed Inputs, Aggregate Farm Output, Taiwan, Cross-Sectional Data for 1967 and 1968, Estimated From a Cobb-Douglas Form Indirect Profit Function, Yotopoulos, Lau, and Lin (1976).

	Price of					Quantity of	Quantity of
	Output	Labor	Animal Labor	Mechanical Labor	Fertilizer	Capital	Land
Output	1.2477	-0.9798	-0.0356	-0.0017	-0.2306	0.0702	0.9298
Labor	2.2477	-1.9798	-0.0356	-0.0017	-0.2306	0.0702	0.9298
Animal Labor	2.2477	-0.9798	-1.0356	-0.0017	-0.2306	0.0702	0.9298
Mechanical Labor	2.2477	-0.9798	-0.0356	-1.0017	-0.2306	0.0702	0.9298
Fertilizer	2.2477	-0.9798	-0.0356	-0.0017	-1.2306	0.0702	0.9298

Table 46. Own-Price Supply Elasticities, Various Agricultural Products, Sierra Leone, Cross-Sectional Data for 1974/75, Estimated From Duality Approach, Strauss (1984).

Product	Own-Price Supply Elasticity
Rice	.11
Root Crops and Other Cereals	.10
Oils and Fats	.02
Fish and Animal Products	.09
Miscellaneous Foods	.15

Table 47. Acreage Response Elasticities With Respect to Real Producer Prices, Cocoa, Nigeria, 1937-58, Estimated From a Nerlovian Type Direct Supply Function, Oni and Olayemi (1974).

Provinces	Acreage Elasticity		
	P_{t-1}	P_{t-2}	Total
Ondo	0.2142	0.4824	0.6966
Oyo	0.5950	0.4950	1.0900
Ibadan	0.1379	0.3251	0.4630
Abeokuta	0.6292	0.3554	0.9846
Ijebu	4.2792	1.4627	5.7419
Colony	0.2413	1.5440	1.7853
Aggregate for Western Nigeria	0.4526	0.4617	0.9143

Table 48. Own-Price Supply Elasticities, Cocoa, Ghana, Various Provinces, 1946-62, Estimated by a Nerlovian Type Direct Supply Function, Bateman (1965).

Region[1]	Cocoa Price		Total Supply Response[2]
	P_{t-K}	P_{t-s}	
Central	.19	.25	.44
Western	.35	.36	.71
Volta	.32	.29	.61
Eastern	---	.32	.32
Old Ashanti	.12	30	.42
Sunyani	.47	.40	.87

[1]Goaso was eliminated because of the poor regression results.

[2]Total supply response is calculated as the sum of the two price elasticities.

Table 49. Own-Price Supply Elasticities and Partial Adjustment Coefficients, Various Agricultural Products, Keneya, 1964-79, Estimated From a Nerlovian Type Direct Supply Function, USDA, FAER No. 194 (December 1983).[a]

Product	Short-Run Elasticity[b]	Coefficient of Lagged Dependent Variable	Long-Run Elasticity[c]
Maize	.534	.194	.663
Wheat	1.506	.633	4.104
Rice	.484	.645	1.363
Marketed:			
Maize	1.149	1.213	-5.394

[a]Elasticities were calculated at the mean values.

[b]The relevant prices for maize and wheat are government announced prices prior to planting in each year. For rice, the elasticities are with respect to actual prices received by producers.

[c]Long-run elasticities are calculated as short-run elasticities divided by one minus the partial adjustment coefficient.

Table 50. Own-Price Supply Elasticities and Partial Adjustment Coefficients, Various Agricultural Products, Tanzania, 1964-78, Estimated From a Nerlovian Type Direct Supply Function, USDA, FAER No. 194 (December 1983).[a]

Product	Short-Run Elasticity[b]	Coefficient of Lagged Dependent Variable	Long-Run Elasticity[c]
Maize	.359	.849	2.377
Wheat	.989	.673	3.024
Rice	.426	1.177	-2.407
Marketed:			
Maize	2.290	.918	27.927
Rice	2.290	1.077	29.740

[a]Elasticities were calculated at the mean values.

[b]The relevant prices for Maize and Wheat are government announced prices prior to planting in each year.

[c]Long-run elasticities are calculated as short-run elasticities divided by one minus the partial adjustment coefficient.

Table 51. Estimates of Own-Price Supply Elasticities, Aggregate Farm Output, Pooled Cross-Sectional (53 Developed and Developing Counties) and Time-Series (1962-64 and 1968-70 averages), Estimated From a Direct Supply Function, Willis Peterson (1979).

	Research Omitted	Research Included
Ordinary Least Squares	1.65	1.25
Instrumental Variables	1.66	1.27

