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9. ABSTRACT
Perhaps no foreign aid program has generated as much debate as the U.S. Agricultural Trade Development and Assistance Act of 1954, known as Public Law 480 (PL480). A "disincentive effect" is created which, under the assumption of a positive supply elasticity, results in a decline in domestic food production. The effect upon development in the agricultural sector is therefore negative. This paper develops an improved econometric model which can be employed to calculate the disincentive effect. The question of the wider relevance of this type of analysis for policy purposes is also considered. Previous quantitative models by Mann, Rogers Srivastava and Heady, and Barnum are reviewed. The specification of a new model is discussed under the following headings: supply, demand, income generation, market-balancing (imports and stocks) and identities. The model was estimated for the period 1952-68, which was chosen to provide the maximum complete data length for pre-"green revolution: conditions. This ensures structural similarity to the sample periods used in previous models. The results are presented and discussed in detail. The model of the Indian cereals market developed in this paper appears to lend support to the argument by Schultz (1960) that food aid may not have a universally beneficial impact upon a recipient nation's economy.

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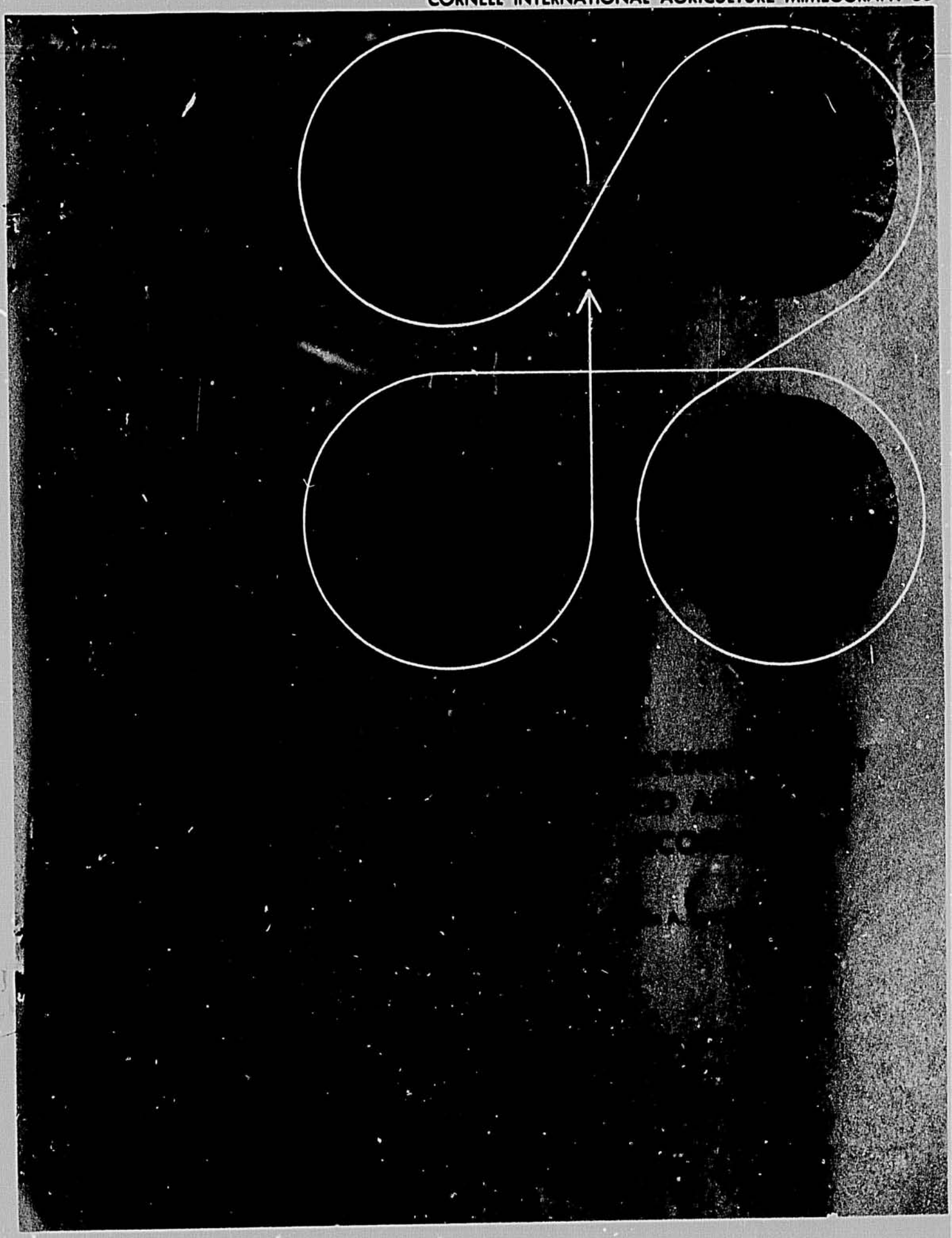

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EVALUATING THE DISINCENTIVE EFFECT OF PL480 FOOD AID: THE INDIAN CASE RECONSIDERED

by

David Blandford and Joachim A. von Plocki

DEPARTMENT OF AGRICULTURAL ECONOMICS

New York State College of Agriculture and Life Sciences
A Statutory College of the State University
Cornell University, Ithaca, New York

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EVALUATING THE DISINCENTIVE EFFECT OF FOOD AID:

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David Blandford and Joachim A. von Plocki*

I. INTRODUCTION

Perhaps no foreign aid program has generated as much debate as the U. S. Agricultural Trade Development and Assistance Act of 1954, known as Public Law 480 (PL480). It is widely used as an illustration of the potential impact of food aid on the economic development of a recipient country (e.g. Isenman and Singer, 1977).

After PL480 was approved in 1954 there was an interlude of several years before economists began to devote much attention to this new genre of foreign aid. It was not until Schultz (1960) published his important article questioning the benefits of such aid that the subject came into vogue. Schultz argued that prices received by farmers are depressed through the increased food supplies created by concessional imports. A "disincentive effect" is created which, under the assumption of a positive supply elasticity, results in a decline in domestic food production. The effect upon development in the agricultural sector is therefore negative.1/ Much of the ensuing scientific discussion has focused upon the relative importance of the disincentive effect.

One of the most significant theoretical contributions to the debate was made by Fisher (1963) who presented a formal analysis of the relationship between food imports and changes in domestic supply. Ignoring the possibility that food aid may increase real income and shift the demand curve to the right then, as Fisher demonstrates, the magnitude of the change in domestic supply depends upon the elasticity

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1/ It may be further reinforced if aid leads to decreased interest in agricultural development by the government of the recipient country.

of supply, the elasticity of demand and the ratio of total demand to domestic supplies.1/

Apart from this contribution many others concentrated on the question of whether there exists any price responsiveness in developing agricultures and what the hypothetical magnitude of such response might be. At least a part of this debate was more a reflection of ideology than of sound economic theory and empirical evidence. The discussion, though often of a circuitous and redundant nature, did serve to emphasize the need for empirical research to test opposing hypotheses.

It was Mann's (1967) major accomplishment to formalize the analytical and statistical framework of a multi-equation econometric model in an attempt to quantify the supposed disincentive effect, using the example of PL480 in India. Mann's approach was to employ the reduced form of his model to derive multipliers which summarized the average impact of food aid upon prices and production. Mann's results, which indicated that the impact was significant, were subsequently challenged by Rogers, Srivastava and Heady (1972) who argued that, by ignoring market differentiation and the income effect of aid, the true effect was considerably over-estimated. Their own model indicated that this was negligible.

These results (particularly the latter) have been widely quoted as evidence of the effects of food aid. However, a close examination of their theoretical and empirical validity reveals severe deficiencies. In this paper the aim is to identify and remedy these deficiencies by developing an improved econometric model which can be employed with greater confidence to calculate the disincentive effect. The question of the wider relevance of this type of analysis for policy purposes is also considered.

II. A REVIEW OF PREVIOUS QUANTITATIVE MODELS

The assessment of the disincentive effect is crucially dependent on the theoretical and empirical validity of the basic structural model. In this section three such models of the Indian cereals market are reviewed:

(A) Mann (1967),
(B) Rogers, Srivastava and Heady (1972), and
(C) Barnum (1971).

(A) Mann's Model.

Mann's model represents a pioneering attempt to analyze the cereals market and to derive quantitative estimates of the effects of food aid

1/ This basic approach was further developed by Seevers (1968). The particular value of this contribution is its consideration of the income effect. The other three variables that are introduced (population, government expenditure, and commercial imports) only undermine the clarity of the theoretical model whose main purpose is didactic.

upon prices and production. The considerable contribution that this work made in formalizing the elements of the market system must be acknowledged.

The model consists of six structural equations: (1) supply; (2) demand; (3) income generation; (4) commercial imports; (5) withdrawal from stocks; and (6) market clearing. These are summarized in table 2.1. PL480 imports are introduced as an exogenous variable in equations (4) and (5) and in the market clearing identity. Equation (3), the income generation equation, reflects the fact that national income cannot be considered as an exogenous variable due to the importance of agriculture and its cereals in the Indian economy. The presence of the remaining equations requires no comment.

Most of the theoretical deficiencies of the model are associated with the supply equation. In the first place, the use of a single linear equation with quantity as the dependent variable to reflect a non-linear relationship (area x yield) has obvious weaknesses. The specification of separate area and yield functions generally proves superior, except in the case where no systematic change in yield has occurred. This does not apply in India where cereal yields during the period considered displayed a strong upward trend.1/ Furthermore, the inclusion of lagged cereal yield (a_{t-1}) in the equation "as a proxy for both weather and technology" (Mann, 1972, p. 135 emphasis added) would seem to undermine the linearity assumption.

Probably the major reason why Mann avoided the specification of separate area and yield functions was the problem of nonlinearity that this would introduce and its consequences for the derivation of the reduced form coefficients and impact multipliers.2/ He continues to avoid non-linearity by using per capita quantities throughout the model. A per capita quantity dependent demand equation certainly raises few problems but a per capita quantity dependent supply equation does seem to be rather curious. Systematic changes in the dependent variable which are attributable to population growth are not reflected in the explanatory variable set and this clearly constitutes an added weakness in the supply function. It is also present in equations 3-5 which employ per capita dependent variables.

A further problem in the supply function is the dating of "dependent" and "explanatory" variables. It appears that the quantity variable (q_t^s) and the yield variable (a_{t-1}) actually relate to the same production period. Mann defines the dependent variable as the availability of domestically produced cereals for consumption in period t but apparently the crop was actually sown and produced in the previous period. This is substantiated by Mann's statement on page 135 "The quantity available from domestic production for human consumption during the year is mostly the result of production decisions made during the previous year"

1/ The linear trend equation, for example, is: $Y = -28.5761 + 0.1494\ T$ ($r=0.87$). Y=cereal yield in tonnes per hectare from table B.1, Appendix B.

2/ This is discussed in Section V of our paper.

Table 2.1. Structural Equations and Variables in Mann's Model.

(1) Supply: $q_t^s = f_1(p_{t-2}, a_{t-1})$

(2) Demand: $q_t^d = f_2(p_t, p_t^r, y_t)$

(3) Income Generation: $y_t = f_3(q_t^s, GE_t)$

(4) Commercial Imports: $I_t^o = f_4(q_t^s, W_t, I_t^p)$

(5) Withdrawal from Stocks: $W_t = f_5(q_t^s, I_t^o, I_t^p, S_t)$

(6) Market Clearing: $q_t^d = q_t^s + I_t^p + W_t + I_t^o$

q^s = per capita net supply (net of feed, seed and industrial uses) from domestic production of cereals.

p = index number of wholesale prices of cereals (1952/3 = 100) deflated by the index of wholesale prices of all commodities.

a = average yield of cereals.

q^d = per capita demand for cereals.

p^r = wholesale price index for food other than cereals (1952/3 = 100) deflated by the index of wholesale prices for all commodities.

y = index of per capita net output (1948/49 = 100 at 1948/49 prices) adjusted from fiscal to calendar years.

GE = per capita expenditures by the central and state governments.

I^o = per capita imports of cereals other than PL480.

W = per capita withdrawal from government stocks.

I^p = per capita imports of cereals under PL480.

S = per capita opening stocks.

t = time period - calendar year.

Estimation period: 1952-63.

and by the fact that the explanatory variable - price, has a two-period, rather than a one-period lag. In this case the quantity and yield variables actually relate to the same period.1/ Yield is included both as an explanatory variable and as part of the dependent variable. The conditions for an independent error term are violated and serial correlation is introduced.

A final deficiency of the supply equation is its failure to reflect rigidities in production response. There is no distinction between short- and long-run price elasticity. In the case of Indian agriculture such a distinction is likely to be important and should be represented, for example, by a lagged production variable.

With respect to the estimated model many of the estimated coefficients have large standard errors. The coefficients in the demand and stock withdrawal equations are particularly imprecise. Unfortunately, Mann does not present any diagnostic statistics such as the Durbin-Watson "d" statistic which would serve as a guide to the presence of autocorrelation.

In conclusion, Mann's model clearly has theoretical and empirical weaknesses which must cast doubt upon its ability to accurately reflect the impact of PL480 imports upon the Indian cereals market. However, as a pioneering contribution it clearly has considerable merit.

(B) The Rogers, Srivastava, and Heady (RSH) Model.

