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9. ABSTRACT

This paper presents a simulation model which grows out of concurrent formulation of a conceptual framework by Lele and Mellor. The simulation model emphasizes the role of foodgrains as a basic wages good constraint to employment, and the relationships between income from foodgrains production and demand for employment creating goods and services. Particular emphasis is given to demand for various agricultural commodities and the effect of different, technologically induced income distribution patterns on that demand.

Using a simulation approach allows experimentation on the economy described by the simulation model. Here, the main focus is on determining the growth and level of employment in various sectors of the economy in response to technological change and household demand patterns.

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MODERNIZING AGRICULTURE, EMPLOYMENT AND ECONOMIC GROWTH
- A SIMULATION MODEL -

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MODERNIZING AGRICULTURE, EMPLOYMENT AND ECONOMIC GROWTH
- A SIMULATION MODEL - 1/

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1. INTRODUCTION

Recent technological breakthroughs in the agricultural sector offer prospect of significant improvement in the economic performances of many low income countries. Modernizing the agricultural sector has important implications with respect to agricultural production, the supply of wage goods and raw materials to the nonagricultural sector, income distribution patterns, employment and migration patterns, intersectoral resource transfers and changes in farm and nonfarm consumer demand [Mudahar, 13]. This calls for developing new theoretical frameworks to analyze these implications and a new set of priorities for development policy. There is a further need to develop empirical quantitative models which will reflect these theoretical frameworks and lead to relevant policy conclusions.

This paper presents a simulation model which grows out of concurrent formulation of a conceptual framework by Lele and Mellor [10]. The simulation model emphasizes the role of foodgrains as a basic wages good constraint to employment, and the relationship between income from foodgrains production and demand for employment creating goods and services. Particular emphasis is given to demand for various agricultural commodies and the effect of different, technologically induced income distribution patterns on that demand. The basic model is presented in this paper and the results from its application are presented in Occasional Paper No. 76.

1/ The research reported in this paper is financed by contract No. AID/csd-2805 entitled, "The Impact of New Technology on Rural Employment and Income Distribution." We are grateful to Roger Selley for a number of the suggestions and formulations built into this model which date from his early association with its development.

The relevance of various existing models of economic growth in the context of modernizing the agricultural sector in low income countries has been analyzed by Mellor [11]. The overall conclusions of that analysis suggest that existing growth models are inappropriate for analysis of repercussions of new technologies in the agricultural sector and hence for answering many of the currently relevant policy questions with respect to economic growth. Past models are particularly inappropriate where there exists a combination of (i) a large population base with relatively elastic labor supply; (ii) acute food problems and relatively inelastic food supply; (iii) high marginal propensity to consume foodgrains by the low-income, laboring class population; and (iv) scarcity of capital with less than perfect capital-labor substitution [Mellor, 11]. Furthermore, many low-income countries have a large agricultural sector and low industrial base along with scarcity of foreign exchange and limited scope for increasing exports. It is this substantial, but common set of conditions which give such urgency to modernizing agriculture if there is to be broad participation in the processes of growth.

In this context, a framework is needed which incorporates modern technologies in the agricultural sector and allows for interaction between the wage goods constraint and level of employment. Lele and Mellor developed a conceptual framework which "provides a positive alternative to the capital-intensive, import-displacing, low-employment growth patterns followed by many low-income countries," [9]. The model developed in this paper is based on that framework and incorporates interactions between agricultural and nonagricultural sectors with a focus on the impact of modernizing agriculture on production, consumption demand, income distribution and the potential levels of employment in various sectors of the economy.

Section 2 provides an outline of simulation methodology; the agricultural and nonagricultural sectors are discussed in sections 3 and 4 respectively; section 5 deals with consumption demand and income distribution; an input-output framework is developed in section 6; the interdependence between the agricultural and nonagricultural sectors is discussed in section 7; the simulation model structure is

summarized in section 8; and the paper concludes with an outline of various relations which involve the feedback mechanism and the potentials for sensitivity analysis.

2. METHODOLOGY

Several alternative methodological approaches exist for development of a mathematical planning model which allows incorporation of the interrelated elements discussed above. A simulation model can incorporate large numbers of equations and allows handling of nonlinear functions. It facilitates, through a set of equations, performance of alternative policy experiments on the economy. Finally, the number of "degrees of freedom", which is an important consideration in estimating various econometric models, does not pose a serious problem in estimating simulation models.

Day [2] provides a general definition of simulation as follows:

> "An economic simulation model is a system of equations, a computer program or an analog device for representing the behavior of an economy or part of an economy. A simulation run is a particular finite sequence of values for a set of endogenous variables determined by the model for a given set of the initial conditions, parameters and exogenous variables."

Simulation may be viewed as a process of experimentation on a mathematical or statistical model.[2/] This includes approaches such as linear programming, dynamic programming, recursive programming and any kind of econometric model. The model developed in this paper is a simultaneous equation system simulation model. The purpose is not to estimate the coefficients of the simultaneous equation system but to generate a growth path for each of the endogenous variables included in the model.

2/ For review of simulation methodology, see Clarkson and Simon [1], Holland [6], Naylor et. al. [14], Orcutt [15], and Shubik [17].

Holland pioneered in constructing simulation models of low income countries in order to analyze the economic dynamics of these economies.[3/] Holland-Gillespie [7] reported the results of their initial effort to develop a large macrotype simulation model of a developing economy with emphasis on development planning and foreign trade policy. However, the agricultural sector was not the main focus of that study.

Johnson et. al.[8] and Halter et. al.[5] developed a detailed systems science simulation model of the agricultural sector and applied it to Nigerian agriculture. They use a building-block approach and developed sub-models for different components of the economy. These sub-models are independent and detailed models in themselves. The national model is obtained by putting together various interacting sub-models.

This paper presents a simultaneous equation system simulation model which is designed to trace out the implications of the modernizing agricultural sector on the supply of wages goods, employment and income distribution. It follows the Lele-Mellor [10] general equilibrium model of a dualistic economy in which growth of employment is determined by the equilibrium between the independent labor and food markets. The model incorporates the distributive bias of technological change in the food-grains sector and lays out a conceptual framework to analyze the dualistic economy with a modernizing agricultural sector. Their model provides the general conceptual framework for the operation of the dualistic economy on which the simulation model, developed here, is based.

Specifically, the simulation model presented here is designed to trace the effects of technological change on agricultural production, employment in the agricultural and the nonagricultural sectors, consumption behavior and demand patterns, and the subsequent effects upon the supply of wage goods to the nonagricultural sector. The simulation model is highly aggregative in nature and is for the Indian economy as a whole. However, the economy is divided into agricultural

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3/ See also Orcutt et. al. [16].

and nonagricultural sectors. The agricultural sector is further divided into foodgrains and nonfoodgrains sectors. The foodgrains are produced by using both traditional and modern technologies. The nonagricultural sector is further divided into agro-industrial and nonagro-industrial sectors. All the sectors are linked with each other through several simple "feedback and dynamic coupling functions".

3. THE AGRICU[illegible] SECTOR AND TECHNOLOGICAL CHANGE

This section (i) describes two subsectors of the simulation model, the foodgrains agricultural sector and the nonfoodgrains agricultural sector; and (ii) analyzes the nature and role of technological change in the foodgrains agricultural sector.

Foodgrains Agricultural Sector

The foodgrains sector includes the production of cereals and pulses. For simplicity, it is assumed that a technological dualism exists in the foodgrains sector and that foodgrains are produced concurrently by using traditional and modern production techniques. The total foodgrains production at a particular point in time can be specified as

$$(1) \qquad Q_F(t) = Q_F^d(t) + Q_F^m(t),$$

where $Q_F(t)$ is the total production of foodgrains in monetary units during t (prices are assumed constant), $Q_F^d(t)$ is the amount of foodgrains produced by traditional production techniques and $Q_F^m(t)$ is the amount of foodgrains produced by modern production techniques.

Traditional Production Techniques

Traditional production techniques are assumed to represent unirrigated land, labor intensive agricultural operations, little or no use of modern forms of capital, and low-yielding local crop varieties. The amount of foodgrains produced by traditional production techniques can be obtained as

$$(2) \qquad Q_F^d(t) = h_F^d(t) \cdot H_{CF}^d(t),$$

where $h_F^d(t)$ is the yield per unit of land during t under traditional

production techniques and $H^d_{CF}(t)$ is the cropped area sown to foodgrains under traditional production techniques.