APPENDIX III.
OWN-PRICE SUPPLY ELASTICITY, UNITED STATES

Appendix III. Own-Price Supply Elasticity, United States

Crop	Region	Period	Author	Method of Estimation[a]	Short-Run Elasticity	Long-Run Elasticity	Other Comments[b]
Aggregate Farm Output	U. S.	1911-57	Griliches	ID	.28 to .30	1.20 to 1.32	
		1920-57	Griliches	DS	.10	.15	
		1921-66	Tweeten & Quance	DS	.16	.19	
		1921-41	Tweeten & Quance	DS	.08	.31	
		1948-66	Tweeten & Quance	DS	.16	.31	
		1921-66	Tweeten & Quance	CL	.25	1.79	
		1921-66	Tweeten & Quance	ID	.26	1.52	
		1910-46	Antle	PF	1.35	--	
		1947-78	Antle	PF	.43	--	
Livestock and Livestock Products	U. S.	1911-58	Griliches	DS	.2 to .3	.70	
Livestock		1921-66	Tweeten & Quance	CL	.38	2.90	
	N. & S. Dakota	1950-70	Weaver	PF	.56 to 1.01	--	
	Various U. S. Regions	1946-79	Saez & Shumway	PF	.006 to .43		5
Ruminant Meat	U. S.	1960-80	Tyers	DS	.13	.50	
Beef		1976	Rojko, et. al.	YA	--	.30	
		1976	Liu & Roningen	DS	--	(.01)	
Mutton & Lamb		1976	Liu & Roningen	DS	--	(.05)	
Non-Ruminant Meat		1960-80	Tyers	DS	.33	.81	
Pork		1924-56	Askari and Cummings	DS	.24 to .60	.48	3
		1976	Rojko, et. al.	YA	--	.50	
		1976	Liu & Roningen	DS	--	(.05)	
Poultry		1976	Rojko, et. al.	YA	--	.90	
Poultry Meat		1976	Liu & Roningen	YA	--	(.24)	
Poultry Eggs		1976	Liu & Roningen	YA	--	(.08)	
Milk		1931-68	Askari and Cummings	DS	.00 to .31	.15 to .81	3
		1976	Rojko, et. al.	YA	--	.40	
Cheese		1976	Rojko, et. al.	YA	--	.60	
		1960-80	Liu & Roningen	YA	--	(.22)	
All Crops		1911-58	Griliches	DS	.16	.23	
		1921-66	Tweeten & Quance	CL	.17	1.56	
Corn	Midwestern States	1963-74	Whittaker & Bancroft	DS	.12	--	1
	Kentucky	1960-79	Read & Riggins	DS	.34 to .56	.93 to 2.07	1
	Texas	1957-79	Shumway	PF	.07	--	7
	U. S.	1909-32	Nerlove	DS	.09 to 1.02	--	
		1969-77	Chambers & Just	DS	.55	--	
		1960-80	Liu & Roningen	DS	--	(.09)	
Rice	U.S.	1962-81	Ito, et. al.	YA	.11	.31	
		1976	Rojko, et. al.	YA	--	(.90)	
		1960-80	Liu & Roningen	DS	--	(.16)	2
		1960-80	Tyers	DS	.35	.75	
	Texas	1957-79	Shumway	PF	.72	--	
Wheat	U.S.	1948-74	Horzuch et. al.	DS	.46 to .52	--	1
		1969-77	Chambers & Just	DS	.50	--	7
	Texas	1957-79	Shumway	PF	.43	--	
	U. S.	1867-1932	Askari & Cummings	DS	.08 to .93	.11 to .80	3
		1976	Rojko, et. al.	YA	--	(2.55)	
		1960-80	Liu and Roningen	DS	--	(15)	
		1960-80	Tyers	DS	.45	.9	
		1960- 80	Sarris & Freebairn	Derived from Rojko, et. al.	.20	--	4
Sorghum	Texas	1957-79	Shumway	PF	.62	--	
Coarse Grains	N. & S. Dakota	1950-70	Weaver	PF	.64 to .74	--	
	Various U. S. Regions	1946-79	Saez & Shumway	PF	.01 to .27	--	5
	U. S.	1976	Rojko et. al.	YA	--	(2.40)	
		1960-80	Liu and Roningen	DS	--	(.09)	6
		1960-80	Tyers	DS	.40	.75	
Food Grains	N. & S. Dakota	1950-70	Weaver	PF	.40 to .79	--	
	Various U. S. Regions	1946-79	Saez & Shumway	PF	.004 to .63	--	5
Oil Crops	Various U. S. Regions	1946-79	Saez & Shumway	PF	.011 to .55	--	5
Oilseeds	U. S.	1976	Rojko, et. al.	YA	--	(3.27)	
Soybeans		1969-77	Chambers & Just	DS	.64	--	7
		1946-66	Houck & Subotnik	A & C	.50 to 3.30	--	3
		1960-80	Liu and Roningen	DS	--	(.10)	
Other Oilseeds	U. S.	1960-80	Liu and Roningen	DS	--	(.25)	
Hay - Forage	Texas	1957-79	Shumway	PF	.10	--	
	Various U. S. Regions	1946-79	Saez & Shumway	PF	.22 to 3.1	--	5
Cotton	Texas	1957-79	Shumway	PF	.25	--	
	Various U. S. Regions	1946-79	Saez & Shumway	PF	.38 to 1.5	--	5
	U. S.	1883-1932	Askari and Cummings	DS	.08 to .67	.08 to .85	3
		1960-80	Liu & Roningen	DS	--	(.25)	
Vegetable-Fruit-Sugar .	Various U. S. Regions	1946-79	Saez & Shumway	PF	.13 to .26	--	5
Vegetables	U. S.	1919-55	Nerlove & Addison	DS	.02 to .36	.04 to 4.70	3
Sugar		1960-80	Liu & Roningen	DS	--	(.07)	

[a]Method of Estimation Codes:

ID = Weighted average of input demand elasticities
DS = Direct estimation of the supply function
C. = Estimated from the crop and livestock components
YA = Estimated from yield and acreage elasticities
PF = Estimated from an indirect profit function (duality approach)
CF = Estimated from an indirect cost function (duality approach)

[b]Other Comments Codes:

1 = Planted acreage is the dependent variable
2 = Wheat acreage is the dependent variable
3 = From table 14, appendix II
4 = From the 1978 GOL Model
5 = Only positive elasticities are considered
6 = Coarse grains other than corn
7 = Per Capita Supply Elasticity

A & C: Askari, Hossein and John Cummings, Agricultural Supply Responses, A Survey of Econometric Evidence. Praeger Publishers, 1976.

The figures in parentheses are elasticities with respect to world prices.

APPENDIX IV.
OWN-PRICE SUPPLY ELASTICITY, CANADA

Appendix IV. Own-Price Supply Elasticity, Canada

Crop	Region	Period	Author	Method of Estimation[a]	Short-Run Elasticity	Long-Run Elasticity
Crop Products	Canada	1971	Lopez	PF	.007	.012
Coarse Grains		1976	Rojko, et. al.	YA	—	.70
		1960-80	Liu & Roningen	DS	—	(.25)
		1960-80	Tyers	DS	.52	.68
		1961-76	Seeley	IIASA	.25	.37
		1961-76	Frohberg & Kromer	IIASA	.78	—
Wheat		1947-66	Schmitz	A & C	.42 to .75	.62 to 1.30
		1960-80	Sarris & Freebairn	Derived from Rojko, et. al.	.17	—
		1976	Rojko, et. al.	YA	—	.65
		1960-80	Liu & Roningen	DS	—	(.06)
		1960-80	Tyers	DS	.33	.53
		1961-76	Seeley	IIASA	.45	.38
		1961-76	Frohberg & Kromer	IIASA	.80	—
Barley		1947-66	Schmitz	A & C	.00	.00
Oilseeds		1976	Rojko, et. al.	YA	—	1.20
Protein Feed		1961-76	Seeley	IIASA	.12	.14
		1961-76	Frohberg & Kromer	IIASA	.40	—
Soybeans		1960-80	Liu & Roningen	DS	—	(.25)
Other Oilseeds		1960-80	Liu & Roningen	DS	—	(.09)
Animal Products		1971	Lopez	PF	.098	.472
Beef		1976	Rojko, et. al.	YA	—	.40
		1960-80	Liu & Roningen	DS	—	(.16)
Pork		1976	Rojko, et. al.	YA	—	.60
		1960-80	Liu & Roningen	DS	—	(.33)
	East & West Provinces	1961-72	Meilke, et. al.	A & C	.16 to .38	.79 to 1.12
Mutton & Lamb		1960-80	Liu & Roningen	DS	—	.35
Poultry		1976	Rojko, et. al.	YA	—	.70
		1960-80	Liu & Roningen	DS	—	(.05)
Ruminant Meat		1960-80	Tyers	DS	.17	.40
		1961-76	Seeley	IIASA	.36	.63
Bovine & Ovine Meats		1961-76	Frohberg & Kromer	IIASA	.46	—
Non-Ruminant Meats		1960-80	Tyers	DS	.31	.84
Milk		1976	Rojko, et. al.	YA	—	.30
Cheese		1976	Rojko, et. al.	YA	—	.60
		1960-80	Liu & Roningen	DS	—	(.15)
Dairy		1961-76	Seeley	IIASA	.45	.89
		1961-76	Frohberg & Kromer	IIASA	-.06	—
Cotton		1960-80	Liu & Roningen	DS	—	(.05)
Sugar		1960-80	Liu & Roningen	DS	—	(.07)

[a]Method of Estimation Codes:

ID = Weighted average of input demand elasticities
DS = Direct estimation of the supply function
CL = Estimated from the crop and livestock components
YA = Estimated from yield and acreage elasticities
PI = Estimated from an indirect profit function (duality approach)
CI = Estimated from an indirect cost function (duality approach)

A & C: Askari, Hossein and John Cummings. Agricultural Supply Response, A Survey of Econometric Evidence. Praeger Publishers, 1976.

