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SOME MARKET EFFECTS OF AGRICULTURAL DEVELOPMENT ON FUNCTIONAL INCOME DISTRIBUTION IN DEVELOPED COUNTRIES

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SOME MARKET EFFECTS OF AGRICULTURAL DEVELOPMENT ON FUNCTIONAL INCOME DISTRIBUTION IN DEVELOPMENT COUNTRIES[1/]

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In dealing with the equity effects of agricultural transformations -- particularly the effects felt through the market -- I don't wish to narrow the discussion unnecessarily. Even though the basis for a transformation could be defined as a nonmarket phenomenon (new variety, e.g.), most of the effects on income distribution will be felt through the market. Public nonmarket actions may be taken to soften or hasten the impact, but even the effects of these nonmarket actions will be felt largely through the market.[2/]

Also included in the category of market phenomena is the "inducement of innovation" by the economic environment (including resource endowments) in the form of technical change. For our purposes, it matters not whether the inducement is felt in the private or in the public sector. Following Hayami and Ruttan, we include as part of induced innovation, "... the process by which public sector invesment in agricultural research, in

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2/ What follows is intended to be descriptive only of a market economy. It abstracts from major institutional changes (land reform, e.g.).

the adaptation and diffusion of agricultural technology, and in the institutional infrastructure that is supportive of agricultural development, is directed toward releasing the constraints on agricultural production imposed by the factors characterized by a relatively inelastic supply" (16, p. 31).

I also am attracted toward the assumption that market forces play an important part in the inducement of many forms of institutional change. Therefore I do not rule out of consideration any but the most direct effects of institutional change on income distribution.

I find it useful to separate household income into three principal components -- returns to unskilled labor, returns to human capital, and returns on nonhuman property. Without dismissing the returns to unskilled labor completely, I wish to concentrate on the effects of human capital and property income on income distribution.

Following Meade (23, p. 82), we express income for a household as

$$(1) \qquad Z = WN + VU$$

where N is the amount of work, W the earnings rate for work, U the amount of nonhuman property, and V the rate of return on property.

Not surprisingly our interest will include the effects of property ownership (U) on the income distribution, and the effects of human capital on the work earnings rate (W), and on the rate of return on property (V). Because another important influence on W is the transfer flexibility of redundant resources, we will be interested in the relationship between human capital and resource transfer flexibility. Finally,

the market linkages we will be trying to identify include the influences generated by the process of agricultural development on the volume, earnings rates, and ownership of earning assets, and on the investments in and rates of return to human capital.

Model of Agricultural Production

First, we develop a model of agricultural production -- a model that will identify the sources of agricultural growth, and reveal the effects on the returns to land and labor of changes in resource endowments and in production technology.

In a Cobb-Douglas world (with constant returns to scale, and all factors variable), we use the following definitions:

Y = level of agricultural output, and $\dot{Y} = \frac{1}{Y}\frac{dY}{dt}$

X = level of nonagricultural output, and $\dot{X} = \frac{1}{X}\frac{dX}{dt}$

Z = $X + Y$ = national output, and $\dot{Z} = \frac{1}{Z}\frac{dZ}{dt}$

L = land used in agriculture, and $\dot{L} = \frac{1}{L}\frac{dL}{dt}$

A = labor force in agriculture, and $\dot{A} = \frac{1}{A}\frac{dA}{dt}$

M = labor force in nonagriculture, and $\dot{M} = \frac{1}{M}\frac{dM}{dt}$

N = $A + M$ = total labor force, and $\dot{N} = \frac{1}{N}\frac{dN}{dt}$

K_1 = stock of land-augmenting capital in agriculture, and

$$\dot{K}_1 = \frac{1}{K_1}\frac{dK_1}{dt}$$

K_2 = stock of human capital in agriculture, and

$$\dot{K}_2 = \frac{1}{K_2}\frac{dK_2}{dt}$$

K_3 = stock of labor-augmenting capital in agriculture, and

$$\dot{K}_3 = \frac{1}{K_3}\frac{dK_3}{dt}$$ 3/

(2) $N_1 = A^{1-\delta_1-\delta_2} \exp(\delta_1\dot{K}_2 t) \exp(\delta_2\dot{K}_3 t)$ = effective supply of labor in agriculture where δ_1 is the elasticity of the effective supply of labor with respect to an increase in human capital, δ_2 the elasticity of the effective supply of labor with respect to labor-augmenting technology, and $1-\delta_1-\delta_2$ the elasticity of the effective supply of labor with respect to unskilled labor.

(3) $\ln N_1 = (1-\delta_1-\delta_2) \ln A + \delta_1\dot{K}_2 t + \delta_2\dot{K}_3 t$

$$\dot{N}_1 = \frac{1}{N_1}\frac{dN_1}{dt} = \frac{1-\delta_1-\delta_2}{A}\frac{dA}{dt} + \delta_1\dot{K}_2 + \delta_2\dot{K}_3$$

3/ From here on, $\dot{K}_1$, $\dot{K}_2$ and $\dot{K}_3$ will be treated as parameters, constant for five- or ten-year periods of time. It is clear that each rate is largely determined within the economic system, but to allow K_1, K_2 and K_3 to have second derivatives in t would place unbearable strain on the model that follows.

(4) $\dot{N}_1 = (1-\delta_1-\delta_2)\,\dot{A} + \delta_1\dot{K}_2 + \delta_2\dot{K}_3$

The rate of growth in the effective supply of labor in agriculture is the algebraic sum of the following rates of growth: agricultural labor force, human capital in agriculture, and labor-augmenting capital in agriculture, each weighted by its importance in determining the effective supply of labor.

(5) $L_1 = L^{1-\alpha} e^{\alpha\dot{K}_1 t}$ = effective supply of land in agriculture where α is the elasticity of the effective supply of land with respect to land-augmenting technology and $1-\alpha$ the elasticity of the effective supply of land with respect to the land area cultivated.

(6) $\ln L_1 = (1-\alpha)\ln L + \alpha\dot{K}_1 t$

(7) $\dot{L}_1 = \frac{1}{L_1}\frac{dL_1}{dt} = \frac{1-\alpha}{L}\frac{dL}{dt} + \alpha\dot{K}_1 = (1-\alpha)\,\dot{L} + \alpha\dot{K}_1$

The rate of growth in the effective supply of land in agriculture is the algebraic sum of the following rates of growth: land area used and land-augmenting capital, each weighted by its importance in determining the effective supply of land.

Write the production function for agriculture,

(8) $Y = N_1^{\beta} L_1^{1-\beta}$

where the constant β represents the elasticity of output with respect to an increase in the effective supply of labor. From (8), we write

(9) $\ln Y = \beta \ln N_1 + (1-\beta) \ln L_1$

(10) $\dot{Y} = \frac{1}{Y}\frac{dY}{dt} = \frac{\beta}{N_1}\frac{dN_1}{dt} + \frac{1-\beta}{L_1}\frac{dL_1}{dt} = \beta\dot{N}_1 + (1-\beta)\dot{L}_1$

(11) $\dot{Y} = \beta(1-\delta_1-\delta_2)\dot{A} + \beta\delta_1\dot{K}_2 + \beta\delta_2\dot{K}_3 + (1-\beta)(1-\alpha)\dot{L} + (1-\beta)\alpha\dot{K}_1$

Thus, the relative rate of growth of agricultural output is directly related to the following rates of growth: labor force, labor-augmenting capital, human capital, land used, and land-augmenting technology, each appropriately double-weighted.

If agricultural labor force is the dependent variable, adjusting itself to market-induced or administered changes in the other variables, we can write

(12) $\dot{A} = \frac{\dot{Y}}{\beta(1-\delta_1-\delta_2)} - \frac{\delta_1}{1-\delta_1-\delta_2}\dot{K}_2 - \frac{\delta_2}{1-\delta_1-\delta_2}\dot{K}_3 - \frac{(1-\beta)(1-\alpha)}{\beta(1-\delta_1-\delta_2)}\dot{L} - \frac{\alpha(1-\beta)}{\beta(1-\delta_1-\delta_2)}\dot{K}_1$

We are also interested in the behavior over time of the marginal products of labor and land. From (9), (3), and (6), we write

(13) $\ln Y = \beta(1-\delta_1-\delta_2)\ln A + \beta\delta_1\dot{K}_2 t + \beta\delta_2\dot{K}_3 t$

$+ (1-\beta)(1-\alpha)\ln L + \alpha(1-\beta)\dot{K}_1 t$

$\frac{1}{Y}\frac{\partial Y}{\partial A} = \frac{\beta(1-\delta_1-\delta_2)}{A}$

(14) $$\frac{\partial Y}{\partial A} = \frac{\beta(1-\delta_1-\delta_2)\ Y}{A}$$

$$\frac{d\left(\frac{\partial Y}{\partial A}\right)}{dt} = \frac{A\beta(1-\delta_1-\delta_2)}{A^2}\frac{dY}{dt} - \frac{\beta Y(1-\delta_1-\delta_2)}{A^2}\frac{dA}{dt}$$

$$\frac{d\left(\frac{\partial Y}{\partial A}\right)}{dt} = \frac{\beta(1-\delta_1-\delta_2)AY}{A^2}\ \frac{1}{Y}\frac{dY}{dt} - \frac{\beta(1-\delta_1-\delta_2)Y}{A^2}\frac{1}{A}\frac{dA}{dt}$$