The yield per unit of land is assumed to increase over time. This increase in yield is the result of improvements in the traditional production techniques and the adoption of labor intensive new technology. Assuming that yield per unit of land is growing at an exogenously given rate, the yield equation can be specified as

$$(3) \qquad h^d_F(t) = [1 + \gamma^d]^t \, h^d_F(0), \quad t=0, 1, \ldots, \tau.$$

where $h^d_F(0)$ is yield per unit of land under traditional production techniques in the initial period and γ^d is the exogenously given positive annual growth rate in yield per unit of land under traditional production techniques.

Modern Production Techniques

Modern production techniques, are assumed to represent irrigated land, modern forms of capital (including chemical and biological innovations) and high-yielding crop varieties. The amount of foodgrains produced by modern production techniques can be specified as

$$(4) \qquad Q^m_F(t) = h^m_F(t) \; H^m_{CF}(t),$$

where $h^m_F(t)$ is the yield per unit of land during (t) under modern production techniques and $H^m_{CF}(t)$ is the cropped area sown to foodgrains under modern production techniques.

Again, the yield per unit of land is assumed to grow at an exogenously specified growth rate. However, this increase is the result of the adoption of modern technology and biological innovations. The yield equation can now be specified as

$$(5) \qquad h^m_F(t) = [1 + \gamma^m]^t \; h^m_F(0), \; t=0, 1, \ldots, \tau.$$

where $h^m_F(0)$ is yield per unit of land under modern production techniques in the initial period and γ^m is the exogenously given positive annual

growth rate in yield per unit of land under modern production techniques. Finally, it is assumed that once modern methods are adopted on a particular portion of land, then the most recent technology available will always be utilized and the farmer will never retreat to the use of traditional technology.

The difference between traditional and modern production techniques, as defined here, is that modern techniques are assumed to require relatively more modern capital, including chemical and biological innovations. The output-land ratio is also higher in the case of modern cultivation methods. Furthermore, the output-labor ratio is higher in the modern foodgrains sector. The initial level of technology and the technological progress for both the traditional and modern production techniques is assumed to be reflected by a proxy parameter included in the yield equation which is specified exogenously.

Cropped Area Under Foodgrains

At the outset, it is assumed that the proportion of cultivated area in foodgrains and nonfoodgrains remains constant over time. The total cultivated area under foodgrains, $H_F(t)$, is comprised of both irrigated and unirrigated area, i.e.,

$$(6) \qquad H_F(t) = H_F^m(t) + H_F^d(t),$$

where $H_F^m(t)$ and $H_F^d(t)$ refer to cultivated irrigated and cultivated unirrigated area under foodgrains, respectively. Given that the irrigated area can be used to grow multiple crops every year, the total cropped irrigated area under foodgrains, $H_{CF}^m(t)$, can be expressed as

$$(7) \qquad H_{CF}^m(t) = [1 + \alpha^m] H_F^m(t), \; 1 \leq \alpha^m \leq 2,$$

where α^m is the coefficient representing the number of crops which can be grown over and above the regular single crop. $\alpha^m = 1$ implies double cropping and $\alpha^m = 2$ implies triple cropping. α^m is assumed to take only the discrete values.

Increase in the cultivated irrigated area under foodgrains is specified as

$$(8) \qquad H_F^m(t) = H_F^m(t-1) + M_F(t),$$

where $M_F(t)$ is the annual addition to the cultivated irrigated area under foodgrains. This annual addition to the irrigated area is determined by

$$(9) \qquad M_F(t) = \mu[H_F(t-1) - H_F^m(t-1)],$$

where μ is given exogenously and refers to the incremental irrigation capacity coefficient.

Similarly, the total cropped unirrigated area under foodgrains, $H_{CF}^d(t)$, can be derived as

$$(10) \qquad H_{CF}^d(t) = [1 + \alpha^d] \; H_F^d(t), \quad 0 \leq \alpha^d \leq 1,$$

where $H_F^d(t)$ is the total cultivated unirrigated area under foodgrains and α^d is the coefficient representing the number of crops which can be grown over and above the regular single crops. Again, α^d is assumed to take only the discrete values. In general $\alpha^d = o$ implying that the unirrigated land is single cropped.

As mentioned above, only a small portion of unirrigated area under foodgrains is brought under irrigation every year implying

$$(11) \qquad H_F^d(t) = H_F^d(t-1) - M_F(t),$$

where $M_F(t)$ is defined by equation (9). From the above it follows that the total cropped area under foodgrains is given by

$$(12) \qquad H_{CF}(t) = H_{CF}^m(t) + H_{CF}^d(t)$$

In order to determine $H_{CF}(t)$, the initial conditions and the parameter values are specified exogenously. Furthermore, irrigated and unirrigated areas under foodgrains are assumed to be synonymous with area under modern and traditional production technology, respectively.

Nonfoodgrains Agricultural Sector

The nonfoodgrains agricultural sector deals with producing commodities such as milk and milk products; meat, eggs and fish; vegetables; fruits and nuts; spices and pickles; jams and jellies; beverages; tobacco and allied products, etc. The total production of nonfoodgrains agriculture is determined by demand rather than supply conditions. The demand consists of (i) household consumption demand, $C_N(t)$, (ii) intermediate demand in other sectors of the economy, (iii) total demand by the government (state and federal), $G_N(t)$, (iv) net exports, $X_N(t)$, and (v) change in the stock of inventories, $I_N(t)$. The consumption demand and intermediate demand is determined endogenously whereas the rest of the demand components are specified exogenously. The total production (demand) of nonfoodgrains agriculture, $Q_N(t)$, can now be specified as

$$(13) \qquad Q_N(t) = \left[\frac{b_{NF}}{1-b_{NN}}\right] Q_F(t) + \left[\frac{b_{NP}}{1-b_{NN}}\right] Q_P(t)$$

$$+ \left[\frac{1}{1-b_{NN}}\right] C_N(t) + \left[\frac{1}{1-b_{NN}}\right] X_N(t)$$

$$+ \left[\frac{1}{1-b_{NN}}\right] G_N(t) + \left[\frac{1}{1-b_{NN}}\right] I_N(t),$$

where $Q_P(t)$ is the total production of agro-industrial products and b_{ij} are the input-output coefficients.

4. THE NONAGRICULTURAL SECTOR

The nonagricultural sector is divided into two categories, the agro-industrial sector and the nonagro-industrial sector. The agro-industrial sector produces commodities such as vegetable oil and other edible oils, sugar, gur, khandsari, cotton and woolen textiles. Similar to nonfoodgrains agriculture production, the total production of agro-industrial products is determined by demand rather than supply. It supplies processed consumer goods to other sectors of the economy and depends upon the agricultural sector for raw materials. Again, the production of nonfoodgrains and agro-industrial products is expressed in value terms at constant prices.

The total demand for agro-industrial products is comprised of (i) household consumption demand, $C_P(t)$, (ii) intermediate demand in other sectors of the economy, (iii) total demand by the government (state and federal), $G_P(t)$, net exports, $X_P(t)$, and (v) change in the stock of inventories, $I_P(t)$. The consumption demand and the intermediate demand are determined endogenously and the other demand components are specified exogenously. The total production (demand) of agro-industrial products can be specified as

$$(14) \qquad Q_P(t) = \left[\frac{b_{PF}}{1-b_{PP}}\right] Q_F(t) + \left[\frac{b_{PN}}{1-b_{PP}}\right] Q_N(t) + \left[\frac{1}{1-b_{PP}}\right] C_P(t) + \left[\frac{1}{1-b_{PP}}\right] X_P(t) + \left[\frac{1}{1-b_{PP}}\right] G_P(t) + \left[\frac{1}{1-b_{PP}}\right] I_P(t),$$

where b_{ij} are the input-output coefficients.

The nonagro-industrial sector, on the other hand, may be viewed as comprised of a consumer goods sector and a capital goods sector. However, these sectors are not analyzed in this paper which is limited to determining the potential level of employment in the nonagricultural sector which can be supported by the foodgrain supply, at constant relative prices. The foodgrains supply (wage goods) to the nonagricultural sector is determined as a residual after meeting all other demands for foodgrains. The per capita consumption demand for foodgrains by the laboring class is determined endogenously by using explicit consumption functions.

5. CONSUMPTION DEMAND AND INCOME DISTRIBUTION

As observed by Engel, the consumption behavior of households is significantly influenced by their income levels. Recent technological breakthroughs in the agricultural sector of many low-income countries has led to increases in production and income levels of rural households. However, there is growing empirical evidence which shows that large farmers have benefitted relatively more from these new technologies than small farmers and the laboring class [12, 13]. This overall increase in per capita income and the growing disparities in income distribution have important implications for consumption behavior of various expenditure classes. Consumption behavior for various expenditure classes can be represented by their marginal propensity to consume and the income elasticities for various consumer commodity groups. The differences in the consumption patterns of different income groups (expenditure classes) has important implications for demand and marketable surplus of foodgrains, and demand for other consumer goods and services.