The figures in parentheses are elasticities with respect to world prices.

APPENDIX V.
OWN-PRICE SUPPLY ELASTICITY, OTHER DEVELOPED COUNTRIES

Appendix V. Own-Price Supply Elasticity, Other Developed Countries

Crop	Region	Period	Author	Method of Estimation[1]	Short-Run Elasticity	Long-Run Elasticity
Wheat	France	1976	Bale & Lutz	Derived from Rojko, et. al	--	.42 to 1.28
	West Germany	1976	Bale & Lutz	Derived from Rojko, et. al.	--	.42 to 1.29
	United Kingdom	1976	Bale & Lutz	Derived from Rojko, et. al.	--	.47 to 1.42
	EC-6	1976	Rojko, et. al.	YA	--	.95
	EC-3	1976	Rojko, et. al.	YA	--	.85
	EC-10	1960-80	Liu & Roningen	DS	--	(.25)
	Other Western Europe	1960-80	Liu & Roningen	DS	--	(.25)
	EC-9	1960-80	Sarris & Freebairn	Derived from Rojko, et. al.	.35	--
	Other Western Europe	1960-80	Sarris & Freebairn	Derived from Rojko, et. al.	.35	--
	EC	1960-80	Tyers	DS	.30	.90
	EC-9	1961-76	Seeley	IIASA	1.08	2.89
	EC	1961-76	Frohberg & Kromer	IIASA	1.09	--
	Austria	1961-76	Frohberg & Kromer	IIASA	1.41	--
	United Kingdom	1924-39	Jones	A & C	.33 to .41	.46 to .98
	United Kingdom	1955-66	Colman	A & C	.17	--
	France	1945-61	Oury	A & C	.63	--
	Japan	1976	Bale & Lutz	Derived from Rojko, et. al.	--	.80 to 2.41
		1976	Rojko, et. al.	YA	--	.30
		1960-80	Liu & Roningen	DS	--	(.08)
		1960-80	Sarris & Freebairn	Derived from	.10	--
		1960-80	Tyers	DS	.30	.60
		1961-76	Frohberg & Kromer	IIASA	.44	--
	Australia & New Zealand	1976	Rojko, et. al.	YA	--	.55
		1960-80	Liu & Roningen	DS	--	(.08)
	Australia	1960-80	Sarris & Freebairn	Derived from Rojko, et. al.	.10	--
		1960-80	Tyers	DS	.30	.90
		1961-76	Seeley	IIASA	.47	.51
		1961-76	Frohberg & Kromer	IIASA	.64	--
		1947-64	Powell & Gruen	A & C	.18	.85
	New Zealand	1945-65	Guise	A & C	.96	1.58
	South Africa	1976	Rojko, et. al.	YA	--	.55
		1960-80	Sarris & Freebairn	Derived from Rojko, et. al.	.12	--
Rice	EC-6	1976	Rojko, et. al.	YA	--	.40
	Other Western Europe	1976	Rojko, et. al.	YA	--	.30
	EC-10	1960-80	Liu & Roningen	DS	--	(.25)
	Other Western Europe	1960-80	Liu & Roningen	DS	--	(.09)
	EC	1960-80	Tyers	DS	.20	.40
	EC	1961-76	Frohberg & Kromer	IIASA	1.49	--
	Japan	1976	Bale & Lutz	Derived from Rojko, et. al.	--	.08 to .24
		1976	Rojko, et. al.	YA	--	.16
		1960-80	Liu & Roningen	DS	--	(.15)
		1960-80	Tyers	DS	.20	.50
		1961-76	Frohberg & Kromer	IIASA	.31	--
		1962-81	Ito, et. al.	YA	.45	.50
	Australia & New Zealand	1976	Rojko, et. al.	YA	--	.16
		1960-80	Liu & Roningen	DS	--	(.10)
	Australia	1960-80	Tyers	DS	.18	.30
		1961-76	Frohberg & Kromer	IIASA	.94	--
	South Africa	1960-80	Liu & Roningen	DS	--	(.05)
Maize	France	1976	Bale & Lutz	Derived from Rojko, et. al.	--	.17 to .52
	West Germany	1976	Bale & Lutz	Derived from Rojko, et. al.	--	.17 to .53
	United Kingdom	1976	Bale & Lutz	Derived from Rojko, et. al.	--	.45 to 1.35
	EC-10	1960-80	Liu & Roningen	DS	--	(.25)
	Other Western Europe	1960-80	Liu & Roningen	DS	--	(.23)
	Japan	1960-80	Liu & Roningen	DS	--	(.29)
	South Africa	1960-80	Liu & Roningen	DS	--	(.25)
Barley	France	1976	Bale & Lutz	Derived from Rojko, et. al.	--	.42 to 1.28
	West Germany	1976	Bale & Lutz	Derived from Rojko, et. al.	--	.42 to 1.28
	United Kingdom	1976	Bale & Lutz	Derived from Rojko, et. al	--	.47 to 1.42
	United Kingdom	1924-39	Jones	A & C	.57 to .63	1.75 to 2.71
	United Kingdom	1955-66	Colman	A & C	.57	--
	Japan	1976	Bale & Lutz	Derived from Rojko, et. al.	--	.80 to 2.41
Oats	United Kingdom	1924-39	Jones	A & C	.11	.16
	United Kingdom	1955-66	Colman	A & C	1.56	--
Coarse Grains	EC-6	1976	Rojko, et. al.	YA	--	.91
	EC-3	1976	Rojko, et. al.	YA	--	.35