In 1972 Rogers, Srivastava, and Heady published a new study of the impact of food aid. They argued that Mann's approach was inadequate since it failed to differentiate between the commercial market and the concessional market, through which food aid was distributed at controlled prices. They therefore attempted to develop a model which would reflect market differentiation.2/

The RSH model (table 2.2) is broadly similar in structure to Mann's model. Consequently many of the inherent weaknesses of that model are perpetuated. Specifically:

(1) the use of a linear quantity-dependent supply function;
(2) the employment of *per capita* quantities throughout;
(3) the absence of a lagged production variable in the supply equation;
(4) the specification error created by the inclusion of yield as an explanatory variable in the supply function.

This last weakness in the supply relationship is further compounded by the inclusion of a rainfall index which relates to the same period

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1/ The question of the time-dating of variables is dealt with in Appendix C.

2/ This model has also formed the basis for a book, Srivastava *et al.* (1975).

Table 2.2. Structural Equations and Variables in the Rogers, Srivastava, and Heady Model.

(1) Supply: $Q^s_t = f_1(P^c_{t-2}, R_{t-1}, T_{t-1})$

(2) Open Market Demand: $Q^d_t = f_2\ (P^c_t, P^r_t, Y_t)$

(3) Concessional Distribution: $Q^c_t = f_3(P^p_t, P^c_t, Y_t, M^p_t)$

(4) Income: $Y_t = f_4(Q^s_t, Q^i_t, G_t)$

(5) Commercial Imports: $M^o_t = f_5(P^c_t, P^r_t, Y_t)$

(6) Withdrawal from Stocks: $W_t = f_6(Q^c_t, M^o_t, M^p_t, C^p_t)$

(7) Market Clearing: $Q^d_t + Q^c_t - Q^s_t - M^p_t - M^o_t - W_t = 0$

Q^s = *per capita* quantity of cereals available from domestic production for consumption.

P^c = deflated index of wholesale prices of cereals.

R = rainfall index.

T = cereal yield.

Q^d = *per capita* quantity of cereals demanded in the open market.

P^r = deflated price of non-cereal foods.

Y = deflated *per capita* consumer income.

Q^c_t = *per capita* quantity of cereals distributed through the concessional market.

P^p = predetermined cereals price charged in the concessional market deflated by a consumer price index.

M_p = *per capita* quantity of concessional imports of cereals under PL480.

Q^i = the value of *per capita* industrial output deflated by the consumer price index.

G = deflated *per capita* government expenditure.

M^o = *per capita* quantity of commercial imports.

W = *per capita* net withdrawals of cereals from government stocks.

C^p = *per capita* internal procurement of cereals by the government.

t = time period - calendar year.

Estimation period: 1956-67.

as yield and hence quantity. While the authors do not acknowledge the consequences for the independence of the error term they do recognize the possibility that collinearity may exist in the explanatory variables set. They cite the low correlation between rainfall and yield as their justification for the inclusion of both variables. Apart from the rather questionable logic of rationalizing a theoretical mis-specification on the grounds of an empirical phenomenon the situation is further complicated by the apparent contradiction between their argument and the results derived by Cummings and Ray (1969), the inventors of the rainfall index in question. Cummings and Ray, in their paper, attempt to demonstrate the opposite conclusion, that rainfall and yield are closely related. By employing a simple linear equation in which cereal yield is expressed as a function of the weather index and trend a highly significant statistical relationship is obtained. The apparent contradiction is not noted in the Roger's paper.

The major distinguishing feature of the RSH model and the reason why it is suggested as a superior alternative to Mann's model is its disaggregation of demand into two separate relationships: open (commercial) market demand (equation 2), and concessional distribution (equation 3). The justification for this is that the concessional market is largely distinct from the non-concessional market, due primarily to qualitative differences between the cereals sold in each. Moreover a major feature of the concessional market is administered prices set at levels below those in the commercial market.

The authors suggest that disaggregation of the two markets provides the opportunity to test Fisher's (1963) hypothesis - that the distribution of cereals at lower prices may lead to an overall expansion of demand which will tend to offset price-reducing and hence supply-reducing effects in the domestic cereals market. The availability of low-priced cereals may generate a real income effect tending to outweigh the substitution effect upon non-concessional demand.1/ While this is an extremely interesting hypothesis we shall subsequently argue that their model does not reflect the influence that the authors seek to demonstrate and substantially biases their results.

In terms of the form of the concessional demand equation (table 2.2, equation 3) a key issue is whether any price response can have been expected to operate in the market. The price of concessionally-distributed cereals was consistently kept below that for cereals in the commercial market and quantities offered for sale were small relative to total demand.2/ It is therefore likely that the concessional market was always subject to excess demand (Shenoy, 1974, pp. 261-3). This

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1/ The magnitude of the effect is dependent upon the price differential, which determines the amount of income freed for expenditure elsewhere, and upon the income elasticity of demand for cereals among those individuals who benefit from concessional distribution.

2/ Although concessional prices varied according to market they were generally in the range 75-90 percent of free market prices. See, for example, Rath and Patvardham (1967, p. 68). Concessional sales represented roughly 10 percent of total sales.

would make price largely irrelevant and place most weight upon availability as the determinant of a rationing process. This line of reasoning appears to be supported by the results of estimation. Both price variables (for concessional and open market cereals) have high standard errors while the availability variable (quantity of concessional imports under PL480) displays high precision.

The most significant problem in the interpretation of this equation is the degree of separation which is assumed between concessional and commercial markets. As an examination of table 2.2 demonstrates, apart from model closure (equation 7), there is little direct linkage between the two demand equations. What direct interrelationship exists is from commercial to concessional demand and not vice versa.1/ There are no explanatory variables which tie the effects of food aid into commercial demand either directly, or indirectly through its influence upon real national income. This lack of linkage is an extremely significant omission. It implies that the model: a) essentially treats concessional and open-market cereals as two entirely different products; and b) fails to reflect the "real income effect" of concessional distribution which the model is supposed to test.

It may be plausible to hypothesize the existence of a real income effect sufficient to offset the disincentive impact of food aid. However, the way in which the RSH model is structured does not allow us to test the hypothesis. Rather, it virtually assumes away any effects of concessional sales and food aid upon prices in the commercial market and hence upon domestic supply.2/ This is one of the model's most serious logical deficiencies.

The authors claim that their model is an improvement over Mann's specification. We would argue that it is theoretically inferior and no better empirically than Mann's model. Many of the estimated coefficients have high standard errors. Most importantly the particularly vital price coefficient in the supply equations has a low level of precision.

(C) Barnum's Model.

Although the publication of Barnum's model pre-dates that of Rogers et al. it was not acknowledged by the latter. Due to this fact, and also to its focus upon all foodgrains rather than just cereals, it seems appropriate to include it at this stage of the discussion. The model (table 2.3) consists of nine equations: (1) acreage; (2) yield; (3) price determination; (4) income generation; (5) imports; and four identities (6) - (9). There is a single demand function expressed in the form of a price determination equation.

1/ Viz. the inclusion of the open market price of cereals in the concessional demand equation (3).

2/ As far as commercial demand is concerned the model actually reflects a scenario in which food aid is given away free to individuals who have no income.

Table 2.3. Structural Equations and Variables in Barnum's Model.

(1) Acreage: $AFG_t = f_1(AFG_{t-1}, PIFG_{t-1}, T, WS_t)$

(2) Yield: $ZFG_t = f_2(F_t, W_t)$

(3) Price Determination: $PIFG_t = f_3(DFG_t, YN_t, N_t, PIDS_t)$

(4) Income Generation: $Y_t = f_4(QFG_t, E_t)$

(5) Imports: $MFG_t = f_5(X_t, BY_t)$

Model Closing Identities (6) - (9)

(6) $QFG_t = AFG_t \cdot ZFG_t$

(7) $DFG_t = MFG_t + QFG_{t-1} = \Delta GFG_t + MPFG_t$

(8) $X_t = QFG_{t-1} - \Delta GFG_t + MPFG_t$

(9) $YN_t = Y_t/N_t$

AFG = area sown to foodgrains.
PIFG = deflated price index for foodgrains.
T = time.
WS = weather index for the pre-sowing period.
ZFG = yield.
F = index of fertilizer use.
W = growing season weather index.
DFG = total quantity (gross) of foodgrains consumed.
YN = real net national product per capita.
N = population.
PIDS = deflated price index of demand substitutes.
Y = net national product.
QFG = gross production of foodgrains.
E = total central and provincial government expenditure.
MFG = volume of non-PL480 imports.
X = availability of foodgrains before commercial imports.
BY = measure of foodgrain import capacity.
ΔGFG = volume of additions to government stocks.
MPFG = volume of foodgrain imports under PL480.

Estimation period: 1948-64.

Major features of the Barnum model are (a) its use of separate area and yield equations rather than a single quantity-dependent supply function; and (b) its employment of both total and per capita variables rather than just per capita forms throughout as in both the Mann and RSH models. These lead to a considerable improvement both theoretically and empirically but do raise problems in the derivation of reduced form coefficients.1/

The model's major weakness lies in its treatment of all foodgrains as a homogeneous aggregate for which PL480 cereal imports are a perfect substitute. On the consumption side it is clearly an approximation to assume perfect substitutability due to the differing physical characteristics of the two commodity groups. However, the assumption of homogeneity may prove adequate for the evaluation of PL480 impact. On the production side an examination of the data reveals that the direction of association between pulse and cereal acreage is negative, a fact which is at variance with the homogeneity assumption.2/ Pulse acreage may not respond in the desired way to PL480 imports and their price effect. Switching between cereals and pulses in production may lead to an underestimate of the true impact of PL480 when aggregate supply of both commodities is employed.

Apart from this problem Barnum's basic model structure represents a major improvement over Mann and Rogers et al. Statistical quality is much improved and greater confidence can be placed in its use as an analytical device. Further developments in this area must clearly follow the Barnum pattern.

III. SPECIFICATION OF A NEW MODEL

A meaningful model should at the minimum include four blocks of functional relationships and a set of model-closing identities. Therefore, the specification of the model is discussed under the following headings:

1. supply;
2. demand;
3. income generation;
4. market-balancing (imports and stocks);
5. identities.

1/ See Section V of this paper.

2/ $r=-0.30$ for Barnum's sample period. Computed from Barnum's data and that in Appendix B.

1. Supply.

The specification of a single quantity dependent supply equation is generally inferior to separate area and yield functions. Furthermore the use of per capita quantities should be avoided. The model therefore includes separate response functions for total area and yield.

It is hypothesized that the area response function is of the form:1/

$$A_t = f_1(A_{t-1}, P_{t-1}, R_t, N_t) \tag{3.1}$$

where A = area sown to cereals
P = deflated wholesale price index for cereals
R = rainfall index
N = population
t denotes a calendar year observation period

As is readily apparent equation 3.1 is a variant of the well-known geometric form distributed lag model (Nerlove, 1958). This formulation is employed to reflect the belief that area adjustment to changes in price is not instantaneous; lags in supply response are present due to behavioral and technological rigidities. A distinction is therefore made between short- and long-run price elasticity of supply.

The rainfall index, which is intended to capture short-term fluctuations in plantings due to weather, is of the type developed by Cummings and Ray (1969). This index is an all-India average whose weights reflect the aggregate impact of rainfall in a given year. As such it can serve to reflect weather-induced fluctuations in both acreage and yield (Ray, 1971). Population is included to capture the general upward trend in acreage associated with population growth. An increasing work force facilitates the expansion of cultivated area devoted to cereal production.

Two alternative yield response functions are hypothesized:

$$Y_t = f_2(R_t, T) \tag{3.2}$$

$$Y_t = f_2'(R_t, F_t) \tag{3.2a}$$

where Y = cereal yield
T = time trend
F = fertilizer use per unit of cultivated area

1/ Detailed information on the definition of variables and data employed is included in Appendix B.

These differ only through uncertainty as to which variable is more appropriate to reflect the systematic effects of technological change. A priori all explanatory variables in these equations are expected to display positive signs in estimation. Rainfall is primarily acreage and yield stimulating when plentiful and a depressant when scarce.1/

2. Demand.

The key question in the specification of demand is the role played by concessionally distributed cereals. The simplest alternative is to assume that, although differences in market structure exist, the best approximation can be achieved through the use of a single demand equation. An appropriate form for such an equation might be:

$$QDC_t = f_3(P_t, PS_t, IC_t) \tag{3.3}$$

where QDC = per capita demand for cereals
PS = deflated price index of consumption substitutes for cereals
IC = real per capita consumer income

Deflation of both prices and income by an appropriate consumer price index ensures that the theoretically necessary homogeneity condition is satisfied (Phlips, 1974, p. 38). A priori the own-price coefficient is expected to be negative and the substitute and income coefficients to be positive.

One reason why a single equation might be an unreasonable approximation was mentioned by Rogers et al. (1972). If major qualitative differences exist between open market and concessionally distributed cereals then it is possible that separate demand relationships should be identified. Qualitative differences certainly exist but it is doubtful if these are sufficiently great to merit different demand functions. Consumers may have a preference for domestic varieties of cereals which is reflected by a willingness to pay a price premium but this is unlikely to imply a fundamental difference in behavior.

A second, and more relevant, reason why one might wish to differentiate between concessional distribution and open-market demand is that the former may exert an income effect upon the latter. The issue then becomes one of how this should be reflected in an aggregate econometric model. It was argued in the previous section that due to rationing price response in the concessional "market" was unlikely to be present. Furthermore, the use of income as an explanatory variable in an administered "demand" equation is likely to be misleading. If concessional distribution should be separately identified it is probably best represented as an exogenously determined variable in an identity.