Table 1 shows the substantial difference among expenditure classes in the marginal propensity to consume different commodities. The proportion of incremental income spent on foodgrains declines substantially for the higher expenditure classes. Landless laborers spend 55 percent of their incremental incomes to purchase foodgrains whereas farmers in the

Table 1: Allocation of Additional Rupees of Expenditure by Rural Expenditure Classes in India, 1964-65

Expenditure Class	No. of Deciles	Economic Characteristics	Mean per Capita Monthly Expenditure	Agricultural Commodities: Foodgrains (a)	Agricultural Commodities: Nonfoodgrains (b)	Agricultural Commodities: Total	Nonagricultural Commodities & Services: Agro-Industrial (c)	Nonagricultural Commodities & Services: Nonagro-Industrial (d)	Nonagricultural Commodities & Services: Total	Grand Total
			Rupees	Percent						
I	Bottom 2	No Land	8.93	55	14	69	18	13	31	100
II	3rd	< 1 acre	13.14	36	22	58	19	23	42	100
III	4th & 5th	1-5 acres	17.18	24	25	49	18	33	51	100
IV	6th, 7th & 8th	5-10 acres	24.13	15	26	41	18	41	59	100
V	9th	10-15 acres	30.71	10	26	36	13	51	64	100
VI	Lower 1/2 of 10th	15-30 acres	41.89	7	28	35	13	52	65	100
VII	Upper 1/2 of 10th	30+ acres	85.84	2	29	31	11	58	69	100

Source: Compiled from Mellor-Lele [12].

(a) includes cereals and pulses

(b) includes milk and milk products; meat, eggs and fish; other foods; tobacco and allied products.

(c) includes vegetable oil, other edible oil, sugar, gur, khandsari, cotton and woolen textiles.

(d) includes footwear, durables, semi-durables, conveyance, consumer services, education, fuel, light, house rent and miscellaneous consumer goods and services.

highest expenditure class spend only two percent. As a result, there will be an increase in the marketable surplus from the farmers represented by higher expenditure classes and the laboring class will provide a market for the increased supply of foodgrains. The proportion of incremental income spent on nonfoodgrains agricultural commodities increases gradually, and more or less stays constant for agro-industrial goods for different expenditure classes. However, the proportion of incremental income spent on nonagro-industrial goods and services increases significantly for higher expenditure classes.

Consumers have been divided into two expenditure classes in this simulation model: (i) laborers (including small farmers) and (ii) enterpreneurs. Consumer commodities are divided into four groups:[4/] (i) foodgrains, (ii) nonfoodgrains, (iii) agro-industrial goods (mainly processed agriculture), and (iv) nonagro-industrial goods and services. We can now specify the log-log-inverse consumption function for the ith expenditure class and j^{th} commodity group as follows:[5/]

$$\log_e c_{ij}(t) = \alpha_{ij} + \frac{\beta_{ij}}{Y_i(t)} + \gamma_{ij} \log_e Y_i(t), \tag{15}$$

where $c_{ij}(t)$ is per capita consumption of ith expenditure class for j^{th} commodity group, $Y_i(t)$ is per capita income of ith expenditure class, and α_{ij}, β_{ij} and γ_{ij} are the consumption function coefficients. The consumption

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4/ The definition of each of these commodity groups is given at the bottom of Table 1.

5/ Goreux [4] and Sinha [18] have suggested and evaluated alternative forms for the consumption function in order to analyze consumption behavior of households in low income countries. Some of these include linear, double-log, semi-log, log-inverse, log-log inverse and hyperbolic forms. For justifications for the use of log-log inverse function to analyze the expenditure patterns in low income countries, see Goreux [4] and Sinha [18]. Desai [3] has also used log-log-inverse function to analyze the consumption expenditure patterns in India. In this study we have chosen the log-log-inverse function partly because we have already used it to obtain consumption coefficients and to analyze the household consumption behavior of different expenditure classes in India.

demand is estimated for both the labor households and entrepreneur households. However, for simplicity, the consumption behavior of urban laborers and entrepreneurs is assumed the same as for corresponding rural laborers and entrepreneurs.

The expenditure elasticity for i^{th} expenditure class and j^{th} commodity group, $e_{ij}(t)$, is given by

$$(16) \qquad e_{ij}(t) = \gamma_{ij} - \frac{\beta_{ij}}{Y_i(t)},$$

which depends upon γ_{ij}, β_{ij} and $Y_i(t)$. The total consumption expenditure for i^{th} expenditure class and j^{th} commodity group in the agricultural sector, $C_{ijA}(t)$, is determined by

$$(17) \qquad C_{ijA}(t) = C_{ij}(t) \; N_{iA}(t),$$

where $N_{iA}(t)$ is the number of consumers in the ith expenditure class in the agricultural sector during t. The total consumption of jth commodity group in the agricultural sector, $C_{jA}(t)$, is the sum of the consumption by the two expenditure classes, ie,

$$(18) \qquad C_{jA}(t) = \Sigma_{i=1}^{2} \; C_{ijA}(t).$$

Similarly, we can determine the total consumption expenditure for i^{th} expenditure class and j^{th} commodity group, $C_{ijN}(t)$, and the total consumption of the jth commodity group, $C_{jN}(t)$, in the nonagricultural sector as

$$(19) \qquad C_{ijN}(t) = c_{ij}(t) \; N_{iN}(t),$$

$$(20) \qquad C_{jN}(t) = \Sigma_{i=1}^{2} \; C_{ijN}(t)$$

where $N_{iN}(t)$ is the number of consumers in the ith expenditure class in the nonagricultural sector.

Both $C_{jA}(t)$ and $C_{jN}(t)$ are changing over time since $c_{ij}(t)$, $N_{iA}(t)$ and N_{iN} are changing in response to various endogenous feedback functions and exogenous variables. The per capita income which determines the levels of per capita expenditure on various commodity groups is changing in response to changes in wage rate and employment levels. The magnitude of $N_{iA}(t)$ and $N_{iN}(t)$ is changing in response to population growth and migration patterns.

6. AGGREGATE OUTPUT AND DEMAND: INPUT-OUTPUT FRAMEWORK

The aggregate output of three major sectors is exhaused by various components of demand. These demand components consist of (i) household consumption demand; (ii) intermediate demand in other sectors of the economy, (iii) total demand by government, (iv) net exports, and (v) changes in the stock of inventories. These demand and supply components can be realistically represented by using a Leontief type input-output framework. The input-output framework allows us to incorporate demand, supply and the interactions among foodgrains, nonfoodgrain and agro-industrial sectors. Algebraically, the total output and demand for these sectors can be formulated as

$$B(t)\ Q(t) + C(t) + X(t) + G(t)\ I(t) = Q(t), \tag{21}$$

where Q(t) is a three-dimensional vector of total output from three sectors; B(t) is a 3 x 3 dimensional matrix of input-output coefficients with b_{ij} as the input of the ith good required to produce a unit of jth good; C(t) is a three-dimensional vector of household demand; X(t) is three-dimensional vector of net export demand; G(t) is a three-dimensional vector of government demand; and I(t) is a three-dimensional vector of change in inventory. C(t) is the sum of household demand in both the agricultural and nonagricultural sectors. All of these supply and demand components are expressed in value terms at constant price levels. In this particular case we can view i=1 as foodgrains sector, i=2 as nonfoodgrains sector, and i=3 as agro-industrial sector.

The solution to equation (21) can be obtained as follows

$$Q(t) = [I-B]^{-1}\ [C(t) + X(t) + G(t) + I(t)], \tag{22}$$

where I is the three-dimensional identity matrix and $[I-B]^{-1}$ is the inverse of [I-B]. For the existence of solution to equation (22), $[I-B]^{-1}$ must be non-singular. Otherwise, $[I-B]^{-1}$ does not exist and a solution can not be obtained.

7. INTERDEPENDENCE BETWEEN AGRICULTURAL AND NONAGRICULTURAL SECTORS

The interdependence between the agricultural and the nonagricultural sectors can be analyzed from four different aspects. These are (i) intermediate demand among sectors; (ii) household demand for nonfarm consumer goods; (iii) food supply and demand; and (iv) labor supply and employment. Each of these four aspects is discussed below.