Appendix V Continued

Appendix V. Own-Price Supply Elasticity, Other Developed Countries, Continued

Crop	Region	Period	Author	Method of Estimation[1]	Short-Run Elasticity	Long-Run Elasticity
Coarse Grains	Other Western Europe	1976	Rojko, et. al.	YA	--	.49
	EC-10	1960-80	Liu & Roningen	DS	--	(.16)
	Other Western Europe	1960-80	Liu & Roningen	DS	--	(.25)
	EC	1960-80	Tyers	DS	.40	.91
	EC-9	1961-76	Seeley	IIASA	.76	1.37
	EC	1961-76	Frohberg & Kromer	IIASA	.93	--
	Austria	1961-76	Frohberg & Kromer	IIASA	.66	--
	France	1946-61	Oury	A & C	.77	--
	Japan	1976	Rojko, et. al.	YA	--	.25
		1960-80	Liu & Roningen	DS	--	(.30)
		1960-80	Tyers	DS	.30	.60
		1961-76	Frohberg & Kromer	IIASA	.38	--
	Australia & New Zealand	1976	Rojko, et. al.	YA	--	.81
		1960-80	Liu & Roningen	DS	--	(.16)
	Australia	1960-80	Tyers	DS	.20	.60
		1961-76	Seeley	IIASA	.39	.48
		1960-80	Frohberg & Kromer	IIASA	.84	--
		1947-64	Jowell & Gruen	A & C	.14	.81
	South Africa	1976	Rojko, et. al.	YA	--	(.60)
Oilseeds	EC-3	1976	Rojko, et. al.	YA	--	.02
	Other Western Europe	1976	Rojko, et. al.	YA	--	.20
	Japan	1976	Rojko, et. al.	YA	--	.43
	Australia & New Zealand	1976	Rojko, et. al.	YA	--	.45
Soybeans	EC-10	1960-80	Liu & Roningen	DS	--	(.25)
	Other Western Europe	1960-80	Liu & Roningen	DS	--	(.14)
	Japan	1960-80	Liu & Roningen	DS	--	(.06)
Other Oilseeds	EC-10	1960-80	Liu & Roningen	DS	--	(.25)
	Other Western Europe	1960-80	Liu & Roningen	DS	--	(.23)
	Japan	1960-80	Liu & Roningen	DS	--	(.25)
	South Africa	1976	Rojko, et. al.	YA	--	(.10)
Protein Feed	EC	1961-76	Frohberg & Kromer	IIASA	.04	--
	Austria	1961-76	Frohberg & Kromer	IIASA	.0	
	Japan	1961-76	Frohberg & Kromer	IIASA	.35	--
	Australia	1961-76	Frohberg & Kromer	IIASA	.0	--
Beef	France	1976	Bale & Lutz	Derived from Rojko, et. al.	--	.20 to .60
	West Germany	1976	Bale & Lutz	Derived from Rojko, et. al.	--	.20 to .60
	United Kingdom	1976	Bale & Lutz	Derived from Rojko, et. al.	--	.20 to .60
	EC-6	1976	Rojko, et. al.	YA	--	.40
	EC-3	1976	Rojko, et. al.	YA		.40
	Other Western Europe	1976	Rojko, et. al.	YA		.40
	Japan	1976	Bale & Lutz	Derived from Rojko, et. al.	--	.33 to .99
		1976	Rojko, et. al.	YA	--	.50
	Australia & New Zealand	1976	Rojko, et. al.	YA	--	.40
Beef & Veal	EC-10	1960-80	Liu & Roningen	DS	--	(.07)
	Other Western Europe	1960-80	Liu & Roningen	DS	--	(.01)
	Japan	1960-80	Liu & Roningen	DS	--	(.08)
	New Zealand	1960-80	Liu & Roningen	DS	--	(.34)
Mutton	EC-6	1976	Rojko, et. al.	YA	--	.30
	EC-3	1976	Rojko, et. al.	YA	--	.30
	Other Western Europe	1976	Rojko, et. al.	YA	--	.30
	New Zealand	1976	Rojko, et. al.	YA	--	.20
Mutton & Lamb	Japan	1960-80	Liu & Roningen	DS	--	(.35)
	EC-10	1960-80	Liu & Roningen	DS	--	(.33)
	Other Western Europe	1960-80	Liu & Roningen	DS	--	(.01)
	New Zealand	1960-80	Liu & Roningen	DS	--	(.07)
Ruminant Meats	EC-9	1961-76	Seeley	IIASA	.27	.27
	EC	1960-80	Tyers	DS	.23	.70
	Japan	1960-80	Tyers	DS	.40	.80
	New Zealand	1961-76	Seeley	IIASA	.24	.60
	Australia	1960-80	Tyers	DS	.18	.36
Bovine & Ovine Meats	EC	1961-76	Frohberg & Kromer	IIASA	.62	--
	Austria	1961-76	Frohberg & Kromer	IIASA	.61	--
	Japan	1961-76	Frohberg & Kromer	IIASA	.07	--
	Australia & New Zealand	1961-76	Frohberg & Kromer	IIASA	.11	--
Pork	EC-6	1976	Rojko, et. al.	YA	--	.70
	EC-3	1976	Rojko, et. al.	YA	--	.70
	Other Western Europe	1976	Rojko, et. al.	YA	--	.50
	EC-10	1960-80	Liu & Roningen	DS	--	(.07)
	Other Western Europe	1960-80	Liu & Roningen	DS	--	(.06)
	Japan	1976	Rojko, et. al.	YA	--	.70
		1960-80	Liu & Roningen	DS	--	(.25)
	Australia & New Zealand	1976	Rojko, et. al.	YA	--	.30
Poultry	EC-6	1976	Rojko, et. al.	YA	--	.70
	EC-3	1976	Rojko, et. al.	YA	--	.70
	Other Western Europe	1976	Rojko, et. al.	YA	--	.60
	Japan	1976	Rojko, et. al.	YA	--	.70
Poultry Meat	EC-10	1960-80	Liu & Roningen	DS	--	(.16)
	Other Western Europe	1960-80	Liu & Roningen	DS	--	(.39)
	Japan	1960-80	Liu & Roningen	DS	--	(.45)
Poultry Eggs	EC-10	1960-80	Liu & Roningen	DS	--	(.14)
	Other Western Europe	1960-80	Liu & Roningen	DS	--	(.19)
	Australia & New Zealand	1960-80	Liu & Roningen	DS	--	(.25)
Non-Ruminant Meats	EC	1960-80	Tyers	DS	.33	1.00
	Japan	1960-80	Tyers	DS	.23	.69
	Australia & New Zealand	1960-80	Tyers	DS	.10	.30