1/ This relationship is only appropriate over a certain range. Too much rainfall could result in flooding and decreased yields. This problem did not occur during the period actually considered (1952-68).

In order to capture the income effect of concessional consumption it is necessary to reflect the impact of changes in the price, or relative price, of concessional cereals upon income in the open market demand function. The exact effect could only be obtained through fairly detailed studies at the household level in which individual consumption behavior under differentiated market conditions were monitored and the influence of food aid upon "effective" consumer income determined. In the absence of such information an aggregate approximation of the impact upon open-market demand must be attempted. One possibility is to redefine (3.3) as an open-market demand equation and deflate the income variable by the ratio of concessional and open-market prices of cereals. Thus:

$$QDC_t^o = f_3'(P_t, PS_t, \frac{IC}{P_t^P/P_t}) \qquad (3.3a)$$

where QDC_t^o = open-market demand equation
P^P = the real administered price of concessionally-distributed cereals

The lower the concessional price relative to the free-market price, the higher the "effective" income in the concessional demand equation. The variable therefore approximates the offsetting effect upon commercial demand created by lower-priced concessional distribution. Through this device we at least achieve a degree of linkage between the two outlets; the crucial factor that was omitted in the approach of Rogers et al. (1972) to this problem.

3. Income-Generation.

Since a large part of the national income of India is generated by agriculture and since cereals are a major product of the sector, income cannot be treated as an exogenous variable. To do so would be to neglect multiplier effects of changes in cereal production. The second most important source of income in India is industrial production therefore, the income generation equation is specified as:

$$I_t = f_4(QS_t, QI_t) \qquad (3.4)$$

where I = total real consumer income
QS = total domestic cereal supply
QI = an index of industrial production

A priori both estimated coefficients are expected to display positive signs.

4. Market-Balancing.

This term is used for those relationships which contribute towards domestic market equilibrium and cannot be considered to be predetermined.

Two elements fall into the category: (a) commercial imports; and (b) stock withdrawal.

Commercial imports, which are determined by government planning, play an important role in bridging the gap between domestic production and total demand. As part of a public food policy their level is likely to be heavily influenced by the anticipated political consequences of "shortages" and by budgetary constraints. It is assumed that these factors can be reflected by the following specification:

$$M_t = f_5(QG_t, FX_t) \tag{3.5}$$

where M = commercial imports
QG = the expected "food gap"
FX = effective level of foreign exchange reserves

The food gap variable represents the anticipated shortfall (with no imports and constant stocks) between estimated demand and domestic availability (the sum of net domestic supply and PL480 shipments). It is assumed that estimates of total demand are based upon the physiologically necessary minimum per capita intake of cereals and population size.1/ The effective foreign exchange variable is defined as nominal foreign exchange holdings deflated by the ratio of world market prices for cereal imports to the price of all other imports. While import plans may not actually be formed using these factors we suggest that they serve as valid proxies for two major influences upon the import decision. A priori both explanatory variables are expected to display positive signs in estimation. A larger expected food gap will increase the pressure to import; larger effective foreign exchange reserves will ease financial restraints upon importing.

Stockholding behavior is an important balancing element in many commodity markets. Unfortunately, due to inadequate data, it is impossible to fully reflect the stocks situation. Information on private storage is unavailable and this component must regrettably be neglected. Fortunately data on the level of public stocks exists and it is the variation in this important component that is incorporated in the model.

It is assumed that withdrawals from publicly held stocks may be represented by the function:

$$W_t = f_6(QG_t, S_t, PR_t) \tag{3.6}$$

where W = withdrawals
S = beginning period stocks
PR = internal procurement of cereals by the government

1/ See Appendix B for the construction of this variable.

The size of the expected food gap and of beginning period stocks can both be expected to exert a positive influence upon withdrawals. The food gap phenomenon will exert increased pressure upon stocks while a larger initial volume of stored cereals will increase the potential for withdrawal. Internal procurement, which represents the amount of domestically produced cereals bought by government and sold through concessional outlets, would a priori be expected to exert a negative influence on withdrawals. The higher the volume of procured cereals released onto the market the lower the pressure upon stocks.

5. Identities.

Several identities are required to close the model. In the first place domestic supply must be defined in terms of area and yield:

$$QS_t = A_t \times Y_t \tag{3.7}$$

where QS = total domestic supply of cereals

Supply is linked to demand through the use of a market-clearing identity whose form depends on whether concessional distribution is separately identified. Since feed/seed usage and spoilage/loss are generally acknowledged to reduce the supply available for human consumption by roughly 12.5 percent then this must also be reflected. If concessional distribution is ignored and equation 3.3 employed, the identity can be written as:1/

$$QD_t = 0.875\ QS_t + M_t + W_t + PL480_t \tag{3.8}$$

where QD = total consumer demand for cereals
$PL480_t$ = total food aid imports

If concessional distribution is separately identified the appropriate form is:

$$QD^o_t + QD^c_t = 0.875\ QS_t + M_t + W_t + PL480_t \tag{3.8a}$$

where QD^o = total demand in the open (commercial) market
QD^c = total concessional distribution

1/ In his comments J. S. Mann expressed the opinion that PL480 imports are not exogenous but an endogenous variable dependent upon the same sort of factors as commercial imports in the model. The authors believe that due to the rigidities of institutional supply it is more reasonable to treat PL480 imports as exogenous and commercial imports as a balancing residual.

Two *per capita* definitions are required:

$$QDC_t = QD_t/N_t \tag{3.9}$$

or alternatively:

$$QDC_t^o = QD_t^o/N_t \tag{3.9a}$$

and:

$$IC_t = I_t/N_t \tag{3.10}$$

Finally, the food gap variable is defined as:

$$QG_t = QM_t - 0.875\ QS_t - PL480_t \tag{3.11}$$

where QM = the physiologically necessary minimum availability of cereals

The model contains eleven endogenous variables and, depending upon exact specification, between eleven and fifteen predetermined variables.1/ These are summarized in table 3.1.

IV. ESTIMATION AND RESULTS

If it is assumed for the moment that the three nonlinear identities (equations 3.7, 3.9, and 3.10) can be accurately approximated by linear equations then the structural form of the model can be expressed in matrix notation as:

$$By_t + \Gamma x_t = u_t \qquad (i = 1, 2, \ldots n) \tag{4.1}$$

where B is a G x G matrix of coefficients on current endogenous variables (G = 11)
Γ is a G x K matrix of coefficients on predetermined variables ($12 \leq K \leq 15$)
and y, x and u are column vectors of G, K, and G elements respectively

The first equation in the model can be written in the general form:

1/ It would clearly be possible to reduce the number of endogenous variables by, for example, combining equations 3.3 and 3.10. However, it simplifies the subsequent derivation of linear approximations if non-linearities are confined to the identity set.

Table 3.1. Summary of the Variables Employed in Model Specification.

Endogenous

1. A = area sown to cereals
2. P = deflated wholesale price index for cereals
3. Y = yield
4. QDC = per capita demand for cereals or QDC^o = per capita open (commercial) market demand
5. QD = total demand for cereals or QD^o = total open (commercial) market demand
6. IC = per capita consumer income
7. I = total consumer income
8. M = commercial imports
9. QG = expected "food gap"
10. W = withdrawal from stocks
11. QS = total domestic availability of cereals

Predetermined

A. Lagged Endogenous

1. A = area sown to cereals
2. P = deflated wholesale price index for cereals

B. Exogenous

3. R = rainfall index
4. N = population
5. T = time trend
6. F = fertilizer use per unit of cultivated area
7. PS = deflated price index of consumption substitutes for cereals
8. P^P = deflated index of the administered price of concessional cereals
9. QI = index of industrial production
10. FX = effective level of foreign exchange reserves
11. S = beginning period stocks
12. PR = internal procurement of cereals by the government
13. QD^c = total concessional distribution of cereals
14. PL480 = food aid imports
15. QM = physiologically necessary minimum availability of cereals

$$y_{1t} = -\beta_2 y_{2t} - \dots - \beta_G y_{Gt} - \gamma_0 x_{0t} - \gamma_1 x_{1t} - \dots \quad (4.2)$$

$$- \gamma_K x_{Kt} + u_{1t}$$

where $x_{0t} = 1$; γ_0 is the intercept

If all the β coefficients on the right-hand side of 4.2 are zero then the dependent variable is solely a function of predetermined variables and the equation can be estimated using ordinary least-squares (OLS). This applies to the area and yield equations (3.1 and 3.2) presented above. Equations 3.3 - 3.6 (demand, income generation, imports, and stock withdrawals) do not satisfy this condition and require a simultaneous estimation technique. The question of identification is therefore relevant. All four equations are in fact over-identified and under assumed error properties the two-stage least-squares (2SLS) method of estimation will provide consistent estimates of the coefficients (Johnson, 1972, pp. 341-48).

The model was estimated for the period 1952-68, which was chosen to provide the maximum complete data length for pre- "green revolution" conditions. This ensures structural similarity to the sample periods used in previous models.1/ The results are presented and discussed below.

All equations are written with standard errors of estimated coefficients in parentheses and are accompanied by the following:

(1) the number of degrees of freedom (DF);
(2) the standard error of the estimate (SE);
(3) the Durbin-Watson statistic (d);2/ and
(4) Theil's inequality coefficient (U2).

Equations estimated using OLS are also accompanied by:

(5) the adjusted coefficient of multiple correlation ($\bar{R}^2$); and
(6) the "F" statistic (F).

The majority of these statistics are well-known and can be found in any standard econometrics text (for example Johnston). Theil's inequality coefficients, of which there are two major variants, were developed to assess the predictive ability of an equation (Theil, 1966).

1/ With only 17 observations the number of degrees of freedom in the reduced forms must inevitably be small. In the final version there are 5 degrees of freedom which compares favorably with other models. The RSH model, for example, contains only 3 degrees of freedom.

2/ The presence of "**" next to the d value indicates that the statistic confirms the null hypothesis of the presence of autocorrelated residuals at the 95 percent level of confidence; "*" indicates that the value lies in the inconclusive region; " " indicates that the null hypothesis is rejected.

Hence [1]:

$$U2 = \frac{\sqrt{\frac{1}{n-1}\sum_{t=2}^{n}(P_t - A_t)^2}}{\sqrt{\frac{1}{n-1}\sum_{t=2}^{n}(A_t - A_{t-1})^2}} \qquad (4.3)$$

where P = predicted value
A = actual value
and $0 \leq U2 \leq +\infty$

The advantage of this measure over its predecessor (U1) is that it provides a useful reference point for evaluation. When U2 is equal to unity the equation under analysis merely performs as well as the "naive" model (one which simply states that A_t is a function of A_{t-1}). A value of less than unity indicates superior predictive performance, while a value in excess of unity indicates inferior predictive performance to the naive model.

1. Supply.

The estimated form of the acreage equation is:[2]

$$A_t = \underset{(12.7230)}{11.1208} + \underset{(0.1967)}{0.3463}\, A_{t-1} + \underset{(0.0720)}{0.1061}\, P_{t-1} + \qquad (4.4)$$

$$\underset{(0.0334)}{0.1104}\, R_t + \underset{(20.9916)}{62.5715}\, N_t$$

DF = 12 d = 1.58* $\bar{R}^2$ = 0.92
SE = 1.40 U2 = 0.51 F = 46.77

All coefficients are of the expected sign and their standard errors are not unacceptably high. The equation as a whole displays good statistical fit and reasonable predictive ability. The short-run elasticity of supply, evaluated at the mean is 0.105 and the long-run elasticity is 0.161. The equation implies an adjustment period of

[1] The equation given is appropriate when "prior information" corresponding to A_o is unavailable. In this case there is a loss of one degree of freedom and the measure actually evaluates predictive ability over n-1 intervals of the sample period. Note that if for some reason an equation is an extremely poor predictor in the first interval the measure will not give an accurate indication of overall predictive ability.

[2] Since this equation has the lagged value of the dependent variable in the explanatory variable set the Durbin-Watson statistic is biased towards randomness. It should therefore be interpreted with care. See Johnston (1972, pp. 309-13).

roughly 2-1/3 years.1/ At first sight these estimates seem reasonable in the context of a less-developed agriculture. Some comparative information on their magnitude is contained in the following section.

Overall the results, in terms of their conformity with a priori expectations, are good and, in terms of statistical criteria, are acceptable. Both theoretically and empirically the supply equation represents a considerable improvement over those employed by Mann and Rogers et al.

Two versions of the yield relationship were estimated. The first, corresponding to equation 3.2 above, gave the following results:

$$Y_t = \underset{(0.1312)}{-0.2412} + \underset{(0.0007)}{0.0024}\, R_t + \underset{(0.0018)}{0.0117}\, T \qquad (4.5)$$

DF = 14 d = 1.43* $\bar{R}^2$ = 0.76
SE = 0.0356 U2 = 0.54 F = 26.47

The second, corresponding to equation 3.2a produced:

$$Y_t = \underset{(0.1014)}{0.3714} + \underset{(0.0010)}{0.0027}\, R_t + \underset{(0.0221)}{0.0945}\, F_t \qquad (4.5a)$$

DF = 14 d = 0.73** $\bar{R}^2$ = 0.58
SE = 0.4774 U2 = 0.71 F = 11.99

A priori there is little to guide selection of the appropriate form of the yield equation. In estimation 4.5 is clearly superior both in terms of statistical fit and error properties. It was therefore selected as the yield function for the model.

2. Demand.

Two different variations of the demand equation (3.3 and 3.3a) were estimated. Particular interest centered upon whether the empirical results would lend support to the assumption of market differentiation and the income effect of concessional distribution.