(15) $$\frac{d\left(\frac{\partial Y}{\partial A}\right)}{dt} = \frac{\beta(1-\delta_1-\delta_2)Y}{A}\left[\dot{Y} - \dot{A}\right]$$

(16) $$\left(\frac{\partial \dot{Y}}{\partial A}\right) = \frac{1}{\frac{\partial Y}{\partial A}}\frac{d\left(\frac{\partial Y}{\partial A}\right)}{dt} = \dot{Y} - \dot{A}$$

From (11) we substitute in (16) the value of $\dot{Y}$, and have

(17) $$\left(\frac{\partial \dot{Y}}{\partial A}\right) = \alpha(1-\beta)\ \dot{K}_1 + \beta\delta_1\dot{K}_2 + \beta\delta_2\ \dot{K}_3 - \beta(\delta_1+\delta_2)\ \dot{A} + (1-\beta)\ (1-\alpha)\ \dot{L}$$

This says that the rate of change in the marginal product of labor varies directly with the growth rates in: land-augmenting capital, human capital, labor-augmenting capital, and land area cultivated; and inversely with the growth rate in the labor force. Under the assumptions, average product of labor turns out to be changing at the same rate as marginal product. That is,

(18) $$\left(\frac{\dot{Y}}{A}\right) = \frac{1}{\frac{Y}{A}}\frac{d\left(\frac{Y}{A}\right)}{dt} = \alpha(1-\beta)\dot{K}_1 + \beta\delta_1\dot{K}_2 + \beta\delta_2\dot{K}_3 - \beta(\delta_1+\delta_2)\ \dot{A} + (1-\beta)\ (1-\alpha)\ \dot{L}$$

From (13), we write

$$\frac{1}{Y}\frac{\partial Y}{\partial L} = \frac{(1-\beta)\ (1-\alpha)}{L}$$

(19) $$\frac{\partial Y}{\partial L} = \frac{(1-\beta)\ (1-\alpha)}{L}\ Y$$

$$\frac{d\left(\frac{\partial Y}{\partial L}\right)}{dt} = \frac{(1-\beta)\ (1-\alpha)}{L^2}\ L\ \frac{dY}{dt} - \frac{(1-\beta)\ (1-\alpha)}{L^2}\ Y\ \frac{dL}{dt}$$

$$\frac{d\left(\frac{\partial Y}{\partial L}\right)}{dt} = \frac{(1-\beta)\ (1-\alpha)\ Y}{L}\left[\frac{1}{Y}\frac{dY}{dt} - \frac{1}{L}\frac{dL}{dt}\right]$$

(20) $$\left(\frac{\partial \dot{Y}}{\partial L}\right) = \frac{1}{\frac{\partial Y}{\partial L}}\ \frac{d\ \frac{\partial Y}{\partial L}}{dt} = \dot{Y} - \dot{L}$$

From (11) we substitute in (20) the value of $\dot{Y}$, and have

(21) $$\left(\frac{\partial \dot{Y}}{\partial L}\right) = \alpha(1-\beta)\dot{K}_1 + \beta\delta_1\ \dot{K}_2 + \beta\delta_2\dot{K}_3 + \beta(1-\delta_1-\delta_2)\ \dot{A} - (\beta + \alpha-\alpha\beta)\ \dot{L}$$

This says that the rate of change in the marginal product of land varies directly with the growth rates in: land-augmenting capital, human capital, labor-augmenting capital, and labor force; and inversely with the growth rate in land cultivated. Under the assumptions, average product of land turns out to be changing at the same rate as marginal product. That is,

(22) $$\left(\frac{\dot{Y}}{L}\right) = \frac{1}{\frac{Y}{L}}\ \frac{d\left(\frac{Y}{L}\right)}{dt} = \alpha(1-\beta)\dot{K}_1 + \beta\delta_1\dot{K}_2 + \beta\delta_2\dot{K}_3 + \beta(1-\delta_1-\delta_2)\ \dot{A} - (\beta + \alpha-\alpha\beta)\dot{L}$$

To show the effects of different rates of growth on $\dot{Y}$, $\left(\frac{\partial \dot{Y}}{\partial A}\right)$ and $\left(\frac{\partial \dot{Y}}{\partial L}\right)$, we rewrite as follows:

$$(11) \qquad \dot{Y} = \alpha(1-\beta)\dot{K}_1 + \delta_1\dot{K}_2 + \delta_2\beta\dot{K}_3 + \beta(1-\delta_1-\delta_2)\dot{A} + (1-\beta)\ (1-\alpha)\ \dot{L}$$

$$(17) \qquad \left(\frac{\partial \dot{Y}}{\partial A}\right) = \alpha(1-\beta)\dot{K}_1 + \delta_1\beta\dot{K}_2 + \delta_2\beta\dot{K}_3 + \beta(-\delta_1-\delta_2)\dot{A} + (1-\beta)\ (1-\alpha)\ \dot{L}$$

$$(21) \qquad \left(\frac{\partial \dot{Y}}{\partial L}\right) = \alpha(1-\beta)\dot{K}_1 + \delta_1\beta\ \dot{K}_2 + \delta_2\beta\ \dot{K}_3 + \beta(1-\delta_1-\delta_2)\dot{A} + (-\alpha\ -\beta+\alpha\beta)\ \dot{L}$$

Increases in $\dot{K}_1$, $\dot{K}_2$ or $\dot{K}_3$ will have the same relative effects on $\dot{Y}$, $\left(\frac{\partial \dot{Y}}{\partial A}\right)$ and $\left(\frac{\partial \dot{Y}}{\partial L}\right)$. An increase in $\dot{A}$ will lead to identical relative increases in $\dot{Y}$ and $\left(\frac{\partial \dot{Y}}{\partial L}\right)$, a decrease in $\left(\frac{\partial \dot{Y}}{\partial A}\right)$. An increase in $\dot{L}$ will correspondingly lead to identical relative increases in $\dot{Y}$ and $\left(\frac{\partial \dot{Y}}{\partial A}\right)$, a decrease in $\left(\frac{\partial \dot{Y}}{\partial L}\right)$.

If the increases in $\dot{K}_1$, $\dot{K}_2$, and $\dot{K}_3$ come about as a result of investments in which each beneficiary participated in proportion to his benefits, then the increases in $\left(\frac{\partial \dot{Y}}{\partial L}\right)$ (and the related increases in land values) and in $\left(\frac{\partial \dot{Y}}{\partial A}\right)$ would be for each land owner and each worker (approximately) a return on his share of the total investment.

Let us examine more carefully each variable in the set influencing the relative changes in the marginal products of land and labor. The most important forms of land-augmenting capital are the biological and chemical inputs (new varieties, fertilizers, and pesticides) and investments in irrigation systems.

The basic and much of the applied research that leads to improved biological and chemical inputs is publicly financed; even for the privately financed research and development, the publicly financed component is highly complementary. Put simply, the information required for producing biological and chemical inputs can be regarded largely as a public good. Many of the specific inputs (especially new plant varieties and fertilizers) are produced in developed countries under reasonably competitive conditions. Thus the economic rent that might have been generated by these improved inputs is largely passed back to the farms, and the benefits ultimately passed on to the consumer. Collectively farmers pay little of the costs of research and extension. Because the supply curves for these biological and chemical inputs are quite elastic, farmers are not required to pay the input prices that would prevail if the input sellers were in a position to capture the productivity gains that result from the use of these improved inputs. Indeed, it is easy to observe significant increases in the value of land well suited for productive new varieties and their complementary inputs.

Other things being equal, irrigation investments will increase output. Two forms of irrigation should be distinguished -- pump and gravity. Usually, investments in pumps and ancillary equipment are made by individual farmers or by small groups of farmers. Because profitability criteria are applied, the additional income can be regarded as a return on the investment. Small gravity projects may sometimes be feasible for individual farmers (or small groups of farmers) and would be quite similar in their economic implications to pump projects.

Large gravity projects are a different matter. Public action is usually required; even then the additional income can be regarded as a return on the irrigation investment, if the marginal irrigator is charged for the water at a rate consistent with the cost of providing the water. If the water supplied is subsidized, then the irrigator's income will be enhanced at a small or no resource cost to him, and the annual value of the subsidy will be capitalized into the value of the land. The extent to which it is capitalized depends on expectations with respect to the duration of the subsidy. A subsidy expected to continue indefinitely will be almost completely capitalized into the value of the land. 4/

As we noted earlier, increases in the rate ($\dot{K}_2$) of agricultural human capital formation would also increase the rate of change in the marginal products of land and labor in the same proportion. Individuals probably bear a larger share of the costs of increased human capital formation (particularly in the form of foregone earnings) than farmers bear of land-augmenting capital investments. Further, local educational expenditures are financed to a considerable extent from taxes on property in local school districts. It seems reasonable to argue that a considerable part of the costs of the human capital formation that increases the rate of return to land and labor in agriculture is borne by the beneficiaries.