Appendix V Continued

Appendix V. Own-Price Supply Elasticity, Other Developed Countries, Continued

Crop	Region	Period	Author	Method of Estimation[1]	Short-Run Elasticity	Long-Run Elasticity
Milk	EC-6	1976	Rojko, et. al.	YA	--	.35
	EC-3	1976	Rojko, et. al.	YA	--	.35
	Other Western Europe	1976	Rojko, et. al.	YA	--	.30
	Japan	1976	Rojko, et. al.	YA	--	.80
	Australia & New Zealand	1976	Rojko, et. al.	YA	--	.40
Cheese	EC-6	1976	Rojko, et. al.	YA	--	.40
	EC-3	1976	Rojko, et. al.	YA	--	.40
	Other Western Europe	1976	Rojko, et. al.	YA	--	.50
	Japan	1960-80	Liu & Roningen	DS	—	(.35)
	Australia & New Zealand	1960-80	Rojko, et. al.	YA	--	1.00
Dairy Butter	EC-10	1960-80	Liu & Roningen	DS	--	(.18)
	Other Western Europe	1960-80	Liu & Roningen	DS	--	(.05)
	Australia & New Zealand	1960-80	Liu & Roningen	DS	—	(.05)
Dairy Cheese	EC-10	1960-80	Liu & Roningen	DS	—	(.23)
	Other Western Europe	1960-80	Liu & Roningen	DS	--	(.33)
	Australia & New Zealand	1960-80	Liu & Roningen	DS	--	(.05)
Dairy	EC-9	1961-76	Seeley	IIASA	.43	.40
	Japan	1961-76	Seeley	IIASA	.58	.88
		1961-76	Frohberg & Kromer	IIASA	.74	—
	New Zealand	1961-76	Seeley	IIASA	.12	.34
Dairy Products	EC	1961-76	Frohberg & Kromer	IIASA	.82	—
	Austria	1961-76	Frohberg & Kromer	IIASA	.73	—
	Australia	1961-76	Frohberg & Kromer	IIASA	.44	--
Sugar	France	1976	Bale & Lutz	Derived from Rojko, et. al.	—	.81 to 2.44
	West Germany	1976	Bale & Lutz	Derived from Rojko, et. al.	—	.43 to 1.30
	United Kingdom	1976	Bale & Lutz	Derived from Rojko, et. al.	—	.22 to .66
	EC-10	1960-80	Liu & Roningen	DS	--	(.13)
	Other Western Europe	1960-80	Liu & Roningen	DS	--	(.09)
	Japan	1976	Bale & Lutz	Derived from Rojko, et. al.	--	.21 to .64
		1960-80	Liu & Roningen	DS	--	(.25)
	Australia & New Zealand	1960-80	Liu & Roningen	DS	--	(.09)
Cotton	EC-10	1960-80	Liu & Roningen	DS	--	(.12)
	Other Western Europe	1960-80	Liu & Roningen	DS	—	(.25)
	Japan	1960-80	Liu & Roningen	DS	—	(.27)

[1]Method of Estimation Codes:

ID = Weighted average of input demand elasticities
DS = Direct estimation of the supply function
CL = Estimated from the crop and livestock components
YA = Estimated from yield and acreage elasticities
PF = Estimated from an indirect profit function (duality approach)
CF = Estimated from an indirect cost function (duality approach)

A & C: Askari, Hossein and John Cummings. Agricultural Supply Response, A Survey of Econometric Evidence. Praeger Publishers, 1976.

The figures in parentheses are elasticities with respect to world prices.

APPENDIX VI.
OWN-PRICE SUPPLY ELASTICITY, ASIAN AND AFRICAN COUNTRIES

Appendix VI. Own-Price Supply Elasticity, Asian and African Countries.

Crop	Region	Period	Author	Method of Estimation	Short-Run Elasticity	Long-Run Elasticity
Aggregate Farm Output	India	1955-56 (Cross-Sectional)	Lau & Yotopoulos	PF	1.166	—
		1960-77	Chhibber	DS (Nerlovian)	—	.06 to .07
		1960-77	Chhibber	Rational Expectations	.11 to .12	.18 to .21
		1960-77	Chhibber	DS	.20 to .30	.30 to .46
		----	Bapna	DS	.20 to .25	.50 to .60
	Pakistan	1962-82	Tweeten	DS	.15 to .39	.35 to .77
	Taiwan	1967-68 (Cross-Sectional)	Yotopoulos, Lau & Lin	PF	1.25	—
Coarse Grains	India	1976	Rojko, et. al.	YA	—	.21
		1960-80	Liu & Roningen	DS	—	(.15)
		1960-80	Tyers	DS	.15	.21
	Sri Lanka	1960-80	Tyers	DS	.15	.20
	Bangladesh	1960-80	Tyers	DS	.01	.04
	Pakistan	1960-80	Tyers	DS	.15	.19
		1961-76	Frohberg & Kromer	IIASA	.17	—
	Turkey	1961-76	Frohberg & Kromer	IIASA	.83	—
	Indonesia	1976	Rojko, et. al.	YA	—	.19
		1960-80	Tyers	DS	.13	.22
	Burma	1960-80	Tyers	DS	.20	.35
	Malaysia	1960-80	Tyers	DS	.52	.65
	Philippines	1960-80	Tyers	DS	.20	.40
	Thailand	1960-80	Tyers	DS	.12	.22
	Thailand	1976	Rojko, et. al.	YA	—	.20
	Taiwan	1960-80	Tyers	DS	.25	.50
	S. Korea	1960-80	Tyers	DS	.52	.65
	Other South Asia	1976	Rojko, et. al.	YA	—	.09
	Other Southeast Asia	1976	Rojko, et. al.	YA	—	(.20)
	East Asia	1976	Rojko, et. al.	YA	—	.15 to .23
		1960-80	Liu & Roningen	DS	—	(.21)
	N. Africa & Middle East	1976	Rojko, et. al.	YA	—	.12 to .14
		1960-80	Liu & Roningen	DS	—	(.25)
	Africa (Subsaharan)	1960-80	Liu & Roningen	DS	—	(.06)
	East Africa	1976	Rojko, et. al.	YA	—	.25
	Egypt	1961-76	Frohberg & Kromer	IIASA	.65	—
	Nigeria	1961-76	Frohberg & Kromer	IIASA	.03	—
Rice	India (Coimbatore District)	1977-78 (Cross-Sectional)	Kerirajan & Flinn	PF	1.32 to 1.96	—
	India	1962-81	Ito, et. al.	YA	.18	.22
		1960-80	Tyers	DS	.22	.29
		1976	Rojko, et. al.	YA	—	.32
		1960-80	Liu & Roningen	DS	—	(.13)
	India (Punjab)	1955-66	Askari & Cummings	A & C	.18	.42
		1951-64	Kaul	A & C	.24	.40
		1960-69	Kaul & Sidhu	A & C	.19 to .24	.64 to .68
	India (Bihar)	1953-63	Nowshivavani	A & C	—	.01 to .22
	India (Benagal)	1911-38	S. Krishna		.06	.19
	Sri Lanka	1962-81	Tyers	DS	.20	.32
		1955-79	Bogahawatte	YA	.31 to .48	—
	Bangladesh	1911-38	Tyers	DS	.13	.74
		1948-63	Hussain	A & C	.03 to .09	—
		1949-68	Cummings	A & C	.13	.19
		1950-68	Askari & Cummings	A & C	.23	1.28
		1962-81	Ito, et. al.	YA	.06	.07
	Pakistan	1960-80	Tyers	DS	.05	.07
		1976	Bale & Lutz	Derived from Rojko, et. al.	—	.15 to .45
		1961-76	Frohberg & Kromer	IIASA	.93	--
		1962-81	Ito, et. al.	YA	.09	.39
		1962-82	Tweeten	DS	.20 to .22	.45 to .66
	West Pakistan	1949-68	Cummings	A & C	.12	.17
	Turkey	1961-76	Frohberg & Kromer	IIASA	.57	—
	Indonesia	1955-79	Liu & Roningen	DS	—	(.12)
		1976	Rojko, et. al.	YA	—	.30
		1960-80	Tyers	DS	.12	.30
		1962-81	Ito, et. al.	YA	.17	.34
		1968-77	Hainggolan & Suprapto	DS	.161	.164
	Thailand	1960-80	Tyers	DS	.05	.08
		1976	Bale & Lutz	Derived from Rojko, et. al.	—	.07 to .22
		1962-81	Ito, et. al.	YA	.34	1.62
		1976	Rojko, et. al.	YA	—	.15
		1960-80	Liu & Roningen	DS	—	(.24)
		1937-63	Behrman	A & C	.17 to .18	.19 to .43
		1951-65	Arondee	A & C	.31	.20
	Burma	1962-81	Ito, et. al.	YA	.04	.04
		1960-80	Tyers	DS	.10	.20
	Malaysia	1960-80	Tyers	DS	.15	.38
	West Malaysia	1951-65	Arondee	A & C	.23 to .25	1.35