The first equation corresponds to 3.3 and hypothesizes a single undifferentiated market. It yields:2/

$$QDC_t = \underset{(32.4055)}{86.0746} - \underset{(0.3196)}{0.8269}\, P_t + \underset{(0.4729)}{0.2685}\, PS_t + \underset{(0.1379)}{0.3183}\, IC_t \qquad (4.6)$$

DF = 13 d = 2.51*
SE = 6.12 U2 = 0.57

1/ The adjustment period can be approximated by $1/(1-\alpha)^2$ where α = the adjustment coefficient. Long-run elasticity is defined by $(1/(1-\alpha)) \times \eta_s$ where η_s is the short-run supply elasticity.

2/ The use of the Durbin-Watson statistic in simultaneous models is subject to qualification (See Christ, 1966, pp. 528-29). Particular care should be taken in the interpretation of the coefficient in a system where lagged dependent variables are present.

All coefficients are of the expected sign. The coefficient on the price of consumption substitutes is imprecise due to a large standard error. The ability of the equation to reflect changes in consumption over the estimation period appears to be acceptable. The estimate of own-price elasticity of demand, evaluated at the mean is -0.546 and the income elasticity is 0.7. Both values seem plausible in the context of a less-developed economy but are further considered in the next section.

The second form of demand equation estimated corresponds to 3.3a above and hypothesizes market differentiation with a positive income effect of concessional distribution. It yields:

$$QDC^{o} = \underset{(48.5604)}{192.5872} - \underset{(0.4245)}{1.5415}\, P_t + \underset{(0.4479)}{0.6800}\, PS_t - \underset{(0.0281)}{0.0177}\, \frac{IC_t}{P^p_t/P_t} \qquad (4.6a)$$

DF = 13 d = 1.55*
SE = 9.52 U2 = 0.68

Contrary to a priori expectations the coefficient on income is negative. The "goodness of fit" of the equation is inferior to 4.6.

On the basis of these results the hypothesis that concessional distribution produces a positive income effect upon the free market is rejected. When it is borne in mind that the price difference between concessional and open market cereals was relatively small it is intuitively obvious that any income effect is likely to be far outweighed by the substitution effect. Only where the income elasticity of demand for additional cereals is very high among individuals benefiting from concessional distribution would we expect there to be any discernible offsetting income effect in the free market.

We conclude that, although the assumption of homogeneity that is implied by the use of a single demand equation is not fully justified, 4.6 represents the best approximation to consumer behavior in the market.

3. Income Generation.

Estimation of the income equation 3.4 yields the following result:

$$I_t = \underset{(6.0531)}{49.9835} + \underset{(0.1432)}{0.3344}\, QS_t + \underset{(0.0315)}{0.4435}\, QI_t \qquad (4.7)$$

DF = 14 d = 2.01
SE = 3.11 U2 = 0.52

Both of the slope parameters are of the expected sign and have small standard errors. The equation seems to perform adequately as a predictor over the estimation period. Since we have no a priori restrictions on the parameters of 4.7 apart from sign it is difficult to comment further upon their appropriateness.

4. Market Balancing.

Estimation of the import function 3.5 yields:

$$M_t = \underset{(0.6891)}{-0.1684} + \underset{(0.0304)}{0.1291}\, QG_t + \underset{(0.0873)}{0.1618}\, FX_t \qquad (4.8)$$

DF = 14 d = 1.13*
SE = 0.62 U2 = 0.74

The equation has coefficients with anticipated signs and low standard errors. Theil's coefficient indicates that it performs reasonably over the sample period as a predictor.

The stock withdrawal equation 3.6 yields:

$$W_t = \underset{(0.4186)}{0.0752} + \underset{(0.0290)}{0.0600}\, QS_t + \underset{(0.2187)}{0.5901}\, S_t - \underset{(0.0765)}{0.2700}\, PR_t \qquad (4.9)$$

DF = 14 d = 1.72
SE = 0.584 U2 = 0.43

This equation is similar to 4.8 with low standard errors and expected signs.

V. AN ASSESSMENT OF THE VALIDITY OF THE MODEL

Our assessment involves two considerations:

1. the "acceptability" of major structural parameters;

2. the predictive performance of the model for key endogenous variables over the sample period.

1. Structural Parameters.

The most important structural parameters in the model are the price response and adjustment coefficients in the supply function, and the income and price coefficients in the demand function. They are discussed in terms of the elasticities that they generate.

In many respects it is a difficult task to assess the validity of these elasticities. The usual approach is through comparison with other

estimates but this is not without its problems. Different approaches tend to vary considerably in method and statistical quality and, most importantly, in their period of estimation. Furthermore the exercise can almost become one of self-fulfilling prophecy. A "norm" is established and the goal becomes one of ensuring conformity. For these reasons it is difficult to draw any firm conclusions about the validity of the estimates. We personally feel that they are reasonable but leave it to the reader to draw his or her own conclusions. A more useful test of validity is contained in the following section where the ability of the model to simulate the value of key endogenous variables is examined.

Supply

Some of the available estimates of price elasticity for the supply of cereals are contained in table 5.1. They are clearly variable and in the short-run range from 0.08 to 0.28. Our own estimate of 0.11 is within the range but is clearly on the low side. Our long-run elasticity is also on the low side.

There are good reasons for believing that price response over the chosen period would tend to be relatively low. Unlike Mann's estimation period the one used in this study includes most of the 1960's, before the advent of the "green revolution". This was a period of general stagnation in the Indian cereals sector. The sensitivity of estimated elasticity of supply to the sample period is an important topic and is further explored in section VII.

Demand

Table 5.2 appears to suggest that the estimated own price and income elasticities are of "reasonable" orders of magnitude. If the same reference period as the NCAER (1970) study is chosen, the values are similar. The shift in the price elasticity from 0.38 to 0.55 as the result of the inclusion of three additional years appears to indicate high sensitivity to data period.

2. Predictive Performance.

The principal objective of this study is to derive multipliers which will permit the calculation of the average impact of PL480 upon the output of cereals in India. It is therefore important that the model as a whole should perform well over the sample period as a predictor of production. One of the methods that can be adopted to evaluate performance is to simulate over the period. Through this means the model's ability to predict key variables and its dynamic stability can be tested.

Two basic approaches to simulation can be employed: (1) reduced-form solution, and (2) structural solution. The latter is the more

Table 5.1: Selected Estimates of Price Elasticity of Supply for Cereals in India.

Researcher	Commodity	Period	Coverage	Function	Estimate	
					Short-Run	Long-Run
NCAER (1962)	Rice	1938/9-59/60	All India	A	0.22	—
NCAER (1962)	Wheat	1938/9-59/60	All India	A	0.16	—
Krishna (1963)	Rice	1914-45	Punjab	A	0.31	0.59
Krishna (1963)	Wheat	1914-45	Punjab	A	0.08	0.14
Blandford/von Plocki	Cereals	1952-68	All India	A	0.11	0.16
Mann (1967)	Cereals	1952-63	All India	P	0.28	--
Rogers/Srivastava/Heady (1972)	Cereals	1956-67	All India	P	0.16*	--

A = Area response function.

P = per capita output response function.

* Value as published by RSH = 0.156 the value that we obtained using RSH data was 0.167.

Table 5.2: Selected Estimates of Demand Elasticities for Cereals in India.

	Researcher	Period	Functional* Form	Estimate
Own Price Elasticity				
	NCAER (1970)	1953-66	L	0.38
	NCAER (1970)	1953-66	DL	0.37
	Blandford/von Plocki	1953-66**	L	0.38
	Blandford/von Plocki	1952-68	L	0.55
	Mann (1967)	1952-63	L	0.34
	Rogers/Srivastava/Heady (1972)	1956-67	L	0.39***
Income Elasticity				
	NCAER (1970)	1953-66	L	0.54
	NCAER (1970)	1953-66	DL	0.62
	Blandford/von Plocki	1953-66**	L	0.67
	Blandford/von Plocki	1952-68	L	0.70
	Mann (1967)	1952-63	L	0.21
	Rogers/Srivastava/Heady (1972)	1956-67	L	1.44***

L = Linear

DL = Double Logarithmic

* Equations used by the NCAER did not involve the price of consumption substitutes and used nominal prices and values. All others included substitutes and used deflated or "real" prices and values.

** Computed to provide a closer comparison with NCAER estimates.

*** Open market demand.

flexible for most applications since, through the use of iterative solution procedures, models involving non-linearities and/or lagged variables can be handled relatively easily (Labys, 1973). However, since the current objective is not to use simulation as a primary vehicle for analysis but to obtain multipliers from the reduced form, it seems more logical to employ a reduced form simulation in examining the validity of the model.

Recalling the structural form in matrix notation given by 4.1 above:

$$By_t + \Gamma x_t = u_t$$

then the reduced form solution is given by:

$$y_t = -B^{-1}\Gamma x_t + B^{-1}u_t$$

which can be re-expressed as:

$$y_t = \Pi x_t + v_t \tag{5.1}$$

where Π is a G x K matrix of coefficients on predetermined variables

The derivation of the Π matrix constitutes a problem since the presence of non-linearities in our identity set makes it impossible to derive the necessary inverse and matrix product. However, a means of overcoming this problem was suggested by Klein (1947). The technique involves the use of Taylor's theorem to derive linear approximations to nonlinear equations.

For a function of two variables x and y having continuous partial derivatives of the nth order the expansion about the points a and b can be expressed as:

$$F(a + dx, b + dy) = F(a,b) + dF(a,b) + d^2F(a,b)/2! + \ldots + d^nF(a,b)/n! + R_n \tag{5.2}$$

where $R_n = d^{n+1}F(C + D)/(n + 1)!$

and C is between a and (a + dx)
D is between b and (b + dy)

The linear approximation is defined by saving only the linear terms in 5.2.

The most convenient way to employ 5.2 is to use the means of variables x and y as evaluation points. Adopting this approach the non-linear identities in the structural model can be re-expressed as:

$$\left.\begin{array}{ll} \text{Identity (3.7)} & QS_t = -\bar{A}\bar{Y} + \bar{Y}A_t + \bar{A}Y_t \\ \text{Identity (3.9)} & QDC_t = \bar{Q}\bar{D}/\bar{N} + (1/\bar{N})QD_t - (\bar{Q}\bar{D}/\bar{N}^2)\ N_t \\ \text{Identity (3.10)} & IC_t = \bar{I}/\bar{N} + (1/\bar{N})I_t - (\bar{I}/\bar{N}^2)\ N_t \end{array}\right\} \quad (5.3)$$

where "-" denotes the mean of a variable

A crucial question is the amount of error that these approximations create. Womack and Matthews (1972) argue that the use of means will give reasonable approximations for data series which fluctuate but have little or no trend. They suggest that other methods for deriving evaluation points must be used if this condition is not met.

In order to illustrate the appropriateness of 5.3, actual and approximated values for the sample period are graphed in figure 5.1. It may be observed that the degree of correspondence is generally quite good.1/ The average absolute deviation of predicted from actual values for the respective identities is:

	Average Absolute Percentage Error
1. Area x Yield	0.56
2. *Per Capita* Demand	0.67
3. *Per Capita* Income	0.67

Errors of less than seven-tenths of one percent seem to be fully acceptable and this method of linearization was therefore employed to derive the reduced form. The resulting Π matrix is presented in table 5.3.

Simulation over the sample period may now be undertaken. Rewriting 5.1:

$$y_t = \Pi_1 y_{t-1} + \Pi_2\ x_t + v_t \qquad (5.4)$$

where Π_1 is a G x G matrix of reduced form coefficients on the lagged endogenous variables (G = 11)
Π_2 is a G x M matrix of coefficients on the exogenous variables (M = 10 plus intercept)

Since interest centers upon the model's deterministic predictive ability over the sample period we take advantage of the assumed property of the error term [E(v) = 0] to derive the form:

$$y_t = \Pi_1\ y_{t-1} + \Pi_2\ x_t \qquad (5.5)$$

1/ Note that contrary to the Womack and Matthews generalization supply and *per capita* income are both strongly upward trending.