4/ Although we are primarily concerned here with distribution effects, we may properly call attention to some efficiency effects. Unless inhibited by administrative regulations or natural conditions, an irrigator faced with a unit water price below the resource cost of making the water available will use more than the optimum amount of water. Less than optimum quantities will be available to some of the other (or potential) irrigators, and the total output from a limited supply of water will be less than is economically possible. The irrigator is also likely to apply more of the other variable inputs than would be the case if the water were appropriately priced.

An increase in the rate ($\dot{K}_3$) of labor-augmenting capital formation would appear to be more like human capital formation in its effect on land and labor returns. Again, an increase in labor-augmenting capital formation would bring about the same increase in the growth rates of the marginal products of labor and land. Public research and extension probably make a smaller contribution to this category, and the investor in labor-augmenting capital may be required to pay for a larger share of the productivity gains than in the case of land-augmenting technology.

An increase in the rate of growth of agricultural labor force (population) will have opposite effects on the rate of change of the marginal products of labor and land. An increase in the rate of population growth would be a result of a greater rate of natural population growth or of migration.

An increase in the rate of change of land area cultivated will also have opposite effects on the growth rate in the marginal products of land and labor. An increase in the rate of change in cultivated land area might result from irrigation investments, from land clearing, drainage, or other investments in land development.

The most pressing set of agricultural problems in developed countries usually includes redundant capacity to produce. Ways are sought to keep the rate of growth of agricultural production within manageable limits. We may regard (11) as a steady state expression of the relevant rates of change.

$$(11) \qquad \dot{Y} = \alpha(1-\beta)\dot{K}_1 + \beta\delta_1\dot{K}_2 + \beta\delta_2\dot{K}_3 + \beta(1-\delta_1-\delta_2)\dot{A} + (1-\beta)\ (1-\alpha)\ \dot{L}$$

Policy managers could -- at least theoretically -- limit the rate of output growth by reducing $\dot{K}_1$, $\dot{K}_2$, $\dot{K}_3$, $\dot{A}$, or $\dot{L}$.[5/] In the real policy world $\dot{K}_1$, $\dot{K}_2$ and $\dot{K}_3$ are treated as parameters and determined with little concern for their effects on the (potential) rate of growth of agricultural output. The instrumental variable used is the cultivated land area, and the policy managers presumably hope that adjustments made in L and the changes in A will bring $\dot{Y}$ to tolerable rates of change. The relevant expression here would be (12).

$$(12) \quad \dot{A} = \frac{\dot{Y}}{\beta(1-\delta_1-\delta_2)} - \frac{\alpha(1-\beta)}{\beta(1-\delta_1-\delta_2)}\dot{K}_1 - \frac{\delta_1}{1-\delta_1-\delta_2}\dot{K}_2 - \frac{\delta_2}{1-\delta_1-\delta_2}\dot{K}_3 - \frac{(1-\beta)\ (1-\alpha)}{\beta(1-\delta_1-\delta_2)}\dot{L}$$

To examine the implications of our model, we need some estimates of annual rates of change in the different time series. Table 1 gives the annual rates that will be used throughout the remainder of the Chapter, and Table 2 gives the parameters that will be used.[6/] The annual rates in Table 1 are estimates (sometimes using proxies of the annual rates of change rate from the 1946-50 average to the 1966-70 average for the U.S. The parameters are estimates derived from historical information on the relative importance of different groups of farm inputs.

5/ More than one level of government contributes to the expenditures that change $\dot{K}_1$, $\dot{K}_2$, and $\dot{K}_3$ -- the policy managers are federal.

6/ See the appendix for the basic data from which the estimates in both tables were obtained, and a discussion of the data, including sources.

Table 1. Data Used in Model Testing. 1/

Item	Definition: Annual Rate of Change in --	Value	Column of Table A.1
$\dot{Y}$	Total farm output	.0165	4
$\dot{K}_1$	Index of total farm inputs: fertilizer and liming materials	.05	10
$\dot{K}_2$	Human capital in the total work force	.04	
$\dot{K}_3$	Index of total farm inputs: Mechanical power and machinery	.02	8
$\dot{A}$	Index of farm population (as of April 1)	-.031	5
$\dot{L}$	Cropland used for crops	-.006	6
$\left(\frac{\partial Y}{\partial L}\right)^{\cdot}$	Average value of farmland per acre	.06	7
$\left(\frac{\partial Y}{\partial A}\right)^{\cdot}$	Average farm wage rate per hour w/o board or room	.039	3
$\dot{N}$	Total population (as of July 1)	.016	2
$\left(\frac{Z}{N}\right)^{\cdot}$	Personal disposable income per capita	.044	1
$\dot{P}$	Prices received by farmers for food products	.004	11
$\dot{P}'$	Consumer price index for food	.02	13
$\left(\frac{Y}{N}\right)^{\cdot}$	Index of civilian food consumption per capita	.0025	12

1/ See Appendix for sources and discussion of data.

Table 2. Parameters Used in Model Testing.1/

Item	Definition	Value
β	Elasticity of agricultural output with respect to a change in the effective supply of labor	0.4
$1-\beta$	Elasticity of agricultural output with respect to a change in the effective supply of land	0.6
α	Elasticity of the effective supply of land with respect to a change in land-augmenting capital	0.6
$1-\alpha$	Elasticity of the effective supply of land with respect to a change in land cultivated	0.4
δ_1	Elasticity of the effective supply of labor with respect to a change in human capital	0.25
δ_2	Elasticity of the effective supply of labor with respect to a change in labor-augmenting capital	0.45
$1-\delta_1-\delta_2$	Elasticity of the effective supply of labor with respect to a change in the agricultural labor force	0.30
η_{yP}	Price elasticity of demand for food products	-.2278
η_{yZ}	Income elasticity of demand for food products	0.162

1/ See Appendix for sources and discussion of parameters.

Suppose the goal for $\dot{Y}$ is .0165 and that the supply managers agree to an annual reduction in cultivated acreage of 0.6 percent ($\dot{L} = -.006$). In this case the reduction in land cultivated is more than offset by the increased use of land augmenting technology $[\alpha\dot{K}_1 + (1-\alpha)\dot{L} = .0276]$, and $\dot{A} = -.0638$. This percentage of -6.38 is the reduction in the agricultural labor force required to hold $\dot{Y}$ to .0165, and may be compared with the annual 1946-70 reduction in farm population of slightly more than 3 percent ($\dot{A} = -.031$). A larger annual acreage reduction of 1.6 percent ($\dot{L} = -.016$) brings the necessary labor force reduction down to 4.66 percent ($\dot{A} = -.0466$). If we accept the estimate of the natural growth rate for the total population ($\dot{N} = .016$) as being applicable to the agricultural population, then an annual rate of outmigration from agriculture of nearly 8 percent would be required for $\dot{L} = -.006$, over 6 percent for $\dot{L} = -.016$.

To evaluate the effectiveness of acreage controls for limiting output when investments in labor- and land-augmenting technology and in human capital are not curtailed, we assume it is desirable to keep the agricultural labor force constant ($\dot{A} = 0$, implying an annual outmigration rate of 1.6 percent).

Let us solve equation (11) for $\dot{L}$.

$$(22a) \quad \dot{L} = \frac{\dot{Y}}{(1-\beta)(1-\alpha)} - \frac{\alpha}{1-\alpha}\dot{K}_1 - \frac{\beta\delta_1}{(1-\beta)(1-\alpha)}\dot{K}_2 - \frac{\beta\delta_2}{(1-\beta)(1-\alpha)}\dot{K}_3 - \frac{\beta(1-\delta_1-\delta_2)}{(1-\beta)(1-\alpha)}\dot{A}$$

If we set $\dot{A} = 0$, then we get $\dot{L} = -.0379$, which says that to keep agricultural output growth under control with an annual outmigration rate of only 1.5 percent would require an <u>annual</u> reduction of almost 3.8 percent in the cultivated acreage.

To examine the relations between changes in acreage and changes in labor force, we refer again to equations (11), (17), and (21), and allow $\dot{A}$ and $\dot{L}$ to vary. From (11) we get

$$(23) \quad .14\dot{A} + .24\dot{L} = -.0127$$

From (17), we get

$$(24) \quad \left(\frac{\partial \dot{Y}}{\partial A}\right) = -.28\dot{A} + .24\dot{L} + .0292$$

Substituting (23) in (24), we obtain

$$(25) \quad \left(\frac{\partial \dot{Y}}{\partial A}\right) = -.42\dot{A} + .0165 = .72\dot{L} + .0546$$

From (21), we have

$$(26) \quad \left(\frac{\partial \dot{Y}}{\partial L}\right) = .14\,\dot{A} - .76\,\dot{L} + .0292$$

Substituting (23) in (26), we obtain

$$(27) \quad \left(\frac{\partial \dot{Y}}{\partial A}\right) = -\dot{L} + .0165 = .5833\dot{A} + .0694$$

Table 3 shows the combinations of annual growth rates in land used and in the agricultural labor force that would hold the growth rate in agricultural output to 1.65 percent, and the growth rates in the marginal products of labor and land that would be associated with each combination of $\dot{L}$ and $\dot{A}$. No reduction in land cultivated ($\dot{L} = 0$) would require an annual reduction

Table 3. Changes in Marginal Products of Labor and Land Associated with Specified Changes in Labor Force and Land Cultivated.