Intermediate Demand

The foodgrains, nonfoodgrains and agro-industrial sectors are highly interdependent in the sense that they use outputs from each other's sector as inputs to produce their own outputs. As a result, an intermediate demand exists for the output of these three sectors. The total output of one particular sector is constrained by the output of other sectors which is made available as an input to that sector. On the other hand, the intermediate demand for the output of a particular sector depends on the "capacity to produce" of other dependent sectors and the magnitude of input-output coefficients. The intermediate demand is explicitly taken into account through the input-output framework described above. The magnitude of the input-output coefficients reflects the degree of interdependence among sectors.

Household Demand for Nonfarm Consumer Goods

As has been reported in Table 1, household demand for nonagro-industrial goods and services increases substantially from lower to higher expenditure class. The landless laborers spend only 13 percent of their incremental income to purchase nonagro-industrial goods whereas the highest expenditure class, represented by the upper half of the 10th decile, spends 58 percent of their incremental income on those goods. This reflects the

creation of potential new demand for nonfarm consumer goods in the rural-agricultural sector and supports the view held by Goerux and Houthakker that demand conditions play a crucial role in the process of industrialization. This aspect of demand has gained an added significance through the "green revolution."

Food Supply and Demand

The foodgrains and other sectors in the economy are interdependent on each other for the supply and demand of foodgrains. The marginal propensity to consume foodgrains out of incremental income by large farming households is relatively very low (Table 1). Furthermore, it is these farmers who produce the major portion of the foodgrains. Consequently, in a context of dynamic growth, the marketable and marketed surplus of foodgrains increases at a faster rate than the production of foodgrains. Because of this high marginal propensity to spend added income on foodgrain the laboring class in both the agricultural and nonagricultural sectors provide the basic market potential for expanded food supplies (Table 1). However, in order to create this additional demand for foodgrains, laborers must have the purchasing power which can come from sustained increase in employment. Thus, both the demand (through employment) and the supply of foodgrains is explicitly included in this model.

Labor Supply and Employment

It is reasonable to assume that the supply of labor from the rural-agricultural sector to the urban-industrial sector is relatively elastic. The conclusion then follows that the immediate economic problem is not of labor supply but rather of providing wages goods and creating demand for labor through creating more employment opportunities in both agricultural and nonagricultural sectors.

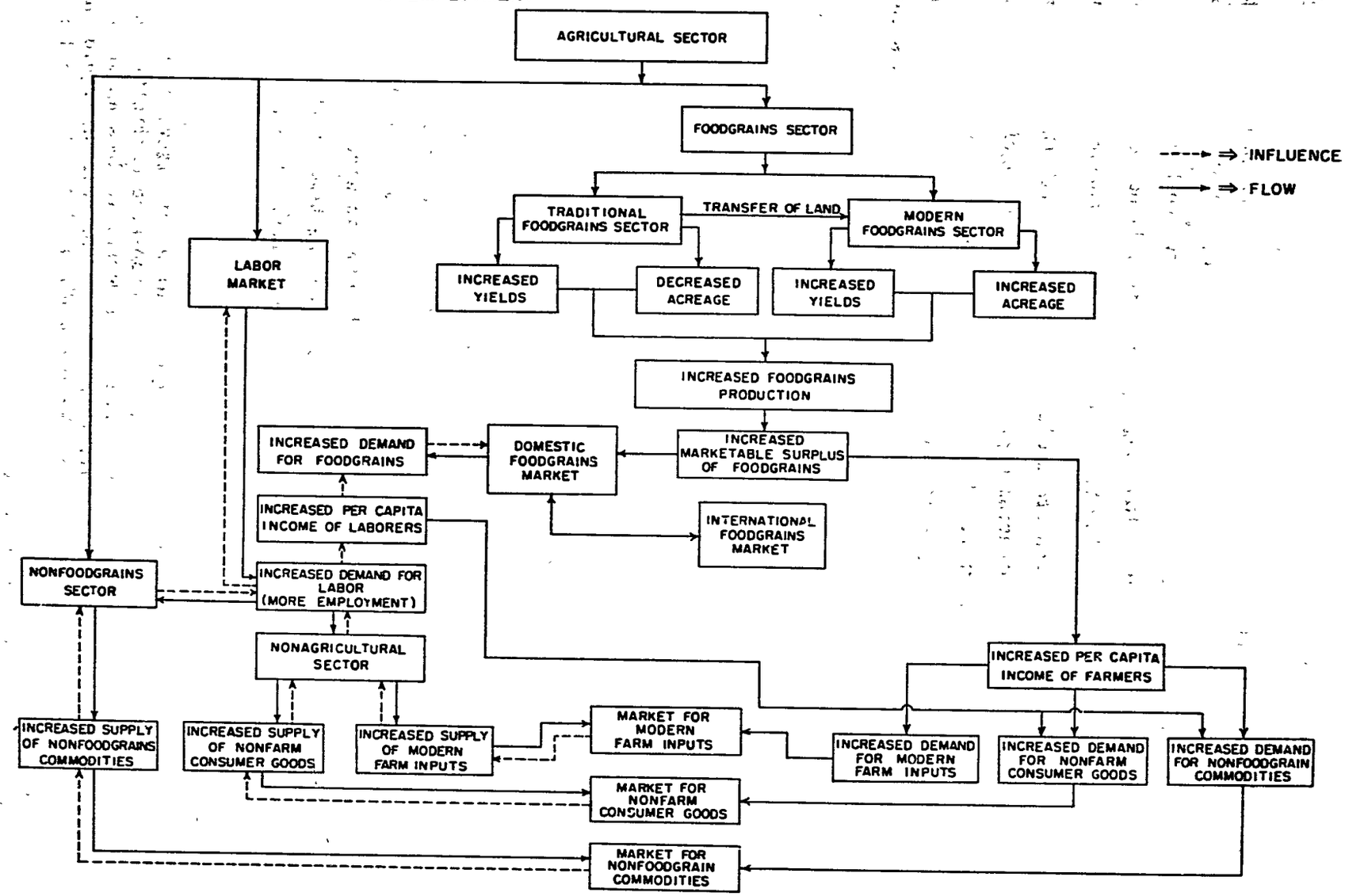
The recent technological breakthroughs in the agricultural sector of the low income countries, as well as other countries, led to ncreases in the marketable surplus of foodgrains and subsequent increases in income levels of all income groups. Given the consumption behavior of farmers falling within the higher income groups, this has led to an increase in

demand for nonfarm consumer goods and an increase in demand for modern production inputs. In order to meet these growing demand components, the nonagricultural sector must increase the supply of these commodities. Most of these commodities can be produced by relatively labor intensive supply industries in the nonagricultural sector which, in turn, should create increased demand for labor with concomitant new employment opportunities. The resulting increased income of this laboring class should create a large demand for foodgrains or wage goods, given their traditional consumption behavior. However, in order to maintain these newly created employment opportunities and prevent an inflationary spiral, the foodgrains sector must be able to meet the increased demand for foodgrains. This interdependence between foodgrains production, demand creation and employment is illustrated in Figure 1. Furthermore, we have to strike a balance between the total supply of and demand for labor as well as foodgrains.

The total labor employed in the nonagricultural sector depends upon the supply of foodgrains produced by the foodgrain sector. By determining the marketable surplus (after meeting all the demand except for household consumption demand for foodgrains by laborers in the nonagricultural sector) and per capita expenditure on foodgrains, we can determine the employment potential generated in the nonagricultural sector as a result of an expansion in the foodgrains sector. It has been assumed (given the supply conditions) that if excess labor demand exists in the nonagricultural sector, labor will migrate from the agricultural sector and keep migrating until a full employment situation is reached in both sectors.

The current experience of many low income countries indicates that both money wages and unemployment have been increasing over time, implying that the Phillips curve is shifting towards the right. However, the development of new agricultural technologies now being more widely used in low income countries makes it possible to increase food supplies which supports a larger labor force through the increased supply of wage goods and hence reduces unemployment. Consequently, there is a possibility of shifting the Phillips curve towards the left and hence reducing either unemployment or both unemployment and inflation. This is shown graphically

FIGURE I. SIMULATION MODEL: CONCEPTUAL FRAMEWORK ILLUSTRATING INTERDEPENDENCE BETWEEN FOODGRAINS PRODUCTION, DEMAND CREATION AND EMPLOYMENT



in Figure 2. In this case, the Phillips curve is represented by PP, the percentage change in wages and unemployment is ΔW_1 and ΔL_1, respectively. However, if we are able to shift the Phillips curve to P' P' through increased supply of foodgrains (wage goods), it will be possible to reduce the unemployment rate to ΔL_2 by keeping the percent change in wages constant.