FIGURE 5.1. ACTUAL AND PREDICTED VALUES FOR LINEARIZED IDENTITIES

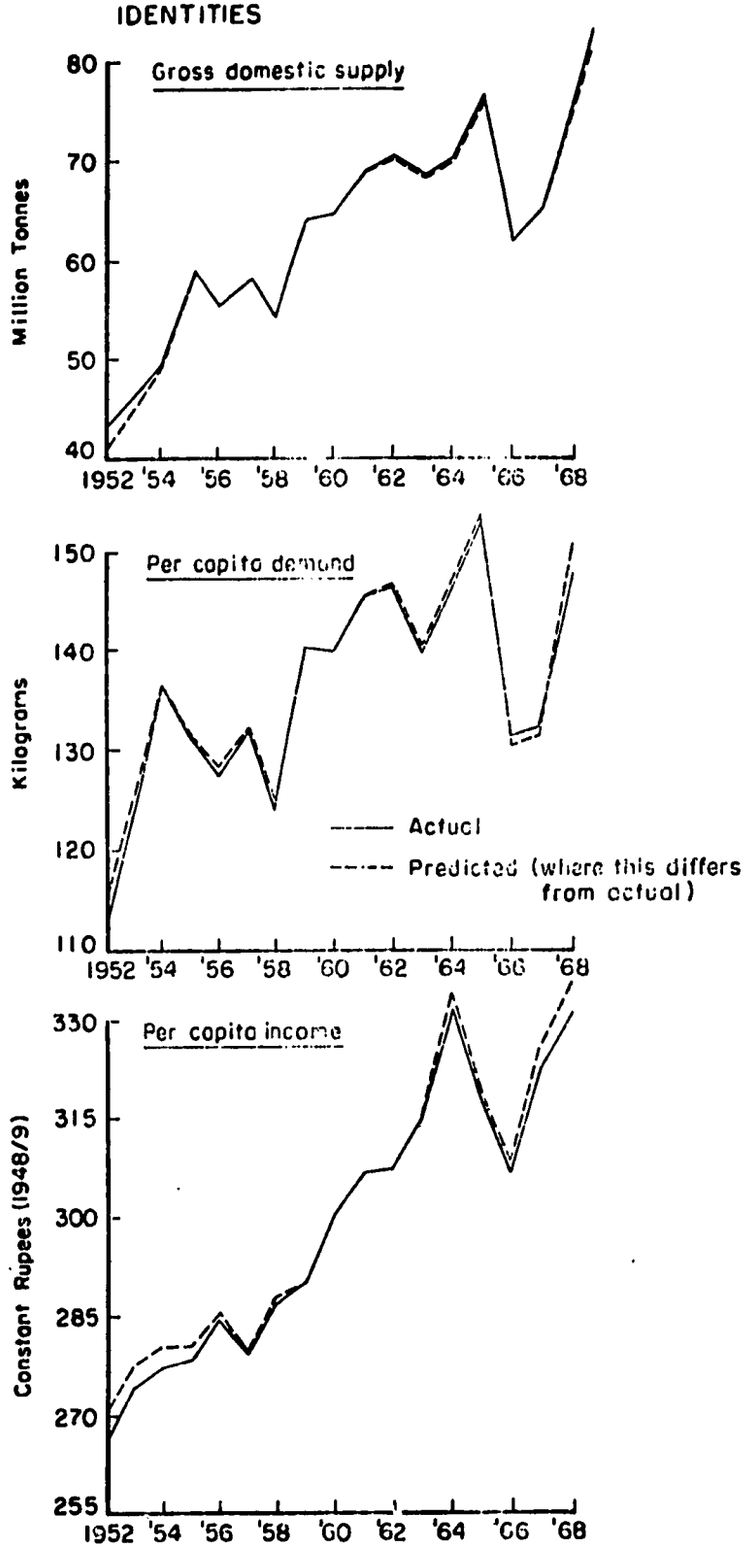


Table 5.3: The Reduced Form of the Model.

Π

	Constant	A_{t-1}	P_{t-1}	R_t	T	PS_t	QI_t	FX_t	S_t	PR_t	N_t	QM_t	$PL480_t$
A_t	11.1208	0.3463	0.1061	0.1104	0.0	0.0	0.0	0.0	0.0	0.0	62.5715	0.0	0.0
Y_t	-0.2412	0.0	0.0	0.0024	0.0117	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
QS_t	-76.7985	0.2426	0.0743	0.2900	1.0480	0.0	0.0	0.0	0.0	0.0	43.8443	0.0	0.0
P_t	229.6927	-0.4056	-0.1242	-0.4848	-1.7520	0.3247	0.3913	-0.4484	-1.6357	0.7484	39.9910	-0.5244	-2.2478
I_t	24.3013	0.0811	0.0249	0.0970	0.3505	0.0	0.4435	0.0	0.0	0.0	14.6620	0.0	0.0
M_t	8.5087	-0.0274	-0.0084	-0.0328	-0.1184	0.0	0.0	0.1618	0.0	0.0	-4.9538	0.1291	-0.1291
W_t	3.2887	-0.0127	-0.0039	-0.0152	-0.0550	0.0	0.0	0.0	0.5901	-0.2700	-2.3030	0.0600	-0.0600
QDC_t	9.5691	0.3946	0.1209	0.4717	1.7044	0.0	0.0	0.3708	1.3526	-0.6189	-241.7375	0.4336	1.8587
QD_t	-55.4013	0.1721	0.0527	0.2058	0.7436	0.0	0.0	0.1618	0.5901	-0.2700	31.1070	0.1892	0.8108
IC_t	356.3634	0.1860	0.0570	0.2223	0.8034	0.0	1.0166	0.0	0.0	0.0	-655.5827	0.0	0.0
QG_t	67.1987	-0.2123	-0.0650	-0.2538	-0.9170	0.0	0.0	0.0	0.0	0.0	-38.3637	1.0000	-1.0000

The use of 5.5 corresponds to the "final" simulation approach identified by Goldberger (1959).1/ Thus only values of the exogenous variables and initial values of lagged endogenous variables are employed as data. Predicted values of endogenous variables in one time period are used as data for prediction in the next and so on.2/ This method requires the greatest dependence upon the model's ability to generate y_t and is the most severe test of its accuracy and dynamic stability.

The results of the simulation are summarized for all endogenous variables in table 5.4. Indicators of predictive accuracy presented are: (1) the root-mean-square (RMS) error, (2) mean error, and (3) Theil's inequality coefficient (U2).

The table indicates that for most variables the average deviation of simulated from actual values is relatively small. The major exception is the withdrawal from stocks variable. In this case the RMS error is large relative to the mean, indicating fairly sizeable inaccuracies. This is perhaps not surprising since the release of cereals from government storage is likely to be highly sensitive to policy considerations, the influence of which is extremely difficult to capture.3/ The poor performance of this particular variable is not serious for the model as a whole due to the relatively small size of the quantities involved.

For virtually all variables the model's predictive ability is better than the naive model. The sole exception is price. If we were interested in using the model to predict the short-run price-effects of a change in PL480 imports this would clearly be a drawback. However, the poor predictive ability for price is not reflected in the model's performance for area and supply. This may be verified by figure 5.2 which demonstrates that the degree of correspondence between actual and simulated values for the two variables is generally quite good. Certainly there is no evidence of any systematic error pattern that would lead us to doubt the model's ability to characterize average response over the sample period.

It may be concluded from the reduced-form simulation that the model's predictive performance is generally acceptable. This is important since greater weight can now be placed upon the results of the multiplier analysis pursued in the following section.

1/ Since the model is relatively small and contains only two lagged endogenous variables it is computationally more efficient to use the Π matrix in table 5.3 directly in the reduced-form simulation. The use of equations 5.4 and 5.5, both here and later in connection with the multiplier analysis, is intended to increase expositional clarity.

2/ See Labys (1973, Chapter 9) for a fuller description of procedure.

3/ Barnum (1971), presumably having observed the poor performance of Mann's (1967) stock equation, treats withdrawals as an exogenous variable.

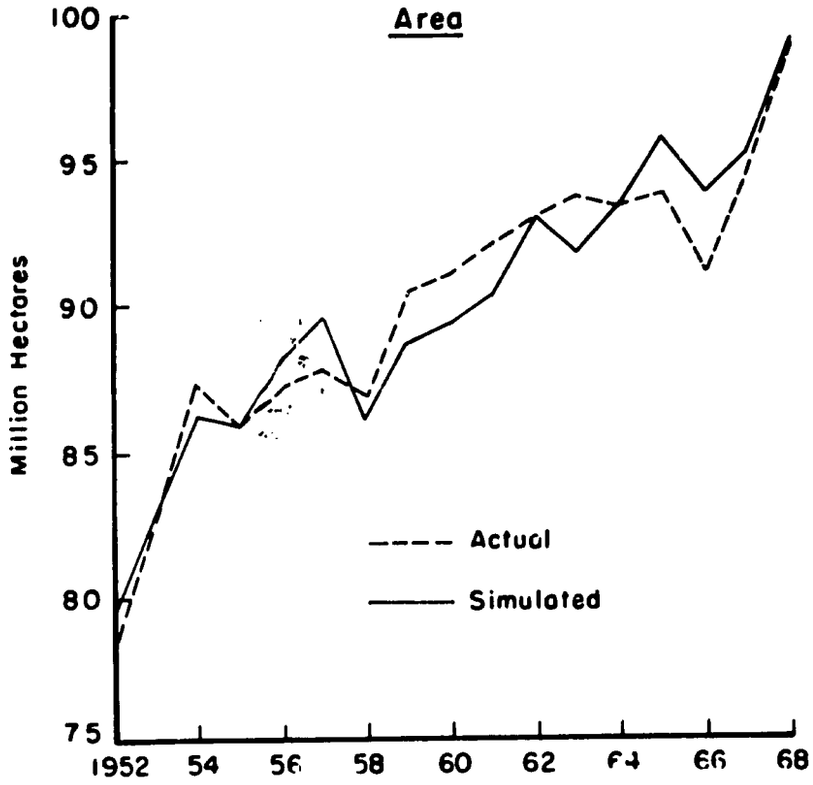
Table 5.4: Results of the Reduced-Form Simulation over the Sample Period.

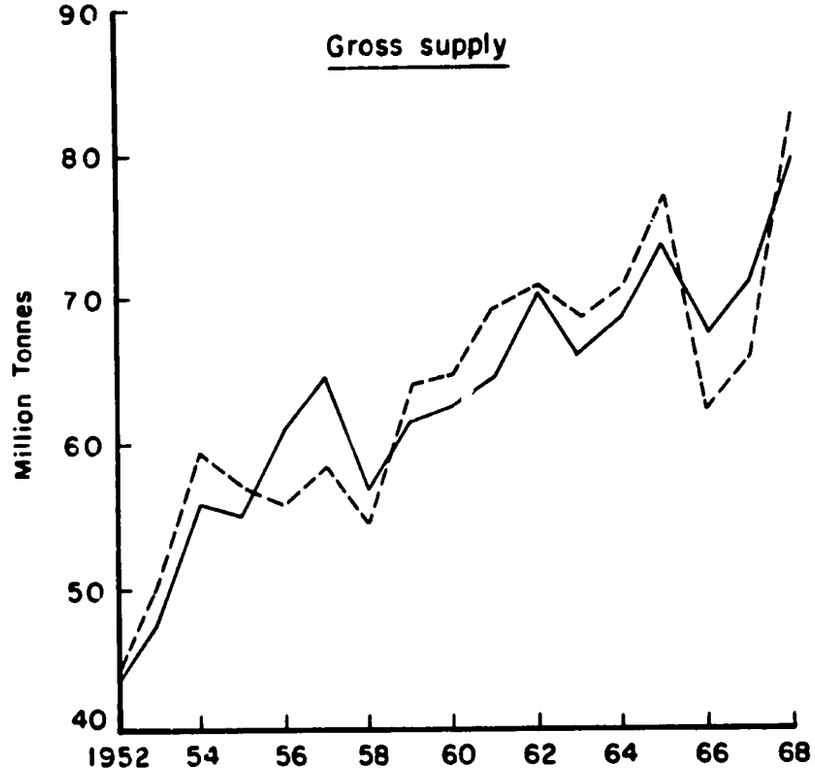
	Mean	RMS Error	Mean Error	Theil's U2 Coefficient
1. Area	89.81	0.33	-0.10	0.55
2. Yield	0.70071	0.00790	*	0.54
3. Supply	63.25	0.87	0.25	0.51
4. Price	89.7	1.8	-0.3	1.35
5. Income	131.16	0.76	0.08	0.55
6. Imports	1.35	0.14	-0.03	0.65
7. Withdrawals	-0.161	0.139	-0.013	0.47
8. Per Capita Demand	135.9	1.4	-0.3	0.61
9. Total Demand	59.58	0.66	0.17	0.57
10. Per Capita Income	298.7	1.7	-1.8	0.79
11. Food Gap	2.22	0.76	-0.22	0.59

Note: Data form reflects original accuracy.

* Necessarily zero since OLS used and no lagged endogenous variables present in the equation.

FIGURE 5.2. ACTUAL AND SIMULATED VALUES OF AREA AND SUPPLY OVER THE SAMPLE PERIOD





VI. THE DISINCENTIVE EFFECT OF FOOD AID

The three questions of interest are:

(1) the impact of PL480 imports during a single time period;
(2) the impact during each of a series of time periods;
(3) the total impact of aid upon production over time.

In order to answer these questions the different types of multipliers can be defined. To facilitate their derivation the reduced form (table 6.1) is re-expressed to conform with equation 5.4 which, it will be recalled, defined the reduced form as follows:1/

$$y_t = \Pi_1 y_{t-1} + \Pi_2 x_t + v_t$$

Lagging by one period:

$$y_{t-1} = \Pi_1 y_{t-2} + \Pi_2 x_{t-1} + v_{t-1}$$

by back-substitution:

$$y_t = \Pi_1^2 y_{t-2} + \Pi_1\Pi_2 x_{t-1} + \Pi_2 x_t + \Pi_1 v_{t-1} + v_t$$

Repeating the same exercise s times yields:

$$y_t = \Pi_1^{s+1} y_{t-s-1} + \sum_{\tau=0}^{s} \Pi_1^{\tau}\Pi_2 x_{t-\tau} + \sum_{\tau=0}^{s} \Pi_1 v_{t-\tau} \qquad (6.1)$$

Assuming the necessary stability condition:

$$\lim_{s\to\infty} \Pi_1^{s+1} = 0 \qquad (6.2)$$

6.1 can be re-written in the final form:

$$y_t = \sum_{\tau=0}^{\infty} \Pi_1^{\tau}\Pi_2 x_{t-\tau} + \sum_{\tau=0}^{\infty} \Pi_1 v_{t-\tau} \qquad (6.3)$$

The impact of PL480 imports during a single time period can be determined from the short-run static or <u>impact</u> multipliers. These are defined by taking the partial derivative of y_t with respect to x_t in 6.3 where $\tau=0$.

$$\Pi^m = \frac{\partial y_t}{\partial x_t} = \frac{\partial}{\partial x_t} (\Pi_1^0 \Pi_2 x_t) = \Pi_2 \qquad (6.4)$$

1/ This exposition follows that in Labys (1973).