Growth Rate in Land Used	Implied Growth Rate in Labor Force	Growth Rate in Marginal Product of Labor	Growth Rate in Marginal Product of Land
$\dot{L}$	$\dot{A}$ 1/	$\dot{\left(\frac{\partial Y}{\partial A}\right)}$	$\dot{\left(\frac{\partial Y}{\partial L}\right)}$
+.06	-.1936	+.0978	-.0435
+.05	-.1764	+.0906	-.0335
+.04	-.1593	+.0834	-.0235
+.03	-.1421	+.0762	-.0135
+.02	-.1250	+.0690	-.0035
+.01	-.1078	+.0618	-.0065
0	-.0907	+.0546	+.0165
-.01	-.0736	+.0474	+.0265
-.02	-.0564	+.0402	+.0365
-.03	-.0393	+.0330	+.0465
-.04	-.0221	+.0258	+.0565
-.05	-.0050	+.0186	+.0665
-.0529	0	+.0165	+.0694
-.06	+.0122	+.0114	+.0765

1/ $\dot{A} = -.0907 - 1.714\,\dot{L}$

of 9.07 percent in the labor force (implying an annual outmigration rate of 10.67 percent); marginal product of labor would grow at an annual rate of 5.46 percent, marginal product of land at an annual rate of 1.65 percent. No reduction in the labor force ($\dot{A} = 0$, implying an annual outmigration rate of 1.6 percent) would require an annual reduction of 5.29 percent in the land used -- if according to our assumptions -- annual output increase is to be limited to 1.65 percent. Marginal product of labor would increase at an annual rate of 1.65 percent, and marginal product of land at an annual rate of 6.94 percent. For a consistent combination of $\dot{A}$ and $\dot{L}$ that might be acceptable, we examine the outcome of an annual reduction of 3 percent in land used ($\dot{L} = -.03$) and a 3.93 reduction in agricultural labor ($\dot{A} = -.0393$, implying an annual outmigration rate of 5.53 percent). This combination would lead to an annual growth rate in the marginal product of land of 4.65 percent, in the marginal product of labor of 3.3 percent, well below the average annual growth, 1946-50 to 1966-70, of 4.4 percent in income per capita $\left[\left(\frac{\dot{Z}}{N}\right) = .044\right]$.

Demand for Agricultural Products

The volume of agricultural products that can be sold in the market depends on the population, the price, the price elasticity of demand, income per capita, and the income elasticity of demand. If increases in agricultural output are allowed to bring about price decreases, then the price elasticity of demand will have much to do with the volume that can be sold in the market. Among the factors that will influence the growth rate in that volume ($\dot{Y}$) are the price elasticity of demand (η_{yp}), the rate of change in the consumer

price index for food ($\dot{P}' = \frac{1}{P'} \frac{dP'}{dt}$), the rate of growth of the population ($\dot{N}$) the income elasticity of demand (n_{yZ}), and the rate of growth of income per capita $\left[\dot{\left(\frac{Z}{N}\right)} = \frac{N}{Z} \frac{d\left(\frac{Z}{N}\right)}{dt}\right]$.

In developed countries, neither the price nor the income elasticity of demand is very large. The absolute value of either seldom exceeds 0.25, and may be somewhat smaller. In the U.S., population growth between 1946-50 and 1966-70 averaged 1.6 percent ($\dot{N} = .016$), and income per capita (in current prices) grew at an average rate of 4.4 percent $\left[\dot{\left(\frac{Z}{N}\right)} = .044\right]$. Because of the volatility of agricultural supply in developed countries, prices of agricultural products are not usually allowed to move freely.

Assume $\eta_{yP} = -0.2278$ and consumer prices for food are allowed to fall annually by 5 percent ($\dot{P}' = -.05$); per capita consumption of food products $\left[\dot{\left(\frac{Y}{N}\right)} = \frac{N}{Y} \frac{d\left(\frac{Y}{N}\right)}{dt} = +.01139\right]$ will rise 1.14 percent per year. With $\dot{\left(\frac{Z}{N}\right)} = .044$ and $\eta_{yZ} = .162$, the annual change in the total consumption of agricultural products is defined as

(28) $\dot{Y} = \dot{\left(\frac{Y}{N}\right)} + \dot{N} + \dot{\left(\frac{Z}{N}\right)} \eta_{yZ}$ where

(29) $\dot{\left(\frac{Y}{N}\right)} = \dot{P}' \eta_{yP}$

For the extreme assumption of $\dot{P}' = -.05$

$Y = .01139 + .016 + (.044)(.162) = .0345$

(30) The relative change in total revenue $= (1+\dot{Y})(1+\dot{P}) - 1 =$

$(1.0345)(0.95) - 1 = -.0172$

The output that could be sold in the market would increase by almost 3.5 percent, but the total revenue from that volume of output would be less by

1.72 percent. With no outmigration and labor force (population) growth of 1.6 percent, total revenue per worker would decline by 3.32 percent. If industrial prices also declined 5 percent annually, then in real terms revenue per worker in agriculture would increase 1.68 percent. This is less than the assumed 4.4 percent increase in income per capita $[\dot{\left(\frac{Z}{N}\right)} = .044]$.

With the same assumptions except that food prices are allowed to fall 2 percent annually, $\dot{\left(\frac{Y}{N}\right)} = .00456$. Then $\dot{Y} = .00456 + .016 + (.044)(.162) = .0277$. Relative change in total revenue would be + .0072. The output that could be sold in the market would increase by 2.77 percent, while total revenue would be more by 0.72 percent. Total revenue per agricultural worker would decline by 0.88 percent. If industrial prices also declined 2 percent annually, revenue per worker in real terms would increase 1.12 percent, much less than the 4.4 percent increase assumed in income per capita. 7/

With all the other assumptions except prices are not allowed to fall at all $(\dot{P}=0)$, $\dot{\left(\frac{Y}{N}\right)} = 0$.

$$\dot{Y} = 0 + .015 + (.045)(.162) = .0223$$

Change in total revenue = +.0223. Output that could be sold in the market would be more by 2.23 percent, as would total revenue. Total revenue per worker would increase by 0.63 percent, and would be the same in real terms, if industrial prices also remain unchanged.

7/ If Z/N is money income, then an increase in money income of 4.4 percent and a decline of 2 percent in the consumer price index would net a 6.6 percent increase in average real income per capita, compared to 1.12 percent for the average agricultural worker.

We are also interested in the relations among the income elasticity of demand of individual households, population growth, income, and the aggregate income elasticity of demand. To examine these relations we write

(31) $Y = \frac{Y}{N} \cdot N$ and $Z = \frac{Z}{N} \cdot N$

Aggregate income elasticity of demand $\eta_{yZ} = \frac{dY}{dZ}\frac{Z}{Y}$

(32) $dY = \frac{Y}{N}\, dN + N\, d\left(\frac{Y}{N}\right)$ $\qquad \frac{dY}{Y} = \frac{dN}{N} + \frac{N}{Y}\, d\left(\frac{Y}{N}\right)$

(33) $dZ = \frac{Z}{N}\, dN + N\, d\left(\frac{Z}{N}\right)$ $\qquad \frac{dZ}{Z} = \frac{dN}{N} + \frac{N}{Z}\, d\left(\frac{Z}{N}\right)$

(34) $$\eta_{yZ} = \frac{\frac{dN}{N} + \frac{N}{Y}\, d\left(\frac{Y}{N}\right)}{\frac{dN}{N} + \frac{N}{Z}\, d\left(\frac{Z}{N}\right)}$$

If we are interested in growth, then we may wish to know how a given growth rate in national output will be divided between population growth and growth in income per capita, and how these changes will influence aggregate income elasticity of demand for a particular group of products (agricultural products, e.g.). Assume $dZ/Z = .06$, and, for a developed country, assume $dN/N = .015$, and income elasticity of demand of an average household $(\eta_o) = .2$, and $\frac{N}{Z}\, d\left(\frac{Z}{N}\right) = .044$.