This model is not concerned with migration nor with the factors which arise to determine a potential migrant's move from the agricultural to the nonagricultural sector. Most migration models are concerned with the process of migration per se rather than the question of sufficient food (wage goods) for the potential migrants in the urban sector. This latter aspect is the main focus of this model.

8. THE SIMULATION MODEL STRUCTURE

The general structure of the simulation model is described both graphically and mathematically. Figure 1 specifically, and Figure 3 more generally, illustrate (i) the basic components of the simulation model, (ii) resource flows and factor movements, (iii) interdependence among various sectors in the economy, (iv) input and output markets, and (v) the changing technology in the agricultural sector.[6/]

The mathematical structure of the simulation model is outlined below. Most of the variables are described in the title of the equation which is followed by a brief description.[7/] In the empirical part of this model, however, we have tried different functional forms in some equations and have incorporated different variables to determine some of the endogenous variables. All of these modifications are not reported in this paper.

Cropped area under foodgrains (total)

6/ All the components related to the capital market of Figure 3, i.e.the demand for and supply of capital goods, are not incorporated explicitly in the present version of the simulation model. However, it does exist in the background of the model and we implicitly refer to the role of liquid and physical capital in the production process of the agricultural and nonagricultural sectors. We realize that it is an obvious shortcoming. However, the model will be extended to incorporate the capital market at a later date.

7/ All the variables used in the simulation model refer to indices unless these are defined otherwise.

FIGURE 2. PHILLIPS CURVE AND THE SUPPLY OF WAGES GOODS

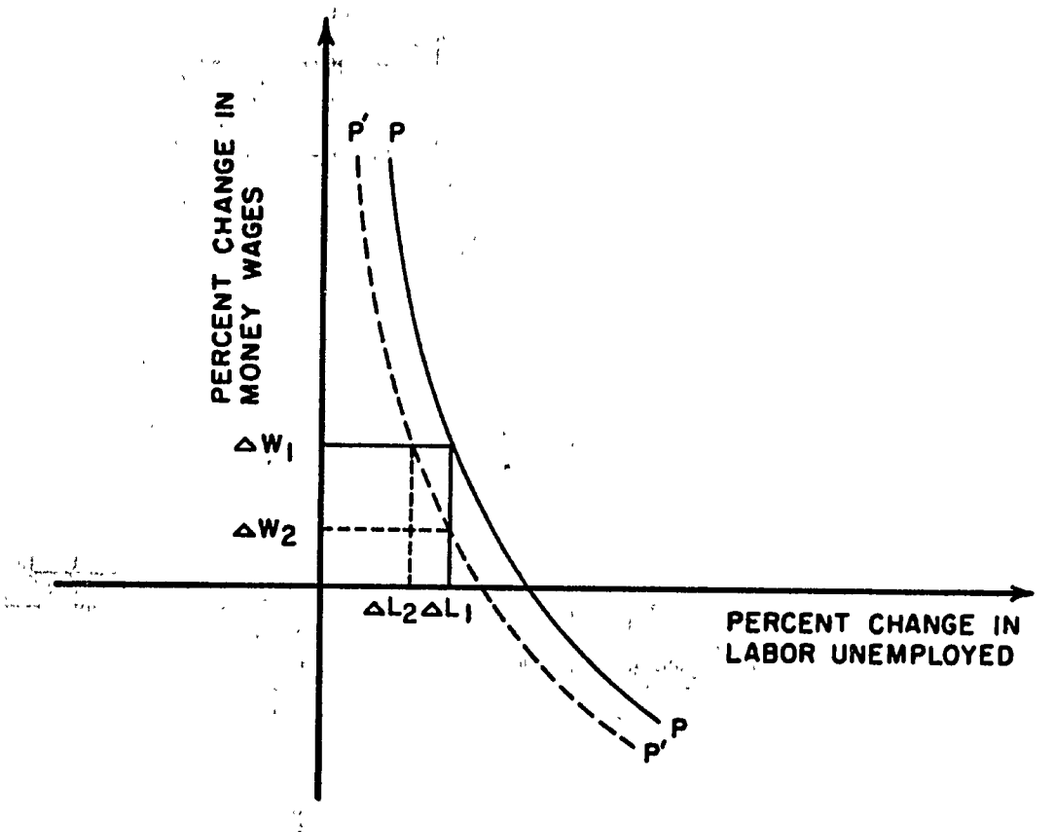
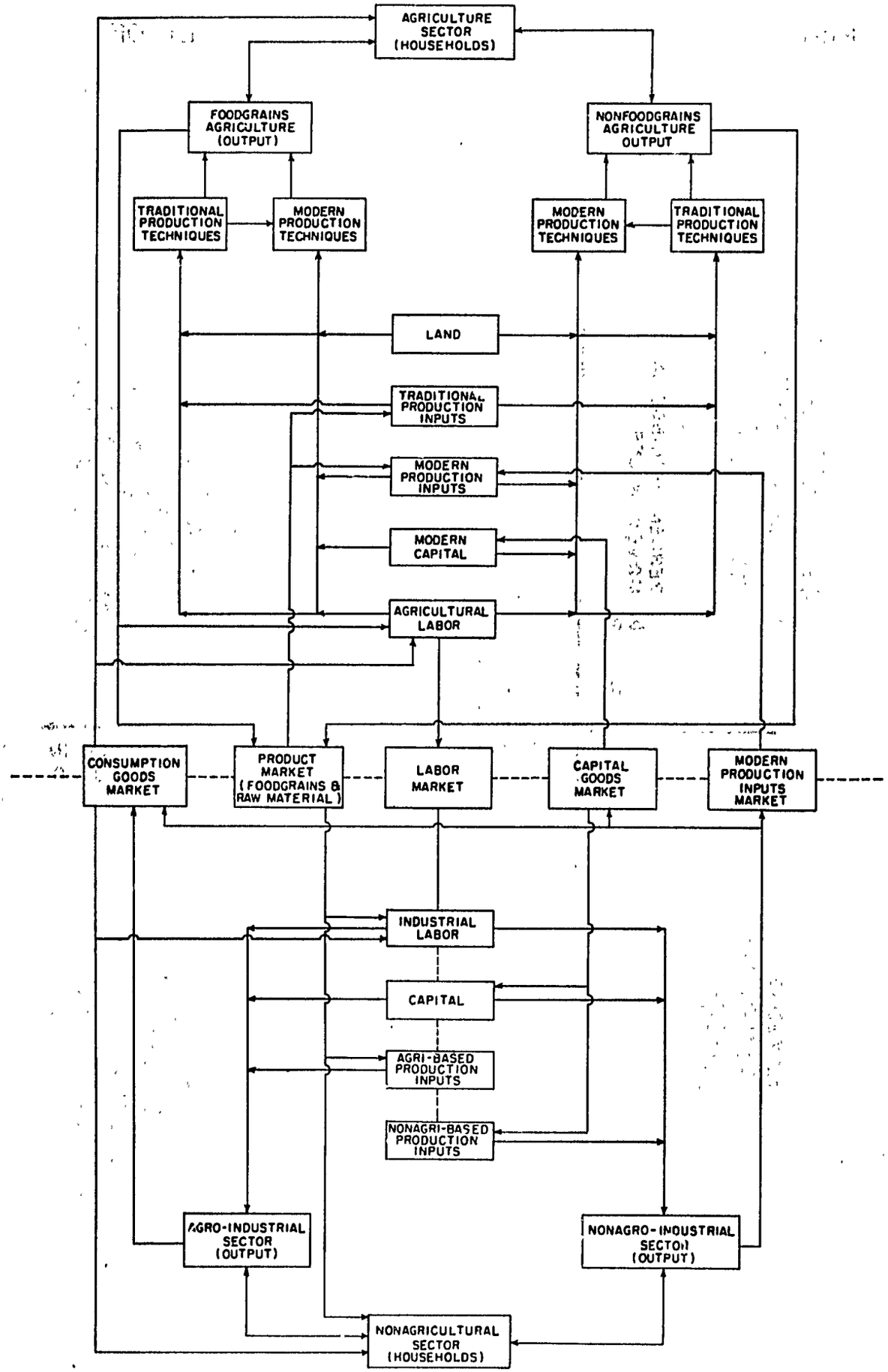


FIGURE 3. DIAGRAMATIC SUMMARY OF THE GENERALIZED SIMULATION MODEL OF THE INDIAN ECONOMY



(23) $$H_{CF}(t) = H^m_{CF}(t) + H^d_{CF}(t)$$

Cropped area under foodgrains (modern technology)