Appendix VI Continued

Appendix VI. Own-Price Supply Elasticity, Asian and African Countries, Continued.

Crop	Region	Period	Author	Method of Estimation[1]	Short-Run Elasticity	Long-Run Elasticity
Rice	Philippines	1960-80	Tyers	DS	.16	.26
		1962-81	Ito, et. al.	YA	.31	.47
		1910-41	Mangahas, Recto, and Ruttan	A & C	.01 to .26	.02 to 1.16
	Taiwan	1962-81	Ito, et. al.	YA	.14	.17
		1960-80	Tyers	DS	.10	.14
	South Korea	1960-80	Tyers	DS	.10	.14
		1962-81	Ito, et. al	YA	.45	.47
	Other South Asia	1976	Rojko, et. al.	YA	--	.055
		1960-80	Liu & Roningen	DS	--	(.14)
	Other Southeast Asia	1976	Rojko, et. al.	YA	--	.20
		1960-80	Liu & Roningen	DS	--	(.16)
	East Asia	1976	Rojko, et. al.	YA	--	.14 to .34
		1960-80	Liu & Roningen	DS	--	(.17)
	N. Africa & Middle East	1976	Rojko, et. al.	YA	--	(.50) to .65
		1960-80	Liu & Roningen	DS	--	(.15)
	Africa (Subsaharan)	1960-80	Liu & Roningen	DS	--	(.17)
	East Africa	1960-80	Liu & Roningen	DS	--	(.35)
	Egypt	1976	Bale & Lutz	Derived from Rojko, et. al.	--	.25 to .75
		1975-78 & 1978-81	DeJanvry, et. al.	PF	--	.32
		1961-76	Frohberg & Kromer	IIASA	2.03	--
	Sierra Leone	1974-75 (Cross-Sectional)	Strauss	PF	.11	--
	Kenya	1964-79	USDA	DS	.48	1.36
	Tanzania	1964-78	USDA	DS	.43	-2.41
	Senegal (area elasticity)	--	USDA	DS	3.00	--
	Nigeria	1961-76	Frohberg & Kromer	IIASA	.35	--
Root Crops and Other Cereals	Sierra Leone	1974-75 (Cross-Sectional)	Strauss	PF	.10	--
Wheat	India	1960-80	Tyers	DS	.31	.41
		1960-80	Sarris & Freebairn	1978 COL	.10	--
	India	1961-76	Seeley	IIASA	(.03)	(.09)
		1960-80	Liu & Roningen	DS	--	(.15)
		1976	Rojko, et. al.	YA	--	.38
	India (Punjab)	1970-71	Sidhu & Basnante (1979)	PF	.710	--
	India (Punjab)	1970-71 (Cross-Sectional)	Sidhu & Basnante (1981)	PF	.63 to .78	--
	India (Punjab dry farming)	1951-64	Kaul	A & C	.25	.27
	India (Punjab irrigated)	1951-64	Kaul	A & C	.08	.09
	India (Punjab)	1950-67	Cummings	A & C	.10	.13
	India (Delhi Union)	1968-75	DeJanvry & Kumar	PF	.24 to .25	--
	India (Delhi)	1953-67	Askari & Cummings	A & C	.25	.28
	Bangladesh	1960-80	Tyers	DS	.10	.67
	Pakistan	1960-80	Tyers	DS	.10	.15
		1976	Bale & Lutz	Derived from Rojko, et. al.	--	.17 to .53
		1961-76	Seeley	IIASA	.22	.51
		1961-76	Frohberg & Kromer	IIASA	.21	--
		1962-82	Tweeten	DS	.14 to .18	.27 to .40
	West Pakistan (dry farming)	1933-59	Falcon	A & C	.00	--
	West Pakistan (irrigated)	1933-59	Falcon	A & C	.10 to .20	--
	West Pakistan	1949-68	Cummings	A & C	.10	.22
		1950-68	Askari & Cummings	A & C	.07	.21
	Turkey	1961-76	Seeley	IIASA	.22	.58
		1961-76	Frohberg & Kromer	IIASA	.82	--
	Indonesia	1960-80	Liu & Roningen	DS	--	(.05)
	Burma	1960-80	Tyers	DS	.20	.31
	Taiwan	1960-80	Tyers	DS	.30	.45
	South Korea	1960-80	Tyers	DS	.30	.45
	Other South Asia	1976	Rojko, et. al.	YA	--	.15
		1960-80	Liu & Roningen	DS	--	(.14)
		1960-80	Sarris & Freebairn	1978 COL	.10	--
	Southeast Asia	1960-80	Sarris & Freebairn	1978 COL	.10	--
	Other Southeast Asia	1960-80	Liu & Roningen	DS	--	(.25)
	East Asia	1976	Rojko, et. al.	YA	--	.45
		1960-80	Liu & Roningen	DS	--	(.25)
	N. Africa & Middle East	1960-80	Sarris & Freebairn	1978 COL	.04	--
		1976	Rojko, et. al.	YA	--	.15 to .25
		1960-80	Liu & Roningen	DS	--	(.05)
	Africa (Subsaharan)	1960-80	Liu & Roningen	DS	--	(.22)
	Egypt	1960-80	Liu & Roningen	DS	--	(.39)
		1961-76	Seeley	IIASA	.70	.76
		1961-76	Frohberg & Kromer	IIASA	1.25	--
		1960-80	Sarris & Freebairn	1978 COL	.12	--
		1953-72	Askari, Cummings & Harik	A & C	.91	.44
		1976	Bale & Lutz	Derived from Rojko, et. al.	--	.12 to .37
	Kenya	1964-79	USDA	DS	1.51	4.10
	Tanzania	1964-78	USDA	DS	.99	3.02
	Nigeria	1961-76	Frohberg & Kromer	IIASA	-.79	--
	East Africa	1960-80	Liu & Roningen	DS	--	(.15)
Maize	India (Punjab)	1914-46	Raj Krishna	A & C	.23	.56

Appendix VI Continued

Appendix VI. Own-Price Supply Elasticity, Asian and African Countries, Continued.