Table 6.1: Expanded Version of the Reduced Form.

	B_1											B_2										
	A_{t-1}	Y_{t-1}	QS_{t-1}	P_{t-1}	I_{t-1}	N_{t-1}	W_{t-1}	QDC_{t-1}	QD_{t-1}	IC_{t-1}	QG_{t-1}	Constant	R_t	T	PS_t	QI_t	PX_t	S_t	PR_t	H_t	QM_t	$PLABO_t$
A_t	0.3463	0	0	0.1061	0	0	0	0	0	0	0	11.1208	0.1104	0	0	0	0	0	0	62.5715	0	0
Y_t	0	0	0	0	0	0	0	0	0	0	0	-0.2412	0.0024	0.0117	0	0	0	0	0	0	0	0
QS_t	0.2426	0	0	0.0743	0	0	0	0	0	0	0	-76.7985	0.2900	1.0480	0	0	0	0	0	43.8443	0	0
P_t	-0.4056	0	0	-0.1242	0	0	0	0	0	0	0	229.6927	-0.4848	-1.7520	0.3247	0.3913	-0.4484	-1.6357	0.7484	33.9910	-0.5244	-2.2478
I_t	0.0811	0	0	0.0249	0	0	0	0	0	0	0	24.3013	0.0970	0.3505	0	0.4435	0	0	0	14.6620	0	0
R_t	-0.0274	0	0	-0.0084	0	0	0	0	0	0	0	8.5087	-0.0328	-0.1184	0	0	0.1618	0	0	-4.9538	0.1291	-0.1291
W_t	-0.0127	0	0	-0.0039	0	0	0	0	0	0	0	3.2887	-0.0152	-0.0550	0	0	0	0.5901	-0.2700	-2.3030	0.0600	-0.0600
QDC_t	0.3946	0	0	0.1209	0	0	0	0	0	0	0	9.5691	0.4717	1.7044	0	0	0.3708	1.3526	-0.6189	-241.7375	0.4336	1.8587
QD_t	0.1721	0	0	0.0527	0	0	0	0	0	0	0	-55.4013	0.2058	0.7436	0	0	0.1618	0.5901	-0.2700	31.1070	0.1892	0.8108
IC_t	0.1860	0	0	0.0570	0	0	0	0	0	0	0	356.3634	0.2223	0.8034	0	1.0166	0	0	0	-655.5827	0	0
QG_t	-0.2123	0	0	-0.0650	0	0	0	0	0	0	0	67.1987	-0.2538	-0.9170	0	0	0	0	0	38.3637	1.3000	-1.0000

The impact multiplier between the ith endogenous and the jth exogenous variable is then given by the $(i,j)^{th}$ element of Π_2. For example, by examination of table 6.1 we can determine from the element $\Pi_{2(4,11)}$ that a unit increase in PL480 (1 million tonnes) decreases the cereal price index in the same year by approximately 2.25 units. Through $\Pi_{2(9,11)}$ it can be seen that roughly 81 percent of such an increase in total imports would be reflected in a net increase in consumption (or roughly 1.86 kg. per capita from $\Pi_{2(8,11)}$), 12.9 percent would displace commercial imports ($\Pi_{2(6,11)}$), and 6 percent would replace withdrawals from government stocks ($\Pi_{2(7,11)}$). Finally $\Pi_{2(11,11)}$ indicates that the food gap (as defined) decreases by the amount of the additional aid.

The values of $\Pi_{2(1,11)}$ and $\Pi_{2(3,11)}$ indicate that due to lags in response there is no "impact" effect upon production. To determine the production effect it is necessary to calculate dynamic multipliers. Two types are relevant: (1) delay (or interim); and (2) cumulative (or total).

The delay multiplier indicates what the future values of endogenous variables would be given a one period, one unit change in the exogenous variables. It is defined by taking the partial derivative of 6.3 with respect to $x_{t-\tau}$.[1/]

$$\Pi^D = \frac{\partial y_t}{\partial x_{t-\tau}} = \frac{\partial}{\partial x_{t-\tau}} \left(\sum_{\tau=1}^{\infty} \Pi_1 \Pi_2 x_{t-\tau} \right) = \Pi_1^{\tau} \Pi_2 \tag{6.5}$$

The cumulative multiplier defines the effect of a one unit change in the exogenous variables when this is sustained over n periods. From 6.3 we define:

$$y_t = \sum_{\tau=1}^{n} \Pi_1^{\tau} \Pi_2 x_t^* \tag{6.6}$$

where x_t^* = the sustained change in the exogenous variables

this may be re-expressed as:

$$y_t = (I + \Pi_1 + \Pi_1^2 + \ldots + \Pi_1^{\tau}) \Pi_2 x_t^* \tag{6.7}$$

[1/] Note that if $\tau=0$, 6.5 reduces to the impact multiplier 6.4.

The cumulative dynamic multiplier is then defined by differentiating 6.7 partially with respect to x_t^*:

$$\Pi^c = \frac{\partial y_t}{\partial x_t^*} = (I + \Pi_1 + \Pi_1^2 + \ldots + \Pi_1^n)\ \Pi_2 \qquad (6.8)$$

As n approaches infinity Π_1^n approaches zero and the cumulative dynamic multiplier becomes the long-run equilibrium or stationary multiplier. Recognizing 6.8 as an infinite series this can be approximated by:

$$\Pi^L = (I - \Pi_1)^{-1}\ \Pi_2 \qquad (6.9)$$

Returning to table 6.1 the delay multiplier upon prices for a unit change in PL480 imports is given by:

$$\frac{\partial P_t}{\partial PL480_{t-\tau}} = \Pi_{2(4,11)}\ \Pi_{1(4,4)}^{\tau} \qquad \tau = 1, 2 \ldots n. \qquad (6.10)$$

If this is multipled by the impact multiplier for lagged price on production $\Pi_{1(3,4)}$ we derive the delay multiplier for the effect of a unit increase of PL480 imports on domestic production.

$$\frac{\partial QS_t}{\partial PL480_{t-\tau}} = \Pi_{2(4,11)}\ \Pi_{1(4,4)}^{\tau}\ \Pi_{1(3,4)} \quad \tau = 1, 2 \ldots n. \qquad (6.11)$$

The cumulative dynamic multiplier is then simply the cumulative sum of the delay multipliers for the appropriate time period. The long-run equilibrium multiplier is the value of the cumulative multiplier when this reaches a stable value at a given level of accuracy.1/

Multiplier values derived from the model are presented in table 6.2 and graphed in figure 6.1. The graph illustrates that the major impact of PL480 is felt in the year immediately after the unit change. The system rapidly stabilizes such that a long-run equilibrium (as defined) is obtained by the seventh period.

The value of the long-run equilibrium multiplier is approximately -0.149. This indicates that a sustained increase of one million tonnes of PL480 imports would lead to a decline in domestic production of 149,000 tonnes. Expressed differently, assuming that all other factors remain constant, the net effect of food aid is to increase the domestic availability of cereals by approximately 85 percent of this volume. Given the fact that commercial imports and withdrawals will also decline the net consumption effect is approximately 66 percent.

1/ See the foot of table 6.2 for the criterion employed.

Table 6.2: The Total Effect of PL480 on Domestic Production.

Year	Delay Multiplier	Cumulated Multiplier
1	-0.16703	-0.16703
2	0.02075	-0.14628
3	-0.00258	-0.14886
4	0.00032	-0.14854
5	-0.00004	-0.14858
6	0.00000	-0.14857
7	--	-0.14857

Long-run equilibrium with the convergence criterion $\Pi^L = \Pi^c$ if $\Pi^c_t - \Pi^c_{t-1} < 1.0 \times 10^{-5}$ is achieved by period 7.

In relation to other estimates, Mann's model defined a long-run multiplier of roughly -0.318 which is more than twice as great as the one derived in this study.1/ On the other hand, the RSH model yielded a value of 0.032 which is only about one tenth of Mann's value and one fifth of our own. Furthermore the time paths of adjustment to PL480 differ considerably between the models. As figure 6.2 illustrates, Mann's model clearly reflects the influence of fairly wide oscillations. Using the same convergence criterion (table 6.2) Mann's cumulative production multiplier does not even reach "long-run" equilibrium by fourteen periods. The RSH multiplier converges after twelve and our own by seven. The reason for the extended and, we would argue, unreasonable adjustment peiods in the two previous multiplier analyses is the use of the erroneous two-period lag on price in their supply equations. In actual fact this lag implies that the effect of PL480 upon production is only defined in even-numbered time periods, odd-numbered periods are left to interpolation.

These results further indicate the weakness of previous multiplier analyses. The disincentive effect of PL480 determined from Mann's model is much too large and the time path of adjustment unreasonable. In the RSH model the production effect is clearly underestimated and adjustment period also overstated.2/ We would argue that if one were to choose between these estimates on the basis of theoretical and empirical validity one would certainly choose the one derived in this study as the most acceptable.

1/ Barnum (1971) did not perform a multiplier analysis and is therefore not included in the discussion.

2/ It should be recalled that in section II it was argued that the structure of the RSH model biases its estimate of the disincentive effect towards zero.

FIGURE 6.1. DELAY AND CUMULATIVE PRODUCTION MULTIPLIERS DERIVED FROM THE MODEL

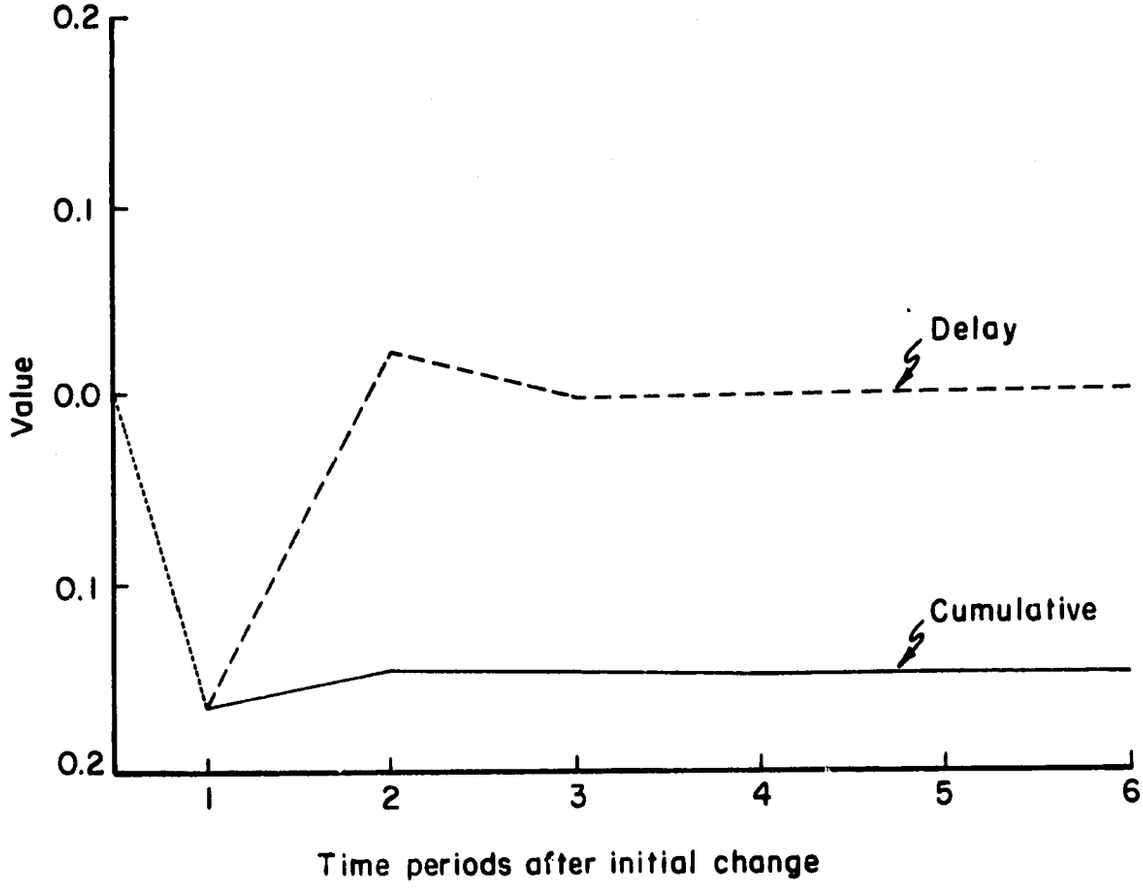
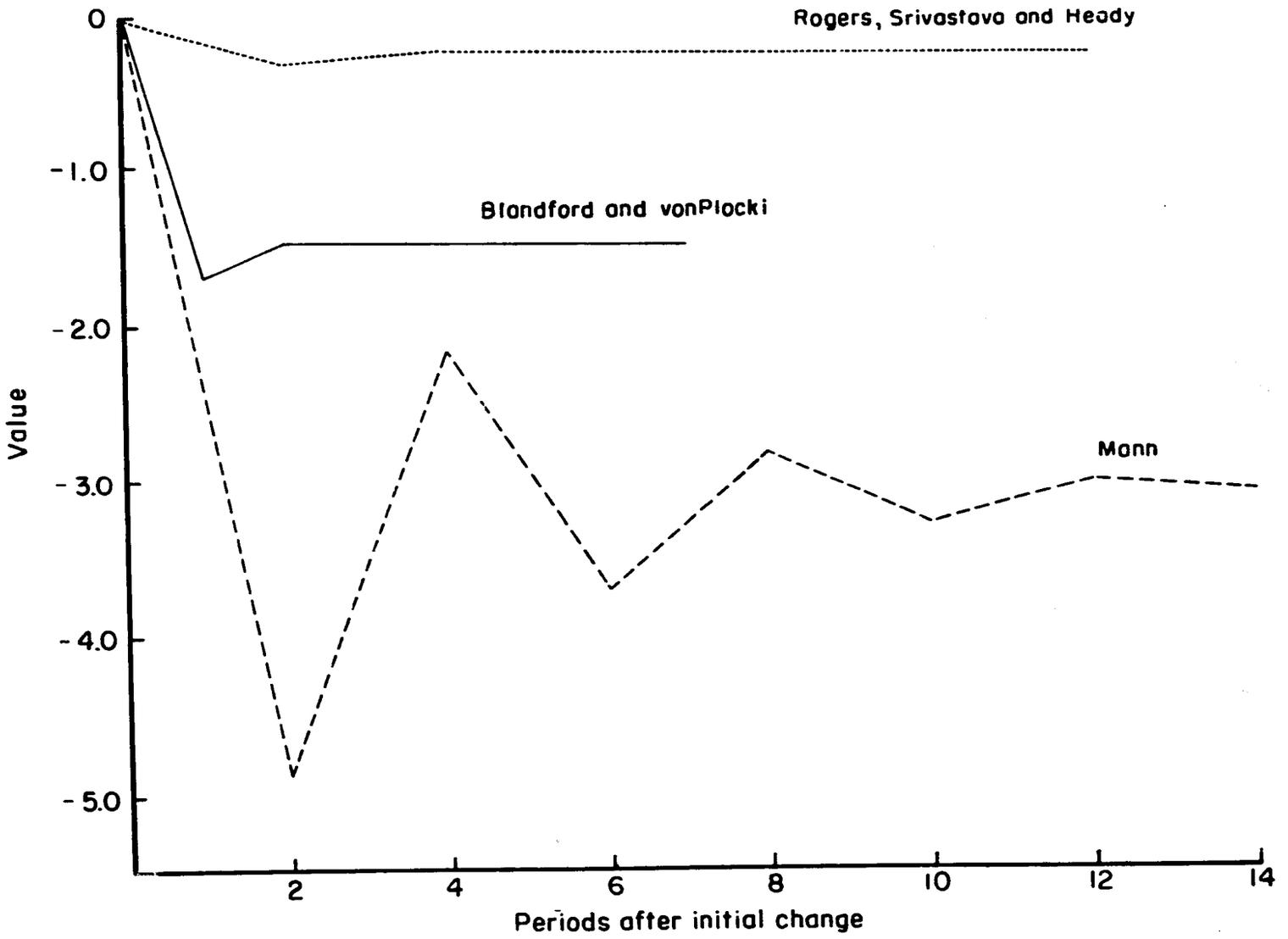