$\frac{N}{Y}\, d\left(\frac{Y}{N}\right) \div \frac{N}{Z}\, d\left(\frac{Z}{N}\right) = 0.2$. Then $\frac{N}{Y}\, d\left(\frac{Y}{N}\right) = .0088$

$$\eta_{yZ} = \frac{.015 + .0088}{.015 + .044} = \frac{.0238}{.069} = 0.4$$

For a developing country, suppose $dN/N = .04$, $dZ/Z = .03$, and $\eta_o = 0.8$. Then $\frac{N}{Z} d\left(\frac{Z}{N}\right) = -.01$ and $\frac{N}{Y} d\left(\frac{Y}{N}\right) = -.008$.

$$\eta_{yZ} = \frac{.04 - .008}{.04 - .01} = \frac{.032}{.03} = 1.067$$

Table 4 shows the values of aggregate income elasticity of demand that would be associated with different values of income growth, national income growth rates, population growth rates, and average household income elasticities of demand for agricultural products.

It is generally believed that household income elasticity of demand for agricultural products is a declining function of the level of income. As average income (Z/N) rises, then η_o would decline, probably in a non-linear manner. It seems unlikely that a one percent rise in Z/N would bring as large a (relative) reduction in η_{yZ} in a low-income country as in a high-income country. It also seems unlikely that a $10 increase in Z/N would bring as large a reduction in η_{yZ} in a high-income country as it would in a low-income country.

We might specify that

$$(35) \quad \frac{d\eta_{yZ}}{\eta_{yZ}} = g\left[\frac{Z}{N}, \frac{N}{Z} d\left(\frac{Z}{N}\right)\right] \qquad g_1 < 0,\ g_2 < 0$$

Unless the developing country can achieve at least as large a growth rate in per capita income as the developed country, it is very unlikely to experience as large reductions in the income elasticity of demand as the developed country.

Table 4. Values of Aggregate Income Elasticity of Demand for Agricultural Products Associated with Different Values of Income Growth, Population Growth and Household Income Elasticity of Demand.

$\frac{dZ}{Z} = .06$

η_o	$\frac{dN}{N} = .015$ a/	$\frac{dN}{N} = .025$ b/	$\frac{dN}{N} = .035$ c/	$\frac{dN}{N} = .045$ d/
0.2	0.40	0.53	0.67	0.80
0.4	0.55	0.65	0.75	0.85
0.8	0.85	0.88	0.92	0.95
1.2	1.15	1.12	1.08	1.05

$\frac{dZ}{Z} = .03$

	$\frac{dN}{N} = .015$ d/	$\frac{dN}{N} = .025$ e/	$\frac{dN}{N} = .035$ f/	$\frac{dN}{N} = .04$ g/
0.2	0.60	0.87	1.13	1.40
0.4	0.70	0.90	1.10	1.30
0.8	0.90	0.97	1.03	1.10
1.2	1.10	1.03	0.97	0.90

a/ $\frac{N}{Z} d \left(\frac{Z}{N}\right) = .045$ b/ $\frac{N}{Z} d \left(\frac{Z}{N}\right) = .035$ c/ $\frac{N}{Z} d \left(\frac{Z}{N}\right) = .025$

d/ $\frac{N}{Z} d \left(\frac{Z}{N}\right) = .015$ e/ $\frac{N}{Z} d \left(\frac{Z}{N}\right) = .005$ f/ $\frac{N}{Z} d \frac{Z}{N} = -.005$

g/ $\frac{N}{Z} d \left(\frac{Z}{N}\right) = -.015$

Notes: $\frac{dZ}{Z}$ is relative change in national income

$\frac{dN}{N}$ is relative change in total population

$\frac{N}{Z} d \left(\frac{Z}{N}\right)$ is relative change in income per capita

η_o is income elasticity of demand for agricultural products of the average household

Changes in η_{yZ} are one index of the rate at which resource adjustments must be made. The lower the η_{yZ} for the products of a given industry (and the larger the rate of decline in η_{yZ}), the larger the adjustments that industry must make in its resource use. Because developed countries are likely to have lower (sometimes much lower) population growth rates than developing countries, they are likely to have higher growth rates in per capita income unless the developing countries achieve correspondingly higher growth rates in national output.

As shown in Table 4, the typical developed country (say, with $dZ/Z = .06$, $dN/N = .015$, and $\eta_o = 0.2$) would have $\eta_{yZ} = 0.40$; $\eta_{yZ} = 0.55$, if η_o is as high as 0.4. Employment growth in the nonfarm sectors would need to be large enough to employ a slowly growing labor force, plus the agricultural labor made redundant by labor-augmenting technology and by low price and income elasticities of demand for agricultural products. A typical developing country (say, with $dZ/Z = .03$, $dN/N = .025$, and $\eta_o = 0.8$) would have $\eta_{yZ} = 0.97$. Employment growth in the nonfarm sectors would need to be large enough to cover a rapidly growing labor force, but not much labor would need to be transferred from agriculture unless labor-augmenting capital formation is rapid.

Production and Demand Integrated

We are working primarily with four relationships

$$(11) \quad \dot{Y} = \alpha(1-\beta)\dot{K}_1 + \beta\delta_1\dot{K}_2 + \beta\delta_2\dot{K}_3 + \beta(1-\delta_1-\delta_2)\dot{A} + (1-\alpha)(1-\beta)\dot{L}$$

(17) $\dot{\left(\frac{\partial Y}{\partial A}\right)} = \alpha(1-\beta)\dot{K}_1 + \beta\delta_1\dot{K}_2 + \beta\delta_2\dot{K}_3 + \beta(-\delta_1-\delta_2)\dot{A} + (1-\alpha)(1-\beta)\ \dot{L}$

(21) $\dot{\left(\frac{\partial Y}{\partial L}\right)} = \alpha(1-\beta)\dot{K}_1 + \beta\delta_1\dot{K}_2 + \beta\delta_2\dot{K}_3 + \beta(1-\delta_1-\delta_2)\dot{A} + [(1-\alpha)(1-\beta)-1]\ \dot{L}$

(26) $\dot{Y} = \dot{\left(\frac{Y}{N}\right)} + \dot{N} + \dot{\left(\frac{Z}{N}\right)}\eta_{yZ}$ where

(27) $\dot{\left(\frac{Y}{N}\right)} = \dot{P}\ \eta_{yP}$

The target variables are growth rate in output ($\dot{Y}$) and in the marginal product of labor $\left[\dot{\left(\frac{\partial Y}{\partial A}\right)}\right]$. We wish to keep $\dot{Y}$ within acceptable limits. We wish to have the marginal product of labor increase at an annual rate of not less than 4.4 percent $\dot{\left(\frac{\partial Y}{\partial A}\right)} \geq .044$. We are also interested in the rate of change in the marginal product of land $\dot{\left(\frac{\partial Y}{\partial L}\right)}$ because of the effect of steady increases in $\frac{\partial Y}{\partial L}$ on the distribution of income. Land is an important component of the nonhuman property (U) of equation (1). It is clear that $\dot{\left(\frac{\partial Y}{\partial L}\right)} > 0$ and especially > .02 will lead to a steady growth in the value of land unless there are offsetting changes in the discount rate (r) by which the stream of future earnings of an asset are converted into present value.

The instrumental variables that remain to us -- subject to equations (11), (17), (21) and (26), and the parameters above -- are changes in the land used in cultivated ($\dot{L}$), changes in the labor used in agriculture ($\dot{A}$), and changes in the relative prices of agricultural products ($\dot{P}$). Even for these instrumental variables, we discover that there are constraints on the changes that may be made in $\dot{A}$, $\dot{L}$ and $\dot{P}$.

In particular, price changes are weak instruments of control. Steadily falling relative prices of agricultural products ($\dot{P}<0$), lead to only small increases in per capita consumption of agricultural products, because price elasticity is realistically assumed to be low ($\eta_{yp} = -.2278$). As far as gross receipts per worker is concerned, the effects of the small increases in volume resulting from lower prices, will be swamped by the effects of the price reductions. Table 5 shows the effects of different rates of change in agricultural prices on the growth rate in per capita consumption of agricultural products, $\dot{\left(\frac{Y}{N}\right)}$, in total consumption of agricultural products ($\dot{Y}$), and in the total revenue from agricultural products ($\dot{TR}$). $\dot{A}'$ is the annual reduction in agricultural labor force that would keep the total revenue per worker growing at an annual rate of 4.4 percent, and $\dot{A}''$ ($= \dot{A}' -.016$) is the outmigration rate that would keep $\dot{A}'$ at the required level.

If agricultural prices were made to increase 2 percent annually, total consumption also would rise by 1.8 percent, total revenue by 3.74 percent, and agricultural labor force would need to decrease by 0.6 percent, requiring outmigration of 2.2 percent. If agricultural prices were held steady ($\dot{P}=0$), total consumption would rise by 2.25 percent, total revenue by 2.25 percent, the agricultural labor force would need to decrease by 2.15 percent, requiring an outmigration rate of 3.75 percent. If prices were allowed to fall 2.5 percent annually ($\dot{P} = -.025$), total consumption of agricultural products would rise by 2.8 percent, total revenue by only 0.25 percent, and agricultural labor force would have to be reduced by 4.15 percent, requiring an outmigration

Table 5. Effects of Specified Rates of Price Change on the Rates of Change in per Capita Consumption of Agricultural Products, in Total Consumption of Agricultural Products, in Total Revenue from Agricultural Products, and in Agricultural Labor Force Reductions Required to Keep Gross Receipts per Worker Increasing at a Specified Rate.