(24) $$H^m_{CF}(t) = \left[1 + \alpha^m\right] H^m_F(t), \quad 1 \leq \alpha^m \leq 2$$

Cropped area under foodgrains (traditional technology)

(25) $$H^d_{CF}(t) = \left[1 + \alpha^d\right] H^d_F(t), \quad 0 \leq \alpha^d \leq 1$$

Net irrigated area under foodgrains

(26) $$H^m_F(t) = H^m_F(t-1) + M_F(t)$$

Net unirrigated area under foodgrains

(27) $$H^d_F(t) = H^d_F(t-1) - M_F(t)$$

Increment in the area under irrigation (foodgrains)

(28) $$M_F(t) = \mu \left[H_F(t-1) - H^m_F(t-1)\right]$$

Net area under foodgrains (irrigated + unirrigated)

(29) $$H_F(t) = H^m_F(t) + H^d_F(t)$$

Yield equation of foodgrains (modern technology)

(30) $$h^m_F(t) = \left[1 + \gamma^m\right] h^m_F(t-1), \quad \gamma^m > 0$$

Yield equation of foodgrains (traditional technology)

(31) $$H^d_F(t) = \left[1 + \gamma^d\right] h^d_F(t-1), \quad 0 < \gamma^d < \gamma^m$$

Total production of foodgrains from modern technology

(32) $$Q^m_F(t) = h^m_F(t)\, H^m_{CF}(t)$$

Total production of foodgrains from traditional technology

(33) $$Q_F^d(t) = h_F^d(t)\ H_{CF}^d(t)$$

Total production of foodgrains (modern technology + traditional technology)

(34) $$Q_F(t) = Q_F^m(t) + Q_F^d(t)$$

Proportion of foodgrains cropped area under modern cultivation

(35) $$\phi\ (t) = \frac{H_{CF}^m(t)}{H_{CF}(t)},$$ $\phi\ (t)$ is increasing over time since $H_{CF}^m(t)$ is increasing at a faster rate than $H_{CF}(t)$

Average output-land ratio of foodgrains (average production per unit of land)

(36) $$h_F(t) = \frac{Q_F(t)}{H_{CF}(t)}$$

Output-labor (employed) ratio of foodgrains (modern technology)

(37) $$q_F^m(t) = \frac{Q_F^m(t) \cdot w}{S_{\ell F}^m(t)}$$

In other words,

$$q_F^m(t) = \frac{Q_F^m(t)}{P_{LAF}^{Em}(t)}$$

where $P_{LAF}^{Em}(t) = \frac{S_{\ell F}^m(t)}{w}$ or $\left[= \frac{Q_F^m(t)}{q_F^m(t)} \right]$.

$P_{LAF}^{Em}(t)$ refers to employed labor force in the modern foodgrains sector and w is the wage rate.

Employed labor's total share in foodgrains production (modern technology)

(38) $$S_{\ell F}^m(t) = \left[s_{\ell F}^m - s_{\ell F}^{m\Delta} \right] Q_F^m(0) + s_{\ell F}^{m\Delta}\ Q_F^m(t)$$

where $Q_F^m(0)$ is the initial output of foodgrains (modern) and $Q_F^m(t)$ is the output of foodgrains (modern) in time t (any time after the initial period); $s_{\ell F}^m$ is labor's share in the initial output and $s_{\ell F}^{m\Delta}$ is labor's share in the incremental output. The expression for $S_{\ell F}^m(t)$ is derived as follows:

$$S_{\ell F}^m(t) = s_{\ell F}^m \, Q_F^m(0) + s_{\ell F}^{m\Delta} \left[Q_F^m(t) - Q_F^m(0) \right]$$

or

$$S_{\ell F}^m(t) = s_{\ell F}^m \, Q_F^m(0) + s_{\ell F}^{m\Delta} \, Q_F^m(t) - s_{\ell F}^{m\Delta} \, Q_F^m(0)$$

or

$$S_{\ell F}^m(t) = \left[s_{\ell F}^m - s_{\ell F}^{m\Delta} \right] Q_F^m(0) + s_{\ell F}^{m\Delta} \, Q_F^m(t)$$

Output-labor (employed) ratio of foodgrains (traditional technology). For comments see equation #37.

$$(39) \qquad q_F^d(t) = \frac{Q_F^d(t) \cdot w}{S_{\ell F}^d(t)}$$

Employed labor's total share in foodgrains production (traditional technology). For derivation see equation #38.

$$(40) \qquad S_{\ell F}^d(t) = \left[s_{\ell F}^d - s_{\ell F}^{d\Delta} \right] Q_F^d(0) + s_{\ell F}^{d\Delta} \, Q_F^d(t)$$

Output-labor (employed) ratio of non-foodgrains. For comments see equation #37.

$$(41) \qquad q_N(t) = \frac{Q_N(t) \cdot w}{S_{\ell N}(t)}$$

Employed labor's total share in non-foodgrains production. For derivation see equation #38.

$$(42) \qquad S_{\ell N}(t) = \left[s_{\ell N} - s_{\ell N}^{\Delta} \right] Q_N(0) + s_{\ell N}^{\Delta} \, Q_N(t)$$

Average output labor ratio of foodgrain.

$$(43) \qquad q_F(t) = \frac{Q_F(t)}{P_{LAF}^{Em}(t) + P_{LAF}^{Ed}(t)}$$

where $P^{Em}_{LAF}(t)$ and $P^{Ed}_{LAF}(t)$ refers to employment in the modern and traditional foodgrains sector, respectively.

Total production of non-foodgrains

$$(44) \qquad Q_N(t) = \left[\frac{b_{NF}}{1 - b_{NN}}\right] Q_F(t) + \left[\frac{b_{NP}}{1 - b_{NN}}\right] Q_P(t) + \left[\frac{1}{1 - b_{NN}}\right] C_N(t) + \left[\frac{1}{1 - b_{NN}}\right] X_N(t)$$

where b_{ij} refer to input-output coefficients, $C_N(t)$ is consumption of non-foodgrains and $X_N(t)$ is net export of non-foodgrains.

Total output of agro-industrial products (processed agriculture)

$$(45) \qquad Q_P(t) = \left[\frac{b_{PF}}{1 - b_{PP}}\right] Q_F(t) + \left[\frac{b_{PN}}{1 - b_{PP}}\right] Q_N(t) + \left[\frac{1}{1 - b_{PP}}\right] C_P(t) + \left[\frac{1}{1 - b_{PP}}\right] X_P(t)$$

Again, b_{ij} refer to input-output coefficients, $C_P(t)$ is the total consumption of processed agriculture and $X_P(t)$ is the net export of processed agriculture. However, in case $X_P(t)$ (or $X_N(t)$, for that matter) has a negative sign, it implies import of processed agriculture. The production of nonfoodgrains and processed agricultural commodities is determined by the demand equations (rather than the supply considerations).

Per capita annual expenditure (or per capita income) of total employed + unemployed) labor in the agricultural sector (index)

$$(46) \qquad y_{LA}(t) = \frac{E_{LA}(t)}{P_{LA}(t)}$$

This equation implies that laborers don't save. In other words, they consume whatever they earn, i.e. per capita annual expenditure is equal to per capita annual income.

Total annual wage bill or expenditure (or total income) of employed labor force in the agricultural sector

(47) $$E_{LA}(t) = w \cdot P^{E}_{LA}(t)$$

Adjusted per capita monthly expenditure of total (employed and unemployed) labor in the economy (in rupees).

(48) $$Y_L(t) = \frac{E_{LA}(t)}{P_{LA}(t)} \cdot X_L = y_{LA}(t).X_L$$

where X_L is the actual total monthly consumption expenditure for the laboring class. It is estimated from the cross-sectional data collected by NSS and NCAER. In this case, $X_L = 16.9$ and is expressed in rupees. By substituting for $E_{LA(t)}$ we obtain

$$Y_L(t) = \frac{w \cdot P^{E}_{LA}(t)}{P_{LA}(t)} \cdot X_L = w \left[\frac{P^{E}_{LA}(t)}{P_{LA}(t)}\right] \cdot X_L = w_I(t) \cdot X_L$$

where $w_I(t)$ is the (effective) implicit wage rate in the economy. In the case of full-employment, $P^{E}_{LA}(t), = P_{LA}(t)$ or $P^{E}_{LA}(t)/P_{LA}(t) = 1$. This implies that when the economy achieves full-employment, $Y_L(t)$ reaches an upper limit which is equal to $(w \cdot X_L)$. In a sense, $Y_L(t)$ is a function of the amount of labor employed. $Y_L(t)$ is used as an independent variable to estimate the consumption functions for foodgrains, non-foodgrains and processed agriculture for the laboring class. However, consumption of foodgrains, non-foodgrains and processed agriculture will not change after $Y_L(t)$ reaches an upper limit. Since

$$0 < \left[P^{E}_{LA}(t)/P_{LA}(t)\right] \leq 1,$$

the expenditure multiplication-factor stays between the upper and lower limits of

$$0 < \left[w \cdot P_L^E (t)/P_L (t) \right] = w_I (t) \leq w.$$

Labor's budget share of foodgrains consumption expenditure in the total monthly consumption expenditure. The annual budget share will be same as the monthly budget share since we have to multiply both the numerator and denominator by 12 to obtain annual budget share. Both cancel out.