Crop	Region	Period	Author	Method of Estimation[1]	Short-Run Elasticity	Long-Run Elasticity
Maize	Punjab	1960-69	Kaul & Sidhu	A & C	.11 to .13	.14 to .16
		1948-65	Haji, Jha & Venkataraman	A & C	.28 to .56	.35 to .66
	Pakistan	1976	Bale & Lutz	Derived from Rojko, et. al.	—	.10 to .30
	Thailand	1976	Bale & Lutz	Derived from Rojko, et. al.	—	.10 to .30
		1960-80	Liu & Roningen	DS	—	(.33)
	Thailand (4 provinces)	1949-63	Behrman	A & C	.27 to 4.47	.41 to 14.17
	Philippines	1910-41	Mangahas, Recto & Ruttan	A & C	Neg. to .12	Neg. to .11
		1946-64	Mangahas, Recto & Ruttan	A & C	Neg. to .23	.42 to 1.14
	Southeast Asia	1960-80	Liu & Roningen	DS	—	(.25)
	East Asia	1960-80	Liu & Roningen	DS	—	(.25)
	Africa (Subsaharan)	1960-80	Liu & Roningen	DS	—	(.57)
	East & North Africa	1960-80	Liu & Roningen	DS	—	(.90)
	Egypt	1960-80	Liu & Roningen	DS	—	(.25)
		1920-40	Askari, Cummings & Harik	A & C	-.16	-.25
		1953-72	Askari, Cummings & Harik	A & C	.04	.09
		1976	Bale & Lutz	Derived from Rojko, et. al.	—	.06 to .18
	Sudan	1951-65	Medani	A & C	.23	.56
	Kenya	1964-79	USDA	DS	.53	.66
	Tanzania	1964-78	USDA	DS	.36	2.38
Miscellaneous Other Crops	Pakistan	1962-82	Tweeten	DS	.15	.50
Miscellaneous Foods	Sierra Leone	1974-75 (Cross-Sectional)	Strauss	PF	.15	—
Other Food of Crop Origin	Egypt	1961-76	Frohberg & Kromer	IIASA	.73	—
	Turkey	1961-76	Frohberg & Kromer	IIASA	.29	—
	Pakistan	1961-76 (Cross-Sectional)	Frohberg & Kromer	IIASA	.53	—
	Nigeria	1961-76 (Cross-Sectional)	Frohberg & Kromer	IIASA	.33	—
Oilseeds (Other than soybeans)	India	1960-80	Liu & Roningen	DS	--	(.15)
Groundnuts	India (Punjab)	1953-66	Askari & Cummings	A & C	.18	.85
	Punjab	1960-69	Kaul & Sidhu	A & C	.51 to .78	3.05 to 3.25
	India	1938-57	NCAER	A & C	.22	—
	Sudan	1951-65	Medani	A & C	.72	1.62
Oils & Fats	Sierra Leone	1974-75 (Cross-Sectional)	Strauss	PF	.02	—
Oilseeds	India	1976	Rojko, et. al.	YA	—	.35
	Indonesia	1976	Rojko, et. al.	YA	--	.32
	Other South Asia	1976	Rojko, et. al.	YA	--	(.15)
	East Asia	1976	Rojko, et. al.	YA	--	(.03) to .27
Other Oilseeds	Indonesia	1960-80	Liu & Roningen	DS	--	(.15)
	Other Southeast Asia	1960-80	Liu & Roningen	DS	--	(.15)
	Africa (Subsaharan)	1960-80	Liu & Roningen	DS	--	(.16)
	N. Africa & Middle East	1960-80	Liu & Roningen	DS	--	(.15)
Soybeans	East Asia	1960-80	Liu & Roningen	DS	--	(.25)
Soybeans	N. Africa & Middle East	1960-80	Liu & Roningen	DS	—	(.19)
Protein Feed	Egypt	1961-76	Frohberg & Kromer	IIASA	.13	—
	Nigeria	1961-76	Frohberg & Kromer	IIASA	.04	—
Cotton	India	1960-80	Liu & Roningen	DS	--	(.25)
	India (Punjab, Desi Variety)	1922-43	Raj Krishna	A & C	.59	1.08
	Punjab (American Variety)	1922-43	Raj Krishna	A & C	.78	1.62
	India	1938-57	NCAER	A & C	.75	—
	India	1922-43	Raj Krishna	A & C	.64	1.33
	West Pakistan	1933-59	Falcon	A & C	.41	--
	Pakistan (Desi)	1950-67	Cummings	A & C	.41	.28
	Pakistan (American)	1950-67	Cummings	A & C	.40	.47
	Pakistan	1962-82	Tweeten	DS	.30 to .44	.88 to 1.03
		1976	Bale & Lutz	Derived from Rojko, et. al.	—	.82 to 2.47
	Indonesia	1960-80	Liu & Roningen	DS	--	(.25)
	Thailand	1960-80	Liu & Roningen	DS	—	(.25)
	Other South Asia	1960-80	Liu & Roningen	DS	--	(.25)
	Southeast Asia	1960-80	Liu & Roningen	DS	--	(.25)
	East Asia	1960-80	Liu & Roningen	DS	--	(.05)
	Africa (Subsaharan)	1960-80	Liu & Roningen	DS	--	(.05)
	N. Africa & Middle East	1960-80	Liu & Roningen	DS	—	(.25)
	Egypt	1960-80	Liu & Roningen	DS	—	(.18)
		1976	Bale & Lutz	Derived from Rojko, et. al.	—	.05 to .15
		1899-1937	Stern	A & C	.38	—
		1914-37	Stern	A & C	.52	—
		1953-72	Askari, Cummings & Harik	A & C	-.09	-.08
	Sudan	1951-65	Medani	A & C	.39	.50
	Nigeria	1948-67	Olayide	A & C	.03 to .04	--
		1948-67	Oni	A & C	.38	.28
Sugarcane (acreage elasticity)	India (Western region)	1950-74	Lal & Singh	DS	.60	2.21
	India (Eastern region)	1950-74	Lal & Singh	DS	.24	.70
	India (Central region)	1950-74	Lal & Singh	DS	.32	.72
	India (Uttar Pradesh)	1950-74	Lal & Singh	DS	.42	1.60
Sugar	India	1960-80	Liu & Roningen	DS	--	(.15)

Appendix VI Continued

Appendix VI. Own-Price Supply Elasticity, Asian and African Countries, Continued.