$\dot{P}'$ 1/	$\left(\frac{\dot{Y}}{N}\right)$ 2/	$\dot{Y}$ 3/	$(\dot{TR})$ 4/	$\dot{A}'$ 5/	$\dot{A}''$ 6/
+.02	-.0046	+.0180	+.0384	-.0056	-.0216
+.01	-.0023	+.0202	+.0304	-.0136	-.0296
+ 0	0	+.0225	+.0225	-.0215	-.0375
-.01	+.0023	+.0248	+.0145	-.0295	-.0455
-.02	+.0046	+.0271	+.0066	-.0374	-.0534
-.025	+.0057	+.0282	+.0025	-.0415	-.0575
-.03	+.0068	+.0293	-.0016	-.0456	-.0616
-.04	+.0091	+.0316	-.0097	-.0537	-.0697
-.05	+.0114	+.0339	-.0178	-.0618	-.0778

1/ Relative change per annum in agricultural prices.
2/ Relative change per annum in per capita consumption of agricultural products.
3/ Relative change per annum in total consumption of agricultural products.
4/ Relative change per annum in total revenue from agricultural products.
5/ Relative reduction per annum in agricultural labor force required to keep gross receipts per worker growing at an annual rate of 4.4 percent.
6/ Annual outmigration rate required to keep gross receipts per worker growing at an annual rate of 4.4 percent ($\dot{A}'' = \dot{A}' - .016$).

rate of 5.75 percent. Finally, if agricultural prices were allowed to fall by 5.0 percent annually ($\dot{P} = -.05$), total consumption would go up 3.4 percent, total revenue down 1.78 percent, and the agricultural labor force would need to be reduced by 6.18 percent, requiring an outmigration rate of 7.78 percent. In general, $\dot{P} = +.02$ might be said to represent the demands of the more militant organizations of farmers; $\dot{P} = -.05$ might be said to represent the case where nearly all the productivity gains in agriculture are passed on to consumers.

If we substitute $\dot{Y} = +.0165$, $\left(\frac{\partial \dot{Y}}{\partial A}\right) = +.044$, and our other parameters in (11) and (17), we obtain the following conditions:

$$(36) \quad .14\dot{A} + .24\dot{L} = -.0127$$
$$.28\dot{A} - .24\dot{L} = -.0148$$

The solution that satisfies these conditions is $\dot{A} = -.0655$ and $\dot{L} = -.01475$. This says that, under our assumptions, to hold agricultural output to an annual increase of 1.65 percent and to make the marginal product of labor increase at an annual rate of 4.4 percent would require an annual reduction in land used of 1.5 percent and an outmigration rate of 8.15 percent!

We are also interested in the effects on the marginal product of land. For the case in the preceding paragraph, $\left(\frac{\partial \dot{Y}}{\partial L}\right) = .03124$.

Table 6 shows some of the possible results of placing a limit on the reductions in cultivated acreage. If land use may not be reduced at all ($\dot{L} = 0$), then annual labor force reduction would need to be 9.07 percent ($\dot{A} = -.0907$) and outmigration rate 10.67 percent ($A' = .1067$);

Table 6. Relative Reductions in Labor Force and Cultivated Acreage Required to Keep Supply in Balance with Demand, and the Resultant Changes in Marginal Product of Labor, Marginal Product of Land, and Outmigration Rate.

$\dot{L}$ 1/	$\dot{A}$ 2/	$\dot{Y}$ 3/	$\dot{\left(\frac{\partial Y}{\partial A}\right)}$ 4/	$\dot{\left(\frac{\partial Y}{\partial L}\right)}$ 5/	$\dot{A}'$ 6/
0	-.0907	.0165	.0546	.0165	-.1067
-.01	-.0736	.0165	.0474	.0265	-.0896
-.02	-.0564	.0165	.0402	.0365	-.0724
-.03	-.0393	.0165	.0330	.0465	-.0553
-.04	-.0221	.0165	.0258	.0565	-.0381

1/ Relative rate of change per annum in cultivated acreage.

2/ Relative rate of change per annum in agricultural labor force.

3/ Relative rate of change per annum in total supply of agricultural products.

4/ Relative rate of change per annum in marginal product of labor.

5/ Relative rate of change per annum in marginal product of land.

6/ Relative outmigration rate per annum from agriculture.

marginal product of labor would increase 5.46 percent annually, marginal product of land 1.65 percent. If land use could be reduced 2 percent annually ($\dot{L} = -.02$), then the annual labor force reduction would need to be 5.64 percent, outmigration rate 7.24 percent; marginal product of labor would increase 4.02 percent, marginal product of land 3.65 percent annually. Worthy of note in this simulation is that marginal product of labor can grow at the desired rate ($\geq .044$) only if the supply adjustment is made through the labor market. If acreage reductions are relied upon to keep supply in balance with demand, the annual increase in the marginal product of labor will not be large enough to keep labor earnings in agriculture from falling farther behind labor earnings in the nonfarm sector.

The marginal product of labor is higher when prices are not allowed to fall than when they are allowed to fall by 2 percent annually, but the marginal product of land is higher when prices are allowed to fall. Marginal product of labor decreases as acreage is reduced 2 or 4 percent, while--as expected--the marginal product of labor increases.

Let us assume that the supply managers reduce acreage by 1 percent (and attempt to hold prices unchanged), but that labor decreases by only 2.36 percent (outmigration rate = 3.96 percent) rather than by the 7.36 percent required to hold output down to an annual increase of 1.65 percent. In this case the annual rate of increase in agricultural output will be 2.35 percent, or 0.74 percent more than the market will absorb at constant prices. Annual overproduction of 0.74 percent would require an annual price reduction of 3.25 percent to absorb the annual oversupply in the market.

If each acre of arable land is equally likely to be chosen for "retirement", then the relative distribution of land holdings by size would not be altered. If less productive acres are chosen for retirement, then the effect would depend upon whether the correlation between size of individual holdings and average productivity of individual holdings was positive, negative, or zero. Positive correlation would tend to increase the variance of gross receipts, other things being equal, negative correlation would decrease the variance, and zero correlation would leave it unchanged.

Our model does not reflect any feedback from changes (especially enforced changes) in the rate of growth of cultivated acreage to the rate of creation (or adoption) of land-augmenting technology. It seems clear that changes in the value of cultivated land due to nonmarket reductions in the acreage cultivated would stimulate the creation and adoption of land-augmenting technology. According to the inducement hypothesis of Hayami and Ruttan (1), a change in $\frac{\partial Y}{\partial L}$ would be a signal not only to farmers but also to research administrators and to decision-makers in the industries producing the inputs that embody land-augmenting technology. One would expect that continuing reductions in the land that could be cultivated would lead to an increase in the rate of land-augmenting technological change.

Because of the restraint on the rate at which land can be taken out of cultivation, the annual outmigration rate from agriculture becomes a crucial factor in the degree to which supply is kept in balance with market demand, and in the growth rate of the marginal products of labor and of land. Although outmigration has been treated as exogenous to our integrated model,

Much of the technical change in agriculture of the last several decades has been embodied in land- and labor-augmenting technology. Almost all of land-augmenting technology enters in the form of variable inputs. The labor-augmenting technology involves both large fixed and variable costs. Any of the labor-augmenting technology that involved economies of scale would affect both the variance and the skewness of agricultural income in such a way as to increase the inequality of income distribution.

In developed countries, one of the programs often used to assist agriculture (usually intended to assist small farmers) is subsidized credit. Agricultural credit could be used for land-augmenting technology, human capital formation, labor-augmenting cpaital, or for the purchase of land. Land-augmenting technology comes embodied in variable inputs, such as seeds, feeds, pesticides, fertilizer, and irrigation water; subsidizing short-term credit might lead to the application of variable inputs beyond the optimum. Agricultural credit is practically never used for human capital. A great deal of agricultural credit is used for labor-augmenting capital such as mechanical equipment and for land, primarily because of loan security. Interest subsidies may well lead to overinvestment in labor-augmenting capital, shifting the demand for labor to the left, below the unsubsidized optimum. If scale economies arise in some lines of agricultural production <u>and</u> if the basis for these economies of scale lies in mechanical equipment, the interest subsidies might well permit the scale of operations of some individual enterprises to be carried past the economic optimum. In either of these eventualities, the required level of migration out of agriculture would be increased, and the effects upon income distribution adverse. Credit subsidies in the form of administrative costs might work somewhat more in

it is clear that the outmigration rate is heavily influenced by the growth rate of employment opportunities in the nonfarm sector, and by the human capital embodied in the redundant agricultural population. The redundant population has little or no control over the growth rate in employment opportunities; what control there is rests with the public managers of monetary and fiscal policy, and of incomes policy. The population that will become redundant and the communities in which they live do have -- at certain stages in the life cycles of the redundant -- some influence over the volume of human capital embodied in the population. We will argue in the next section that there is a systematic tendency in United States rural areas to under-invest in human capital formation, particularly in formal schooling.