(49) $$\pi_{LCF}(t) = \frac{C_{LF}(t)}{Y_L(t)}$$

Per capita monthly consumption expenditure on foodgrains by labor in the economy

(50) $$C_{LF}(t) = \text{Exp.} \left[\beta_{OF} + \frac{\beta_{1F}}{Y_L(t)} + \beta_{2F} \log Y_L (t) \right]$$

Labor's annual consumption index of expenditure on foodgrains

(51) $$I_{LCF} (t) = \pi_{LCF} (t) \cdot w_I (t)$$

Labor's expenditure elasticity of foodgrains consumption

(52) $$e_{LF}(t) = \frac{\beta_{2F} Y_L (t) - \beta_{1F}}{Y_L (t)}$$

Labor's budget share of non-foodgrains consumption expenditure in the total monthly consumption expenditure (see equation #49 for comments).

(53) $$\pi_{LCN}(t) = \frac{C_{LN} (t)}{Y_L (t)}$$

Per capita monthly consumption expenditure on non-foodgrains by labor in the economy

(54) $$C_{LN} (t) = \text{Exp.} \left[\beta_{ON} + \frac{\beta_{1N}}{Y_L (t)} + \beta_{2N} \log Y_L (t) \right]$$

Labor's annual consumption index of expenditure on non-foodgrains

(55) $$I_{LCN}(t) = \pi_{LCN}(t) \cdot w_I(t)$$

Labor's expenditure elasticity of non-foodgrains consumption

(56) $$e_{LN}(t) = \frac{\beta_{2N} Y_L(t) - \beta_{1N}}{Y_L(t)}$$

Labor's budget share of consumption expenditure on processed agricultural commodities in the total monthly consumption expenditure (see equation #49 for comments)

(57) $$\pi_{LCP}(t) = \frac{C_{LP}(t)}{Y_L(t)}$$

Per capita monthly consumption expenditure on processed agriculture by labor in the economy

(58) $$C_{LP}(t) = \text{Exp.}\left[\beta_{OP} + \frac{\beta_{1P}}{Y_L(t)} + \beta_{2P} \log Y_L(t)\right]$$

Labor's annual consumption index of expenditure on processed agriculture

(59) $$I_{LCP}(t) = \pi_{LCP}(t) \cdot w_I(t)$$

Labor's expenditure elasticity of processed agriculture consumption

(60) $$e_{LP}(t) = \frac{\beta_{2P} Y_L(t) - \beta_{1P}}{Y_L(t)}$$

Adjusted per capita monthly expenditure of entrepreneurs in the economy

(61) $$Y_E(t) = \left[\frac{E_{LA}(t)}{P_{LA}(t)} \cdot X_L\right] \frac{X_E}{X_L} = Y_L(t)\left[\frac{X_E}{X_L}\right]$$

The estimated value of X_E is 44.1 rupees. X_E refers to the actual total monthly consumption expenditure by the entrepreneurs. For further comments see equation #48.

Per capita monthly consumption expenditure on foodgrains by entrepreneurs in the economy

$$(62) \qquad C_{EF}(t) = \text{Exp.}\left[\beta_{OF} + \frac{\beta_{1F}}{Y_E(t)} + \beta_{2F} \log Y_E(t)\right]$$

Per capita monthly consumption expenditure on non-foodgrains by entrepreneurs in the economy

$$(63) \qquad C_{EN}(t) = \text{Exp.}\left[\beta_{ON} + \frac{\beta_{1N}}{Y_E(t)} + \beta_{2N} \log Y_E(t)\right]$$

Per capita monthly consumption expenditure on processed agriculture by entrepreneurs in the economy

$$(64) \qquad C_{EP}(t) = \text{Exp.}\left[\beta_{OP} + \frac{\beta_{1P}}{Y_E(t)} + \beta_{2P} \log Y_E(t)\right]$$

Marketable surplus (supply) of foodgrains after meeting intermediate and consumption requirements in the agricultural sector.

$$(65) \qquad S_F(t) = Q_F(t) - b_{FF}\, Q_F(t) - C^T_{FA}(t) - \beta_{FN}\, Q_N(t)$$

Total consumption expenditure on foodgrains in the agricultural sector (labor plus entrepreneurs)

$$(66) \qquad C^T_{FA}(t) = C^T_{LFA}(t) + C^T_{EFA}(t)$$

Total consumption expenditure on foodgrains by laborers in the agricultural sector

$$(67) \qquad C^T_{LFA}(t) = I_{LCF}(t) \cdot P_{LA}(t)$$

Total consumption expenditure on foodgrains by entrepreneurs in the agricultural sector

$$(68) \quad C^T_{EFA}(t) = \frac{C_{EF}(t)}{Y_E(t)} \cdot [p_A \cdot P_E(t)] \cdot w_I(t)$$

where $P_E(t)$ is the total number of entrepreneurs in the agricultural and nonagricultural sectors. The proportion of entrepreneurs in the agricultural sector is represented by the coefficient p_A.

Demand for foodgrains in the nonagricultural sector

$$(69) \quad D_{FN}(t) = b_{FP}\, Q_P(t) + C^T_{FN}(t)$$

Total consumption expenditure on foodgrains in the nonagricultural sector

$$(70) \quad C^T_{FN}(t) = C^T_{LFN}(t) + C^T_{EFN}(t)$$

Total consumption expenditure on foodgrains by labor in the nonagricultural sector (All the labor is assumed to be employed. See equation for determining the labor employed in the nonagricultural sector).

$$(71) \quad C^T_{LFN}(t) = I_{LCF}(t) \cdot P^E_{LN}(t)$$

Total consumption expenditure on foodgrains by entrepreneurs in the nonagricultural sector

$$(72) \quad C^T_{EFN}(t) = \left[\frac{C_{EF}(t)}{Y_E(t)}\right] \cdot [p_N \cdot P_E(t)] \cdot w_I(t)$$

where the coefficient p_N represents the fraction of entrepreneurs in the nonagricultural sector.

Proportion of foodgrains marketed out of the agricultural sector

$$(73) \quad p(t) = \frac{S_F(t)}{Q_F(t)}$$

The total amount (production) of foodgrains is exhausted by (i) intermediate demand in the agricultural and

nonagricultural sector, and (ii) consumption of foodgrains by labor and entrepreneurs in the agricultural and nonagricultural sector.

Total consumption expenditure on non-foodgrains (required to determine the total demand for non-foodgrains)

$$(74) \qquad C_N(t) = C^T_{NA}(t) + C^T_{NN}(t)$$

Total consumption expenditure on non-foodgrains in the agricultural sector

$$(75) \qquad C^T_{NA}(t) = C^T_{LNA}(t) + C^T_{ENA}(t)$$

Total consumption expenditure on non-foodgrains by laborers in the agricultural sector

$$(76) \qquad C^T_{LNA}(t) = I_{LCN}(t) \cdot P_{LA}(t)$$

Total consumption expenditure on non-foodgrains by entrepreneurs in the agricultural sector

$$(77) \qquad C^T_{ENA}(t) = \left[\frac{C_{EN}(t)}{Y_E(t)}\right] [p_A \cdot P_E(t)] \cdot w_I(t)$$

Total consumption expenditure on non-foodgrains in the nonagricultural sector

$$(78) \qquad C^T_{NN}(t) = C^T_{LNN}(t) + C^T_{ENN}(t)$$

Total consumption expenditure on non-foodgrains by laborers in the nonagricultural sector

$$(79) \qquad C^T_{LNN}(t) = I_{LCN}(t)\, P^E_{LN}(t), \; [P^E_{LN}(t) = P_{LN}(t)]$$

Total consumption expenditure on non-foodgrains by entrepreneurs in the nonagricultural sector

$$(80) \qquad C^T_{ENN}(t) = \left[\frac{C_{EN}(t)}{Y_E(t)}\right] \cdot [p_N \cdot P_E(t)] \cdot w_I(t)$$