Crop	Region	Period	Author	Method of Estimation[1]	Short-Run Elasticity	Long-Run Elasticity
Sugar	India (Uttar Pradesh)	1953-64	Nowshirvani	A & C	-.04 to .63	-.29 to 1.19
	India (Punjab)	1951-64	Kaul	A & C	+.09	.73
	India (Madras)	1947-65	Madhavan	A & C	.52 to .63	.66 to 1.21
Sugarcane	Pakistan	1962-82	Tweeten	DS	.30 to .48	.44 to .94
Sugar	Indonesia	1960-80	Liu & Roningen	DS	--	(.09)
	Thailand	1960-80	Liu & Roningen	DS	--	(.14)
	Thailand	1976	Bale & Lutz	Derived from Rojko, et. al.	--	.08 to .24
	Philippines	1914-64	Askari	A & C	.08 to .13	.13 to .16
	Other South Asia	1960-80	Liu & Roningen	DS	--	(.19)
	Southeast Asia	1960-80	Liu & Roningen	DS	--	(.17)
	East Asia	1960-80	Liu & Roningen	DS	--	(.10)
	Middle East	1960-80	Liu & Roningen	DS	--	(.05)
	Africa (Subsaharan)	1960-80	Liu & Roningen	DS	--	(.07)
	Egypt	1960-80	Liu & Roningen	DS	--	(.16)
Cocoa (Acreage Elasticity)	Nigeria (Ondo)	1937-58	Oni & Olayemi	DS	--	.70
	Nigeria (Oyo)	1937-58	Oni & Olayemi	DS	--	1.09
	Nigeria (Ibadan)	1937-58	Oni & Olayemi	DS	--	.46
	Nigeria (Abeokuta)	1937-58	Oni & Olayemi	DS	--	.98
	Nigeria (Ijebu)	1937-58	Oni & Olayemi	DS	--	5.74
	Nigeria (Colony)	1937-58	Oni & Olayemi	DS	--	1.79
	West Nigeria	1937-58	Oni & Olayemi	DS	--	.91
Cocoa	Nigeria	1947-63	Behrman	A & C	--	.45
		1948-67	Olayide	A & C	.15 to .20	--
	Ghana (Central)	1946-62	Bateman	DS	--	.44
	Ghana (Western)	1946-62	Bateman	DS	--	.71
	Ghana (Volta)	1946-62	Bateman	DS	--	.61
	Ghana (Eastern)	1946-62	Bateman	DS	--	.32
	Ghana (Ashanti)	1946-62	Bateman	DS	--	.42
	Ghana [illegible])	1946-62	Bateman	DS	--	.87
	Ghana (Old Areas)	1949-62	Bateman	A & C	.39	.77
	Ghana (Medium Areas)	1949-62	Bateman	A & C	.42 to .51	1.28
	Ghana (New Areas)	1949-62	Bateman	A & C	.61 to .87	1.06
	Ghana	1947-63	Behrman	A & C	--	.71
Coffee	Kenya	1946-64	Maitha	A & C	.15	.38
		1946-64	Ford	A & C	--	.38
	Africa	1943-60	Behrman	A & C	.14 to .24	.37 to .60
Rubber	Thailand	1976	Bale & Lutz	Derived from Rojko, et. al.	--	.09 to .28
Mutton & Lamb	India	1960-80	Liu & Roningen	DS	--	(.35)
	N. Africa & Middle East	1960-80	Liu & Roningen	DS	--	(.68)
Ruminant Meat	India	1960-80	Tyers	DS	.04	.20
	Sri Lanka	1960-80	Tyers	DS	.01	.05
	Bangladesh	1960-80	Tyers	DS	.05	.20
	Pakistan	1960-80	Tyers	DS	.10	.30
	Burma	1960-80	Tyers	DS	.33	3.30
	Malaysia	1960-80	Tyers	DS	.19	.38
	Philippines	1960-80	Tyers	DS	.13	.50
	Thailand	1960-80	Tyers	DS	.33	1.00
	Indonesia	1960-80	Tyers	DS	.25	1.00
	Taiwan	1960-80	Tyers	DS	.25	.50
	South Korea	1960-80	Tyers	DS	.25	.50
Swine & Ovine Meat	Pakistan	1961-76	Frohberg & Krower	IIASA	.18	--
	Turkey	1961-76	Frohberg & Krower	IIASA	.41	--
	Egypt	1961-76	Frohberg & Krower	IIASA	.38	--
	Nigeria	1961-76	Frohberg & Krower	IIASA	.34	--
Livestock & Livestock Products	Pakistan	1962-82	Tweeten	DS	.14 to .15	.28 to .50
Beef		1976	Bale & Lutz	Derived from Rojko, et. al.	--	.15 to .45
Beef & Veal	N. Africa & Middle East	1960-80	Liu & Roningen	DS	--	(.21)
Fish & Animal Products	Sierra Leone	1974-75 (Cross-Sectional)	Strauss	PF	.09	--
Non-Ruminant Meats	India	1960-80	Tyers	DS	.25	1.00
	Sri Lanka	1960-80	Tyers		.25	1.25
	Bangladesh	1960-80	Tyers		.36	2.57
	Pakistan	1960-80	Tyers		.25	1.00
	Singapor	1960-80	Tyers		.37	.75
	Malaysia	1960-80	Tyers		.37	.75
	Indonesia	1960-80	Tyers		.25	1.00
	Burma	1960-80	Tyers		.24	1.41
	Philippines	1960-80	Tyers		.52	.87
	Thailand	1960-80	Tyers		.24	.64
	South Korea	1960-80	Tyers		.37	.75
	Taiwan	1960-80	Tyers		.37	.75
Pork	East Asia	1960-80	Liu & Roningen	DS	--	(.08)
Poultry - Meat	East Asia	1960-80	Liu & Roningen	DS	--	(.35)
Poultry - Eggs		1960-80	Liu & Roningen	DS	--	(.35)
Dairy - Butter	India	1960-80	Liu & Roningen	DS	--	(.18)
Dairy Products	India	1961-76	Seeley	IIASA	(.01)	(.01)
	Pakistan	1961-76	Seeley	IIASA	.15	.20
		1961-76	Frohberg & Krower	IIASA	.49	--
	Turkey	1961-76	Frohberg & Krower	IIASA	.33	--
	Egypt	1961-76	Frohberg & Krower	IIASA	.72	--
	Nigeria	1961-76	Frohberg & Krower	IIASA	.14	--
Other Animal Products	Thailand	1961-76	Seeley	IIASA	.70	.72
	Nigeria	1961-76	Seeley	IIASA	.19	.25
		1961-76	Frohberg & Krower	IIASA	.21	--
	Pakistan	1961-76	Frohberg & Krower	IIASA	.36	--
	Turkey	1961-76	Frohberg & Krower	IIASA	.45	--
	Egypt	1961-76	Frohberg & Krower	IIASA	.55	--

[1] Method of Estimation Codes:

ID = Weighted average of input demand elasticities
DS = Direct estimation of the supply function
CL = Estimated from the crop and livestock components
YA = Estimated from yield and acreage elasticities
PF = Estimated from an indirect profit function (duality approach)
CF = Estimated from an indirect cost function (duality approach)

A & C: Askari, Hossein and John Cumming. Agricultural Supply Response, A Survey of Econometric Evidence. Praeger Publishers, 1976.

The figures in parentheses are elasticities with respect to world prices.

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