One important limitation of our integrated production and demand model should be pointed out. Equations (11), (17) and (21) are expressed in terms of physical units -- growth rates in physical output, growth rates in the marginal physical products of labor and of land. The effect of volume offered for sale on prices received enters through η_{yp} in equation (27) and the effect of income on volume purchased through equation (26). What has not been considered explicitly is the influence of the costs of purchased factors on average farm incomes and on the distribution of farm incomes. If total costs changed over time in the same proportion as total revenues, then this influence could be ignored with little concern for distortions. It is clear from Table A.4 that the structure of agricultural production costs has been changing steadily over the last twenty years. It is not clear what effects the changes in the structure of costs have had on the variance or skewness of incomes.

favor of smaller farmers who are reasonable enough credit risks to qualify for loans at all.

Underinvestment in Human Capital in Rural Areas

The price and income elasticity of demand for agricultural products declines steadily in developed countries as income per capita rises. At the same time, investments in human capital, and in land- and labor-augmenting technology make large and steady output increases possible. To keep supply in balance with demand requires that the resources made redundant by demand conditions and technological change be transferred out of agriculture.

The basic resources in agriculture are labor (A), land (L) and capital (K_1, K_2, and K_3). Land can be retired, capital investments can be curtailed, but the primary need is for human resources to be transferred to gainful employments outside agriculture. The capacity of particular individuals to make these adjustments depends on the human capital embodied in them. In turn this human capital is composed of the years and quality of schooling, the years and nature of work experience, levels of health, location, and so on.

Here we are face-to-face with one difficulty facing rural people in the United States. The fact is that public schools are operated by local units of government (school districts), and are financed to a considerable extent out of local fiscal resources. This offers each school district some range of choice as to how much and what quality of schooling to provide to

the youth of that district. Larger urban areas tend to have their own school districts, while farming areas and the villages and small cities that provide farming areas and themselves with urban services tend to be grouped together in school districts. Within the options open to them, rural people are in a position, in conjunction with small town residents, to choose the volume and quality of education for rural youth.

What do they choose? Two clues are available as to their preferences with regard to investments in human capital.

1. Within their fiscal resources, rural communities choose to spend less per pupil in all forms of education, and rural youth "choose" to obtain fewer years of schooling than their urban counterparts. It is not clear that all rural communities always have the fiscal capacity to spend as much as other communities, or that all rural youth always have a bona fide opportunity to obtain as many years of schooling as urban youth. Nonetheless, the differences between urban and rural in expenditures per pupil and in average years of schooling are large and suggestive.

2. Within their capacity to exchange their political power for desired public goods and services, rural people have placed investments in human capital far down on their list of priorities. What are their priorities? According to T. W. Schultz (27, p. 129):

> These price supports, acreage restrictions, and subsidies hold top priority in United States farm policy. Virtually all of the time and thought of the United States Department of Agriculture, the agricultural committees of Congress, and the farm organizations is spent on them. They exhaust the political influence of farm people. But these programs do not improve the schooling of farm children; they do not reduce the inequalities in personal distribution of wealth and income; they do not remove or alleviate poverty in agriculture. On the contrary, they worsen the distribution of income within agriculture.

It is not only a matter of rural communities choosing other public "goodies" ahead of investments in human capital. 8/ More often than not, rural citizens have utilized their political power in opposition to human capital investments. Listen to Schultz (27, p. 126) again:

> Except for agricultural vocational training and for landgrant teaching, research, and extension work, there is strong opposition to any and all federal aid to education. There is also objection to public measures for medical care and health facilities.

In terms of their ability to obtain nonagricultural employment, how important is the educational disadvantage of rural youth? Let us digress for a moment to discuss the structural nature of human capital formation.

Let H_1 be the human capital obtained by means of formal education

t_1 is the years of schooling, weighted by quality

C is a measure of inherited cognitive and social learning capacity

(37) Then $H_1 = f(C, t_1)$ $f_c > 0$, $f_t > 0$

Let t_2 be the years spent in on-the-job training and work experience, weighted by earnings during that time.

8/ This discussion assumes that the rate of return on investments in human capital is higher for farmers than the rates of return on other fixed investments in agriculture -- land purchases or improvements, mechanical equipment, irrigation facilities, and so on. This hypothesis has not been conclusively verified for the agricultural sector. For a farm household, it may well be true, if offspring are likely to go into nonfarm employment. The situation is less clear for offspring likely to remain in farming. Here we are discussing a set of issues that badly needs to be illuminated by economic and sociological research. As far as public expenditures on education are concerned, the household income distribution in the rural community may well be a neglected factor in determining the optimum level and composition of local expenditures on education.

(38) Then $H_2 = g(C, H_1, t_2)$ $g_C > 0$, $g_h > 0$, $g_t > 0$

This says that human capital formation from on-the-job training and work experience is a function not only of (weighted) years spent working, and learning capacity, but also of the human capital previously formed through education.

Finally, total human capital

(39) $H = h(H_1, H_2)$ $h_1 > 0$, $h_2 > 0$

If an estimate of an individual's human capital is desired, H_1 might be obtained from foregone earnings plus resource costs of the education, appropriately weighted. H_2 might be derived from earnings and H_1, while H could be obtained from some weighted combination of H_1 and H_2, allowing for interaction. H could be used to obtain an estimate of earnings potential.

We have already noted that rural youth are likely to have fewer years of schooling and of poorer quality. Learning capacity being normally distributed among all youth, rural youth of the same age would be likely, on the average, to have lower H_1's than their urban counterparts. But the story doesn't end here.

Unless the rural youth migrates toward an urban area immediately after he finishes his formal education, his work experience will add to his H_2 only at a severely discounted rate. As far as nonagricultural employment is concerned, agricultural work does not add much to earning potential. Compared to his urban peer, the ruralite who migrates from

> ...It is true that these (actual) earnings are far less than average earnings for nonfarm workers. The chief reason for this is undoubtedly the lower skill levels of farm workers.

If skill levels translate roughly into human capital [as defined in (37), (38) and (39)], then Christensen appears to be saying that the actual (or potential) earnings of farm workers approximate pretty well the market return on the volume of human capital they represent.

There is another point to be made on the effect of different levels of human capital on income distribution. 9/ For this demonstration we borrow concepts from Meade (23, p. 82). Write income

(1) $Z = WN + VU$ where

N = hours worked

W = earnings per hour

U = earning assets owned

V = rate of return on assets

Because we are interested in income distribution, we write

(40) $Var(Z) = Var(WN) + Var(VU) + 2r(WN,VU) \sqrt{Var(WN) \cdot Var(VU}$

where r is the correlation between WN and VU. If there is no association between W or N on the one hand and V or U on the other, then r approaches 0 and the variance of income will hardly be greater than the sum of the variances of WL and VU. Correlation between WN and VU would make the variance of Z greater than it would be if W, N, V and U were all distributed normally and were independent of each other.

9/ For an excellent discussion, see Mincer (24).

rural schooling and farm work experience in search of urban employment is at a severe disadvantage, if labor earnings are largely a return on invested human capital.

This disadvantage would make itself felt in at least two ways. The rural migrant would be less likely than his urban peer to find gainful employment at all. Finding employment, the rural migrant would, on the average, be likely to earn less. Abstracting from any differential effects of learning capacity, the growth of human capital over time of the rural migrant after he obtains employment would be likely to lie below that of his urban peer, and to have a lesser slope.

Incomplete but suggestive confirmation of the above conclusion comes from a recent study by Laurits Christensen (6), who allocated farm income to labor and capital, using both the labor basis and the asset basis. In Christensen's own words (p. 3), "After making this allocation we assess whether it is plausible to conclude that the opportunity costs of all farm inputs have been adequately compensated by farm income."

Christensen concluded (p. 11):

> Based on the methods we have used it is clear that the returns to farm factors of production measure up very well. Furthermore, farm returns appear to be comparable with nonfarm returns regardless of the levels of government expenditures which have varied greatly over our sample period. This would imply that the massive government expenditures in farming have done little but encourage the misallocation of resources. This is a topic for further research.
>
> The measurement of opportunity costs for farm sector factors of production deserves a great deal of additional research. While such evidence is accumulating we feel that there should be more skepticism of the conventional arguments which allege that farm income has been substandard.

What can we say about the associations among W, N, V and U? Let us write W, N, V and U in terms of the variables on which we believe they depend.

$$(41) \quad W = \delta(H) \qquad \delta_H > 0$$

Under almost any set of conditions, N is a function of H. 10/ 11/

$$(42) \quad V_j = V(H_1, U_{j-1}) \qquad V_H > 0 \qquad V_u > 0$$

$$(43) \quad U_j = U(U_0, \sum_{i=1}^{j-1} Y_i, H) \qquad U_u > 0 \qquad U_y > 0 \qquad U_H > 0$$

Under the assumed conditions, WN and VU would be positively correlated with each other through the direct correlation of W, N, V and U with H.