FIGURE 6.2. COMPARISON OF THE TIME PATHS OF THE CUMULATED PRODUCTION MULTIPLIERS OF THE THREE MODELS



VII. THE STABILITY OF THE ESTIMATE

Up to this point the "standard" approach to the estimation of the disincentive effect has been pursued. A market model has been formulated, estimated, and then used to derive the relevant multipliers. This was the approach originally taken by Mann and repeated by Rogers et al. Its end result is an estimate of the disincentive effect which is compared to the results of other studies.

As in other analyses no attempt has been made to examine the sensitivity of the estimate of disincentive to changes in the sample period. It was noted in section V that data period seems to play a significant role in determining the value of elasticities. If supply parameters in particular tend to change dramatically over time then this may have important implications for assessing the effects of food aid. In order to determine the stability of estimated producer response through time the area response equation (3.1) was fitted to twenty-one different data periods within 1952-68, ranging in length from a minimum of twelve years to the full seventeen.1/ The resulting array of long-run elasticities is presented in table 7.1.

The table demonstrates that estimates of the price elasticity of supply can change fairly dramatically depending upon sample period.2/ Some years, especially 1952 and 1968, tend to increase the estimate while others, most notably 1967, tend to decrease it. The table reveals that not only the value but even the sign of the elasticity can change if the reference period is changed. Estimates based on a period including 1952 and/or 1968 would lend support to the proponents of the hypothesis that farmers in less-developed agriculture respond positively to price (e.g. Krishna, 1963; Falcon, 1964; Schultz, 1964). The choice of a period like 1955-67 would lend support to the opposite view (e.g. Olson, 1960; Khatkhate, 1963).

A more detailed analysis of data and results would probably reveal that the shifts in elasticity are mainly the product of the high degree of aggregation employed. Shifts could probably be reduced through the use of a more sophisticated model incorporating better approximators of weather conditions, technological change, and differential regional or product response.3/

1/ Shorter periods were omitted due to the relatively small number of degrees of freedom involved.

2/ Not all these estimates would prove acceptable on the basis of statistical criteria.

3/ The important question of parameter stability in econometric models has not received the attention it merits. One particularly valuable contribution is that of Silvestre (1969).

Table 7.1: Estimates of the Long-Run Elasticity of Supply Derived from Different Sample Periods.

From: \ To:	1963	1964	1965	1966	1967	1968
1952	.1774	.1887	.2083	.2018	.1510	.1606
1953		.0575	.0240	.0315	.0155	.0653
1954			-.0382	-.0023	-.0033	.0514
1955				-.0076	-.0300	.0387
1956					-.0495	.0384
1957						.0216

As the price elasticity of supply plays an important role in the calculation of multipliers it is reasonable to assume that their values will also be affected by shifts in elasticity. To examine this proposition the whole model was estimated over a series of different data periods and the appropriate reduced form and long-run equilibrium multiplier of food aid on domestic production derived. The results of this exercise are presented in table 7.2. Restricted by degrees of freedom required for the derivation of two-stage least-squares estimates the array of multipliers is necessarily smaller than that in table 7.1.

The table demonstrates that the size of the disincentive effect is heavily dependent upon the choice of estimating period. The selection of 1952-65, for example, would seem to indicate that a sustained increase of one million tonnes of food aid would lead to a decline in domestic production of roughly 195,000 tonnes in the long-run. The choice of 1953-67 would indicate a decline of less than 25,000 tonnes.

Comparing the supply elasticities of table 7.1 and the multipliers of table 7.2 it seems reasonable to hypothesize that the size of the production multiplier is strongly associated with the long-run elasticity for the same period. The correlation between the two is high (r=0.94) and figure 7.1 demonstrates a strong positive association between the estimates.1/ It may be concluded that the estimate of the disincentive effect is strongly dependent upon the estimate of the supply elasticity which is in turn strongly dependent upon sample period.

It is doubtful that this feature is peculiar to this particular model. The price response estimates derived from the equations employed by Mann and by Rogers et al. display exactly the same general characteristic. Mann's estimates over the period 1952-68 vary from a high of 0.3286 in 1952-65 to a low of -0.1774 in 1956-67.2/ The equation used by Rogers et al., which interestingly enough produces higher values than Mann's over the period, varies from 0.4113 in 1952-64 to 0.1866 in 1957-68.3/ Given the same pattern of behavior in terms of estimated elasticities it is reasonable to infer a similar pattern in the estimated disincentive effect.

1/ Note that the sign on the production multiplier is reversed for this analysis.

2/ It proved impossible to obtain the original yield data employed by Mann and so that of RSH was used instead. As a result the estimates may differ slightly from those obtainable with the original data.

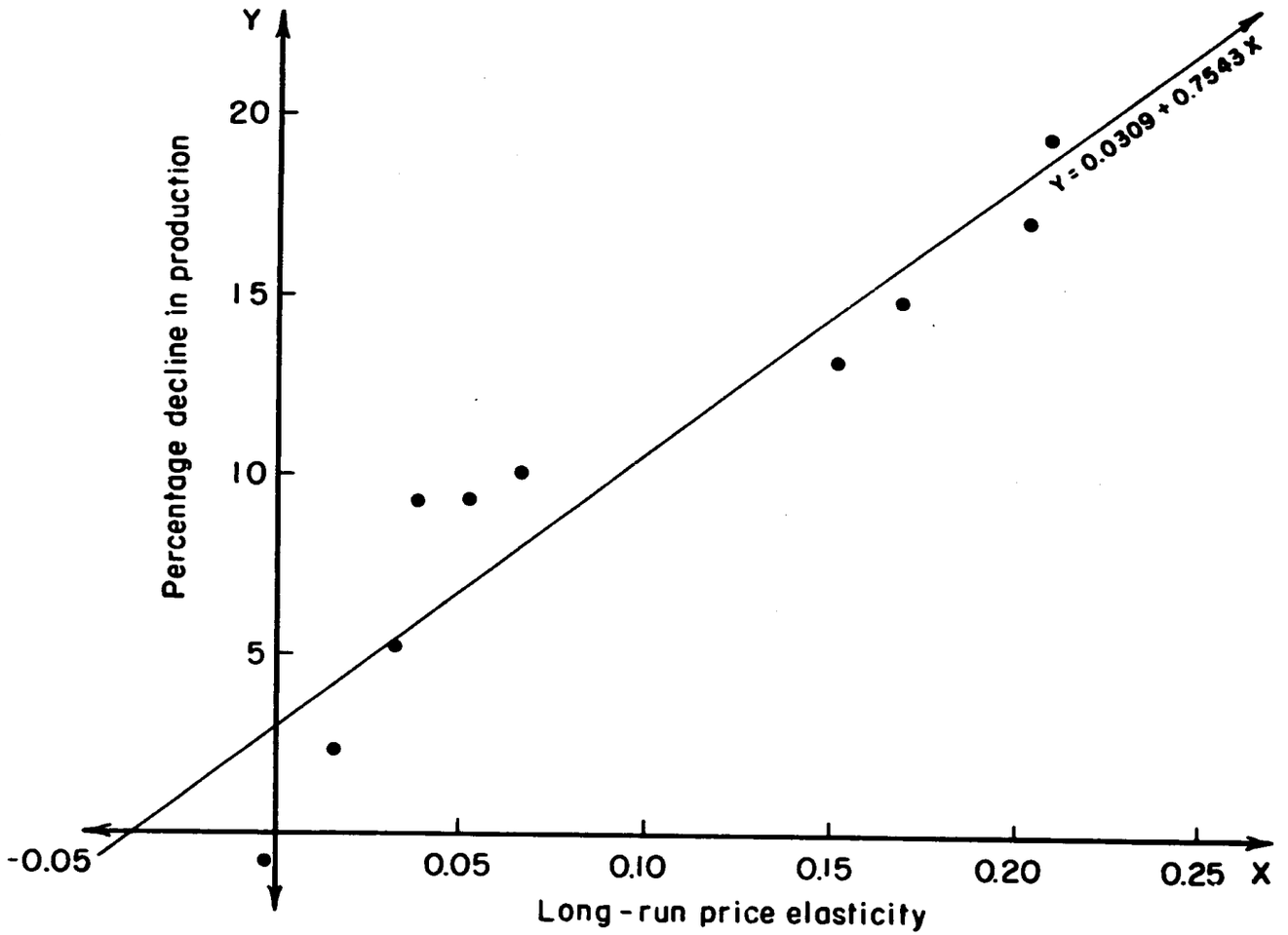
3/ Due to the generally higher estimates derived from the RSH equation the array of elasticities lie wholly in the positive quadrant. For shorter sample periods the elasticity becomes strongly negative. For example, for 1958-67 the value equals -.2759. These estimates were derived using the original data.

Table 7.2: Long-Run Equilibrium Production Multipliers Derived from Different Sample Periods.

From: \ To:	1963	1964	1965	1966	1967	1968
1952			-.1951	-.1707	-.1311	-.1486
1953				-.0529	-.0242	-.1002
1954					+.0066	-.0945
1955						-.0924
1956						
1957						

----- corresponds to the same block as in Table 7.1.

FIGURE 7.1. THE RELATIONSHIP BETWEEN LONG-RUN ELASTICITY OF SUPPLY AND THE ESTIMATED DISINCENTIVE EFFECT OF FOOD AID



VIII. CONCLUSION

The model of the Indian cereals market developed in this paper appears to lend support to the argument by Schultz (1960) that food aid may not have a universally beneficial impact upon a recipient nation's economy. It indicates that, for the sample period 1952-68, a one unit increase in such aid leads to a decline in domestic production of roughly 0.15 units and a net increase in consumption of only 0.66 units.1/ While these results can be viewed with greater confidence than those derived from previous studies considerable dangers exist in the use of these, or any other estimates, for policy purposes.

Sample period can have a dramatic impact upon the estimated disincentive effect. We are after all dealing with a highly aggregated model which relies on data that are not always fully appropriate or reliable. Compared to the sophistication of econometric techniques the quality of basic data in most developing countries is inadequate. In the interpretation of econometric research it is vital never to lose sight of this fact.

As a final cautionary example, consider the effects of a relatively small error in the data employed by Rogers *et al*. (1972) where in the estimation of the supply function one observation on an explanatory variable is incorrect.2/ Correction of the error increases the estimate of supply elasticity in their model from 0.17 to 0.20. Hence, a single error of 6 percent in a single observation on one variable changes the value of an elasticity by 15 percent! This example should serve to highlight the danger of placing too much faith in models displaying high sensitivity to poor data.