Total consumption expenditure on processed agriculture commodities (required to determine the demand for processed agriculture)

$$(81) \qquad C_P(t) = C^T_{PA}(t) + C^T_{PN}(t)$$

Total consumption expenditure on processed agriculture commodities in the agricultural sector

$$(82) \qquad C^T_{PA}(t) = C^T_{LPA}(t) + C^T_{EPA}(t)$$

Total consumption expenditure on processed agricultural commodities by laborers in the agricultural sector

$$(83) \qquad C^T_{LPA}(t) = I_{LCP}(t)\ P_{LA}(t)$$

Total consumption expenditure on processed agricultural commodities by entrepreneurs in the agricultural sector

$$(84) \qquad C^T_{EPA}(t) = \left[\frac{C_{EP}(t)}{Y_E(t)}\right] \cdot [p_A \cdot P_E(t)] \cdot w_I(t)$$

Total consumption expenditure on processed agricultural commodities in the nonagricultural sector

$$(85) \qquad C^T_{PN}(t) = C^T_{LPN}(t) + C^T_{EPN}(t)$$

Total consumption expenditure on processed agricultural commodities by laborers in the nonagricultural sector

$$(86) \qquad C^T_{LPN}(t) = I_{LCP}(t)\ P^E_{LN}(t), \ [P^E_{LN}(t) = P_{LN}(t)]$$

Total consumption expenditure on processed agricultural commodities by entrepreneurs in the nonagricultural sector

(87) $$C^{T}_{EPN}(t) = \left[\frac{C_{EP}(t)}{Y_E(t)}\right] \cdot [p_N \cdot P_E(t)] \cdot w_I(t)$$

Growth equation for the entrepreneurs both in the agricultural and non-agricultural sectors

(88) $$P_E(t) = [1 + \theta_E]\ P_E(t-1)$$

where θ_E is the rate of growth of entrepreneurs.

Growth equation for the total (agricultural and nonagricultural) labor force

(89) $$P_L(t) = [1 + \theta_L]\ P_L(t-1)$$

One can consider θ_E and θ_L as the net growth rates for the entrepreneural and laboring class, respectively, after taking into account both the birth rates and death rates.

Total labor force in the agricultural sector (all the labor force in the nonagricultural sector is assumed to be fully employed)

(90) $$P_{LA}(t) = P_L(t) - P^{E}_{LN}(t)$$

Total labor force employed in the nonagricultural sector (in a sense the employment rate is determined by the amount of foodgrains available in the nonagricultural labor sector)

(91) $$P^{E}_{LN}(t) = \frac{Q^{R}_{F}(t)}{I_{LCF}(t)}$$

Residual quantity of foodgrains after meeting (i) intermediate demand, (ii) consumption demand for entrepreneurs, and (iii) consumption demand for laborers in the agricultural sector

(92) $$Q_F^R(t) = Q_F(t) - b_{FF}\, Q_F(t) - b_{FN}\, Q_N(t) - b_{FP}\, Q_P(t)$$

$$\Gamma\ C^T_{LFA}(t) - C^T_{EFA}(t) - C^T_{EFN}(t) - X_F(t)$$

Total labor force employed in the agricultural sector

(93) $$P^E_{LA}(t) = P^E_{LAF}(t) + P^E_{LAN}(t)$$

Agricultural labor force employed in the foodgrains sector

(94) $$P^E_{LAF}(t) = P^{Em}_{LAF}(t) + P^{Ed}_{LAF}(t)$$

Agricultural labor force employed in the modern foodgrains sector [$q^m_F(t)$ is determined by equation #37]

(95) $$P^{Em}_{LAF}(t) = \frac{Q^m_F(t)}{q^m_F(t)} = \frac{S^m_{\ell F}(t)}{w}$$

Agricultural labor force employed in the traditional foodgrains sector [$q^d_F(t)$ is determined by equation #39]

(96) $$P^{Ed}_{LAF}(t) = \frac{Q^d_F(t)}{q^d_F(t)} = \frac{S^d_{\ell F}(t)}{w}$$

Agricultural labor force employed in the non-foodgrains sector [$q_N(t)$ is determined by equation #41]

(97) $$P^E_{LAN}(t) = \frac{Q_N(t)}{q_N(t)} = \frac{S_{\ell N}(t)}{w}$$

Proportion of the agricultural labor force employed

(98) $$\Psi_A(t) = \frac{P^E_{LA}(t)}{P\ \ (t)}$$

Proportion of the total labor force employed in the nonagricultural sector

$$(99) \qquad \Psi_N(t) = \frac{P^E_{LN}(t)}{P_L(t)}$$

Percentage increase in the foodgrains production

$$(100) \qquad P_{QF\Delta}(t) = \left\{\frac{[Q_F(t) - Q_F(t-1)]}{Q_F(t-1)}\right\} 100$$

Percentage increase in marketable surplus of foodgrains

$$(101) \qquad P_{SF\Delta}(t) = \left\{\left[\frac{S_F(t) - S_F(t-1]}{S_F(t-1)}\right]\right\} 100$$

Percentage increase in the demand for foodgrains outside of the agricultural sector

$$(102) \qquad P_{DFN\Delta}(t) = \left\{\left[\frac{D_{FN}(t) - D_{FN}(t-1)}{D_{FN}(t-1)}\right]\right\} 100$$

Percentage increase in the labor force employed in the agricultural sector

$$(103) \qquad P_{LAE}(t) = \left\{\frac{[P^E_{LA}(t) - P^E_{LA}(t-1)]}{P^E_{LA}(t-1)}\right\} 100$$

Percentage increase in the labor force employed in the nonagricultural sector

$$(104) \qquad P_{LNE}(t) = \left\{\frac{[P^E_{LN}(t) - P^E_{LN}(t-1)]}{P^E_{LN}(t-1)}\right\} 100$$

Percentage increase in the labor force employed in the foodgrains agriculture sector

$$(105) \quad P_{LFAE}(t) = \left\{ \frac{[P^E_{LAF}(t) - P^E_{LAF}(t-1)]}{P^E_{LAF}(t-1)} \right\} 100$$

Percentage increase in the labor force employed in the non-foodgrains agriculture sector

$$(106) \quad P_{LNAE}(t) = \left\{ \frac{[P^E_{LAN}(t) - P^E_{LAN}(t-1)]}{P^E_{LAN}(t-1)} \right\} 100$$

9. FEEDBACK, SYSTEM DYNAMICS AND SENSITIVITY ANALYSIS

In the mathematical formulation of the simulation model, many endogenous variables depend on their past values and are functionally related to the past values of other endogenous variables. As a result, the outcome of past actions influences the current state of the system through these functional relationships. These feedback functions when explicitly included make the above system dynamic. Consequently, we can generate growth paths for the endogenous variables and analyze their behavior over time. The feedback functions here refer to those mathematical relations which are intertemporal in nature. In other words, those endogenous relations in which the current value depends upon past consequences.

The dynamic elements incorporated in this model include (i) increase in net irrigated area under foodgrains by bringing previously unirrigated areas under irrigation; (ii) the yield per unit of land or output-land ratios for foodgrains, produced under both modern and traditional technologies, are changing over time; (iii) the per capita consumption expenditure on various commodity groups for laborers and entrepreneurs in both sectors is changing in response to changes in income and patterns of income distribution; and (iv) increase in size of the labor force over time which is increasing in response to population growth.

By specifying the values of parameters, initial conditions and feedback functions, we can solve the system for t=1. The solution vector of

endogenous variables along with the exogenous information serves as a benchmark to set up the problem for $t=2$. The cycle repeats thereon from $t=0, \ldots, \tau$.

One of the major advantages of a simulation approach is that it allows experimentation on the economy described by the simulation model. We can generate growth paths of the endogenous variables under alternative simulation runs, each describing a different set of policy programs. This provides a set of policy regimes to choose from by the policymakers, depending upon their economic, social and political feasibility. The sensitivity analysis helps to trace out the role of the magnitude of various parameters and control variables. In this particular model the main focus is on determining the growth and level of employment in various sectors of the economy in response to technological change and household demand patterns. Some of the parameters which can be changed to generate alternative growth paths are (i) yield increase coefficients, each reflecting the nature of technological change; (ii) coefficient determining the amount of area to be brought under irrigation every year (which in turn determines the number of crops which can be grown annually on the same piece of land and the yield per unit of land); (iii) coefficients determining the multiple cropping intensity; (iv) population growth rate; and finally (v) the initial distribution of population between laborers and entrepreneurs.

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