There will, of course, always be a desire to derive "evidence" for such important policy questions as the disincentive effect of food aid, and this paper indicates the feasibility of obtaining an indication of approximate orders of magnitude for a *particular time period*. But such an estimate is not necessarily appropriate to other time periods, and *a fortiori* it cannot be used to infer the likely effect of food aid in other markets or other countries.

1/ Since total consumption increases food aid may still be judged to be desirable (Mann, 1967, p. 145).

2/ The error relates to the rainfall index. The value used for 1967 was 88.38, the actual value is 83.38. Compare Srivastava *et al*. (1975) and Cummings and Ray (1969).

APPENDIX A

Summary of the Final Structural Form of the Model and Its Component Variables

Equations.

1. Area: $A_t = 11.1208 + 0.3463\ A_{t-1} + 0.1061\ P_{t-1} + 0.1104\ R_t + 62.5715\ N_t$

2. Yield: $Y_t = -0.2412 + 0.0024\ R_t + 0.0117\ T$

3. Demand: $QDC_t = 86.0746 - 0.8260\ P_t + 0.2685\ PS_t + 0.3183\ IC_t$

4. Income: $I_t = 49.9835 + 0.3344\ QS_t + 0.4435\ QI_t$

5. Imports: $M_t = -0.1684 + 0.1291\ QG_t + 0.1618\ FX_t$

6. Stock Withdrawals: $W_t = 0.0752 + 0.0600\ QG_t + 0.5901\ S_t - 0.2700\ PR_t$

7. $QS_t = A_t Y_t$

8. $QD_t = 0.875\ QS_t + M_t + W_t + PL480_t$

9. $QDC_t = QD_t / N_t$

10. $IC_t = I_t / N_t$

11. $QG_t = QM_t - 0.875\ QS_t - PL480_t$

Variables.

Endogenous

1. A = area sown to cereals
2. Y = yield
3. QS = total domestic cereal supply
4. P = deflated wholesale price index of cereals
5. I = total consumer income
6. M = commercial imports

7. W = withdrawal from stocks

8. QDC = *per capita* demand for cereals

9. QD = total demand for cereals

10. IC = *per capita* consumer income

11. QG = expected "food gap"

Predetermined

A. Lagged Endogenous

1. A = area sown to cereals

2. P = deflated wholesale price index for cereals

B. Exogenous

3. R = rainfall index

4. T = time trend

5. PS = deflated price index of consumption substitutes for cereals

6. QI = index of industrial production

7. FX = effective level of foreign exchange reserves

8. S = beginning period stocks

9. PR = internal procurement of cereals by the government

10. N = population

11. QM = physiologically necessary minimum availability of cereals

12. PL480 = food aid imports

t = calendar year.

APPENDIX B

The Data and Their Sources

See the accompanying table B.1. Sources are contained in the list of references and are referenced thus - Source (number).

1. A_t = area sown to cereals in millions of hectares. The figures relate to the Indian agricultural year e.g. A_{52} refers to the production period July 1951 - June 1952. Source (32) 1964-72.

2. Y_t = average yield of cereals in tonnes per hectare. Calculated using 1. above and total cereal production from Source (7), 1972, table 1, page 7 for 1956-58 and corresponding tables of earlier issues for 1952-56.

4. P_t = wholesale price index for cereals. Relates to calendar years, base (100) = 1952/53 deflated by wholesale price index for all commodities. Source (7), 1969, page 196. The use of the same wholesale price index in the estimation of supply and demand implies an assumption of constant marketing margins.

5. I_t = national income in constant 1948/49 prices (in rupees, 100 crores), adjusted from financial to calendar years. Source (7), 1966, page 152, for 1952-64 and 1972, page 156, for 1965-68.

6. M_t = commercial imports of cereals in millions of tonnes. Calendar years. Source (27), page 258.

7. W_t = withdrawals of cereals from government stocks in millions of tonnes. Calendar years. Source (7), 1971, page 162.

14. R_t = rainfall index. Construction follows that in Source (3).

16. PS_t = deflated price index of consumption substitutes for cereals. Derived from 4 above and the wholesale price index for all commodities. Source (7). The weights used are P_t = 312, PS_t = 192 and 504 for the wholesale index of all food commodities.

17. QI_t = index of the volume of industrial production, base 1956 = 100. Source (16).

18. FX_t = effective foreign exchange reserves. The value of exports (f.o.b.) plus net capital inflows (adjusted from financial to calendar years) deflated by the ratio of the price index for cereal imports to the ratio for all imports. Value of exports and net capital inflows Source (32) 1970. Price index for cereal imports from Source (7), 1971. S.102, Table 8. Price index for all imports from Source (31), 1970-71, page 229. Both indices have as their base 1963/64 = 100.

19. S_t = beginning period stocks in millions of tonnes. Calendar years. Source (7), 1971, page 35.

20. PR_t = internal procurement of cereals by the government in millions of tonnes. Calendar years. Source (7), 1971, page 35.

21. N_t = midyear population in billions. Source (7), 1974, p. 192 for 1961-68 and earlier issues for 1952-60.

22. QM_t = physiologically necessary minimum availability of cereals. Uses 1950 per capita availability of 141.4 kg (net production of 1949/50 + net imports + withdrawals = total availability) as a constant which is multiplied by 21. 1950 was generally regarded as a year of balanced food provision due to favorable weather conditions during the growing season. See, for example, Mellor, J. W. and A. K. Dar "Determinants and Development Implications of Foodgrain Prices in India, 1949-64" American Journal of Agricultural Economics, 50 (1968) page 964.

23. $PL480_t$ = cereal imports under PL480 in millions of tonnes. Calendar years. Source (27).

Additional Data.

24. QD_t^c = quantity of cereals distributed through the concessional market in millions of tonnes. Calendar years. Source (7), 1970, page 48, table 4.

25. F_t = fertilizer input per hectare in kg. Calendar years. Total fertilizer use Source (8), table 1.23, page 75. Per hectare obtained by dividing by variable 1.

26. P_t^p = index of predetermined (administered) prices in the concessional market, base 1956-57 = 100. Deflated by the wholesale index of all commodities. Calculation of the index involved data for issue prices of wheat. These were obtained from Source (7), 1956, 1961 and 1970. The wholesale price index is that found in Source (32). The construction of this variable parallels that adopted by Rogers et al. (1972).

Table B.1: Data Used in the Model.

Year	1. A_t	2. Y_t	3. QS_t	4. P_t	5. I_t	6. M_t	7. W_t	8. QDC_t	9. QD_t	10. IC	11. QG	12. A_{t-1}	13. P_{t-1}	14. R_t
1952	78.18	.55738		97.2	97.75	3.93	-0.618					78.23	85.3	81.9
1953	82.24	.60812		96.4	103.05	2.04	0.483					78.18	97.2	88.2
1954	87.33	.67804		84.4	106.42	0.83	-0.202					82.24	96.4	110.1
1955	85.94	.66423		79.6	108.58	0.60	0.746					87.33	84.4	101.6
1956	87.34	.63894		89.9	113.10	1.25	0.602					35.94	79.6	116.8
1957	87.82	.66287		93.6	113.56	0.88	-0.856					87.34	89.9	126.2
1958	86.94	.62972		94.3	119.17	1.21	0.269					87.82	93.6	94.9
1959	90.45	.70748	1 x 2	90.3	122.83	0.68	-0.492	(3+6+7+23)/21	3+6+7+23	5/21	22-3-23	86.94	94.3	104.4
1960	90.99	.71297		85.7	130.22	0.79	-1.403					90.45	90.3	103.3
1961	92.01	.75333		80.8	135.86	1.16	0.165					90.99	85.7	104.6
1962	92.98	.76308		83.1	139.15	0.75	0.355					92.01	80.8	118.0
1963	93.57	.73338		84.2	145.81	0.37	0.022					92.98	83.1	96.6
1964	93.23	.75693		90.4	156.55	0.84	1.243					93.67	84.2	98.6
1965	93.74	.82112		89.8	153.02	1.09	-1.063					93.23	90.4	109.7
1966	91.09	.68505		89.7	151.93	2.24	-0.137					93.74	89.8	82.5
1967	94.24	.69911		98.1	162.61	2.75	0.278					91.09	89.7	89.7
1968	98.72	.84026		97.9	170.13	1.53	-2.126					94.24	98.1	108.6
	Million hectares	Tonnes/ hectare	Million tonnes	Index 1952/53=100	Rupees, 100 crores 1948/49 prices	Million tonnes	Million tonnes	Kilograms	Million tonnes	Rupees	Million tonnes	Million hectares	Index 1952/53=100	Index

Table B.1: Data Used in the Model. (Continued)

Year	15.	16.	17.	18.	19.	20.	21.	22.	23.	Additional Data Employed 24.	25.	26.
	T	PS_t	QI_t	FX_t	S_t	PR_t	N_t	QM_t	$PL480_t$	QD^c_t	F_t	P^P_t
1952	52	98.6	75.8	6.21739	1.32	3.48	.3696	51.27	-----	6.80	0.11000	129.53
1953	53	107.3	77.8	6.42771	1.94	2.09	.3761	52.15	-----	4.60	0.15528	114.81
1954	54	108.2	83.1	4.74157	1.46	1.43	.3829	53.07	-----	2.15	0.15871	105.03
1955	55	101.0	91.9	5.35131	1.67	0.13	.3902	54.03	-----	1.64	0.17733	105.13
1956	56	99.7	100.0	7.71665	0.92	0.04	.3978	55.06	0.147	2.08	0.20449	97.09
1957	57	100.5	104.2	7.80408	0.32	0.30	.4058	56.13	2.743	3.05	0.21407	91.74
1958	58	105.3	107.7	7.95632	1.18	0.53	.4143	57.26	2.001	3.98	0.29894	90.09
1959	59	109.4	116.9	7.58913	0.91	1.81	.4233	58.46	3.176	5.16	0.28601	86.21
1960	60	105.4	130.2	7.08397	1.40	1.28	.4327	59.73	4.340	4.94	0.40708	81.30
1961	61	103.6	141.0	7.15168	2.80	0.54	.4424	61.05	2.330	3.98	0.34485	79.37
1962	62	107.5	152.9	6.28245	2.64	0.48	.4522	62.46	2.880	4.37	0.44526	78.74
1963	63	109.8	167.3	7.47839	2.28	0.75	.4620	63.97	4.180	5.18	0.64069	75.76
1964	64	112.6	177.8	7.20932	2.26	1.43	.4721	65.51	5.419	8.67	0.72616	67.57
1965	65	111.0	188.1	8.10125	1.02	4.03	.4820	67.09	6.354	10.08	0.90463	64.28
1966	66	111.0	192.6	11.06460	2.08	4.01	.4932	68.72	8.059	14.09	0.92678	77.62
1967	67	120.6	195.3	9.92924	2.22	4.47	.5042	70.39	5.962	13.17	1.52122	69.16
1968	68	120.6	198.5	11.32619	1.96	6.81	.5154	73.93	4.209	10.39	2.09633	87.32
	Years	Index 1952/53=100	Index 1956=100	Rupees, crores deflaced	Million tonnes	Million tonnes	Billion people	Million tonnes	Million tonnes	Million tonnes	10 kg/ hectare	Index 1956/57=100

APPENDIX C

An Explanation of Time-Lags

The time period for the main economic indicators of Indian agriculture (production, yields, area, and prices) is the agricultural year from July to June (tables C.1. and C.2.). This creates a dating problem since most other economic data relate to calendar years. The figures for income and foreign exchange have to be adjusted from financial year (April to March) to calendar years.

As the main part of the cereal production in the agricultural year, 1949/50 for example, would be harvested and marketed during the calendar year 1950 it is logical to assume that domestic production of 1949/50 equals the total domestic supply of 1950. This resolves the dating problem for supply, area, and yield variables. To achieve model closure we employ the same period (calendar year) in the price index for supply and demand.

The remaining problem is the time-lag that should be assumed between price and supply-response. As the peak marketing periods are November - February for rice and May - June for wheat it seems reasonable to assume that price in these months will influence the production decision in the following period. We would therefore argue that average prices in calendar year, 1949 for example, will exert a major influence on the production decision of the 1949/50 season which in turn produces the supply of cereals in calendar 1950. Thus a time-lag of one year exists between price and area. While this is an approximation it is more logical than the two period lag assumed by Mann and Rogers *et al*.

Table C.1.: Sowing and Harvesting Periods of Crops.

Season	Period	Sowing	Harvesting	Principal Crop (Cereals)
Kharif	May-Oct. 15	May-July	Sept.-Oct.	Jowar, Bajra, Maize, Rice
Zaid Kharif	Aug.-Jan.	Aug.-Sept.	Dec.-Jan.	Rice, Jowar
Rabi	Oct. 15-Apr. 15	Oct.-Dec.	Feb.-April	Wheat, Barley
Zaid Rabi	Feb.-May	Feb.-Mar.	April-May	- - - - - - - - - - - - - -

Table C.2.: Crop Marketing Year.

Crop	Duration of Marketing Year	Duration of Peak Marketing Periods
Rice	Oct.-Sept.	Nov.-Feb.
Wheat	Apr.-Mar.	May-June

Source: Government of India, Directorate of Economics and Statistics, Ministry of Food, Agriculture, Community Development and Co-operation, Bulletin of Food Statistics, New Delhi, 1972, p. 172.

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