10/ Two comments may be made on the relation between N and H. First, the level of embodied human capital may well influence directly the hours of work an individual would offer in the market. It is often rumored (but not adequately verified, to my knowledge) that higher-income workers offer more hours of work. The second comment concerns involuntary unemployment. The variance of H in which we would be interested is the actual hours worked. This might differ substantially from the hours of work desired by the worker. If workers with less human capital (years of schooling and work experience) were more likely than average to be unemployed, then the correlation between N and H would be greater than zero. If the data used to estimate the regression of H upon L happened to include cross-sections when unemployment was high, then the relation between H and N would be significant and H would make a significant contribution through N to the variability in income.

11/ In a paper presented at the 1971 Annual Meetings of the American Economic Association, Paul Schultz (26) reported log variances of income for full-time workers less than one-third of the log variances for all individuals who worked in 1969; this relation held for white and negro males, as well as for white and negro females.

The importance of off-farm earnings in the income streams of farmers confers additional importance on human capital investments, if we are willing to concede that human capital is an influential factor in the level of off-farm earnings of farm operators (or family members). Table 7 shows the order of magnitude of off-farm earnings, and some notion of the relation of farm and nonfarm earnings to farm size as measured by gross sales class. 12/

As far as income distribution is concerned, it seems clear that large systematic differences in human capital between rural and urban residents will lead to differences in the means and variances of incomes, operating through the processes of migration, unemployment or underemployment, asset ownership, and above all through the relation of earnings rates to human capital.

Farm Asset Ownership and Income Distribution

The formulation in equation (1) provides a framework for examining another aspect of income distribution.

(1) $Z = WN + VU$

We have argued that the distribution of labor earnings (WN) will be influenced significantly by the distribution of human capital. There may be some association between W and N (through H or other unspecified variables),

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12/ The influence of agricultural programs on income distribution has been reasonably well documented, and will not be emphasized here. For good analyses, see Bonnen (3, 4) and McKee and Day (22).

Table 7. Income per Farm Operator Family from Farm and Off-Farm Sources, by Value of Sales Classes, 1965, 1969.

Gross sales class (thousand dollars)	Number of farms 1965 (thousands)	Number of farms 1970 (thousands)	Realized net farm income per farm 1965 (thousand dollars)	Realized net farm income per farm 1969 (thousand dollars)	Off-farm income per farm 1965 (thousand dollars)	Off-farm income per farm 1969 (thousand dollars)	Total net farm income per farm 1965 (thousand dollars)	Total net farm income per farm 1969 (thousand dollars)
40 or more	159	226	25.4	27.5	4.5	5.5	29.9	33.0
20 to 40	287	377	9.9	10.5	2.5	3.2	12.4	13.7
10 to 20	487	513	6.2	6.5	2.3	3.1	8.5	9.6
5 to 10	502	363	3.5	3.6	3.2	4.5	6.7	8.1
2.5 to 5	430	251	2.0	2.1	3.5	4.9	5.5	7.0
Less than 2.5	1,474	1,165	1.0	1.1	4.6	7.0	5.6	8.1
All farms	3,340	2,895	4.2	5.4	3.7	5.3	7.9	10.7

Source: Economic Tables, Economic Research Service, U.S. Department of Agriculture, Washington, D. C. January 1971, Tables 37 and 39.

but we assume that, for our immediate purpose, the association may safely be ignored. 13/ Labor supply curves are usually depicted as (eventually) having a backward slope. We will also assume that Cov (V,U) is small although we have argued elsewhere that V and U are associated through the influence of human capital on each.

We are particularly interested in V and U because assets (land and capital) play an important role in agriculture, as we demonstrate below. The importance of earning assets in agriculture has grown very rapidly during the last five decades. Allen Smith of the U.S. Department of Agriculture wrote in February 1971: "Investment in production assets per farm worker in agriculture has increased 15 times since 1940 and more than doubled in the last 10 years." (28, p. 101).

From Smith (28, pp. 101-102) the specifics are as follows:

> Using average number of total farm workers, including both self-employed and hired, and average number of production workers only for manufacturing, average investment per farm worker was $50,020; per production worker in manufacturing enterprises, $35,222. ...The investment per employee, including both production and management, in manufacturing enterprises is $25,846; ...
>
> ...With all workers included and with farming assets valued on a cost basis, investment per farm worker in 1969 was $28,833 as against $25,846 per worker in manufacturing enterprises.
>
> The value of land has appreciated rapidly in recent years. This land appreciation, combined with a declining number of farm workers, has tended to increase the value of production assets per worker very rapidly when calculated on a current value basis.

13/ $E(WN) = Cov\ (W,N) + E(W)\ E(N)$. We assume for the moment that $Cov\ (W,N) \rightarrow 0$.

Apparently the difference between $50,020 per worker and $28,833 is due largely to the appreciation in land values which result from using current land values (as opposed to cost basis in the much lower estimate).

If we use equation (1) in our formulation of income for the purpose of studying income distribution, we must take account of capital gains, which appear to be very important in U. S. agriculture. The order of magnitude of capital gains can be seen from Table 8, taken from a recent article by Bhatia (2). For the 1947-68 period, nominal capital gains amounted to $166 billion. Corrected for changes in purchasing power, the total becomes $94 billion. These estimates include capital gains on farm real estate, livestock, crop inventories, and machinery and motor vehicles. In nominal terms, these were $141.5 billion, $5.1 billion, $3.9 billion, and $15.6 billion respectively for the 1947-68 period; adjusted for changes in purchasing power the same figures were $87.9 billion, - $1.9 billion, - $0.3 billion, and $8.8 billion respectively. It should be stressed that the data in the table are nominal and accrued (based on current values), neither real nor realized values. 14/

Though not precisely addressed to the income distribution question, some data on the distribution of farm assets are available. If value of gross value of sales can be thought of as a proxy for owned assets, then Table 9 provides some information both on the distribution of assets and on the direction of change over time in that distribution. It appears from Table 9 that the first moment is increasing, while the second and third moments

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14/ A rough indication of the distribution of assets among farm units is found in Table 7.

Table 8. Nominal Capital Gains and Income in Agriculture for Selected Years, 1948-68.

Year	Farm income	Farm capital gains	Farm gains as percent of farm income	Accrued gains as percent of personal income
	(billions of current dollars)			
1948	21.0	3.2	15.2	7.4
1950	16.9	10.9	64.5	21.8
1955	14.5	3.0	20.7	23.3
1960	15.9	3.9	14.5	1.7
1964	16.7	9.2	55.1	19.6
1968	20.2	14.5	71.8	n.a.

Source: Kul B. Bhatia, "On Estimating Capital Gains in U.S. Agriculture," AJAE, 53:502-506 (August 1971), p. 505.

Table 9. Number of Farms by Sales Class, 1960-70, with Projections to 2000, in thousands.

Economic class by value of sales in thousands of dollars	1960 adjusted 1/	1965 adjusted 1/	Estimated 1970 adjusted 1/	Projected 2/ 1980	2000
Under 2.5	1,848	1,474	1,165	704	314
2.5 to 5	617	430	251	178	69
5 to 10	660	502	363	221	82
10 to 20	497	487	513	320	159
20 to 40	227	287	377	270	188
40 to 100	90	124	172	171	166
100 to 200	23	36	32	41	46
200 to 500			14	22	33
500 to 1,000			8	6	11
1,000 and over				6	20
Total	3,962	3,340	2,895	1,939	1,088

1/ Adjusted for census underenumeration and to be consistent with number of farms reported (SRS for 1960 and 1965).

2/ Census farm concept without adjustments.

Source: R. F. Daly, J. A. Dempsey and C. W. Cobb, "Farm Numbers and Sizes in the Future," in Size, Structure and Future of Farms, Ames, Iowa State University Press, 1972, Table 17.3.

are declining. The distribution of farm assets, changes over time, and the effects upon the size distribution of farm and total income is another research project.

Professor Lianos (21) of the University of California at Davis has developed evidence that indicates that labor's relative share declined sharply from 1949 through 1963. Three measures were developed; "one [estimate, S_L] based on gross output, and one [estimate, S_L'] based on value added, were obtained by deflating wage rate estimates by the index of prices paid by farmers (1957-59 = 100) and output estimates by the index of prices received by farmers (1957-59 = 100) ...a third estimate, S_L'' has been obtained by using money wages and by dividing the resulting wage bill by gross output in current prices." (21, p. 413)

The results are shown in Figure 1 and in Table 10. What stands out from the figure and the table is that the relative share of labor has declined by more than 50 percent in real terms (S_L and S_L'), by approximately one-third in current values (S_L''). In terms of deflated gross output, the relative share of labor dropped in less than 20 years from more than 2/5 to less than 1/5. If we look at deflated value added, the decline is from nearly 3/4 to 1/3. For gross output and money wages in current prices, the relative share fell from almost 3/8 to slightly over 1/5. Most of these declines took place in the 1954-63 decade.

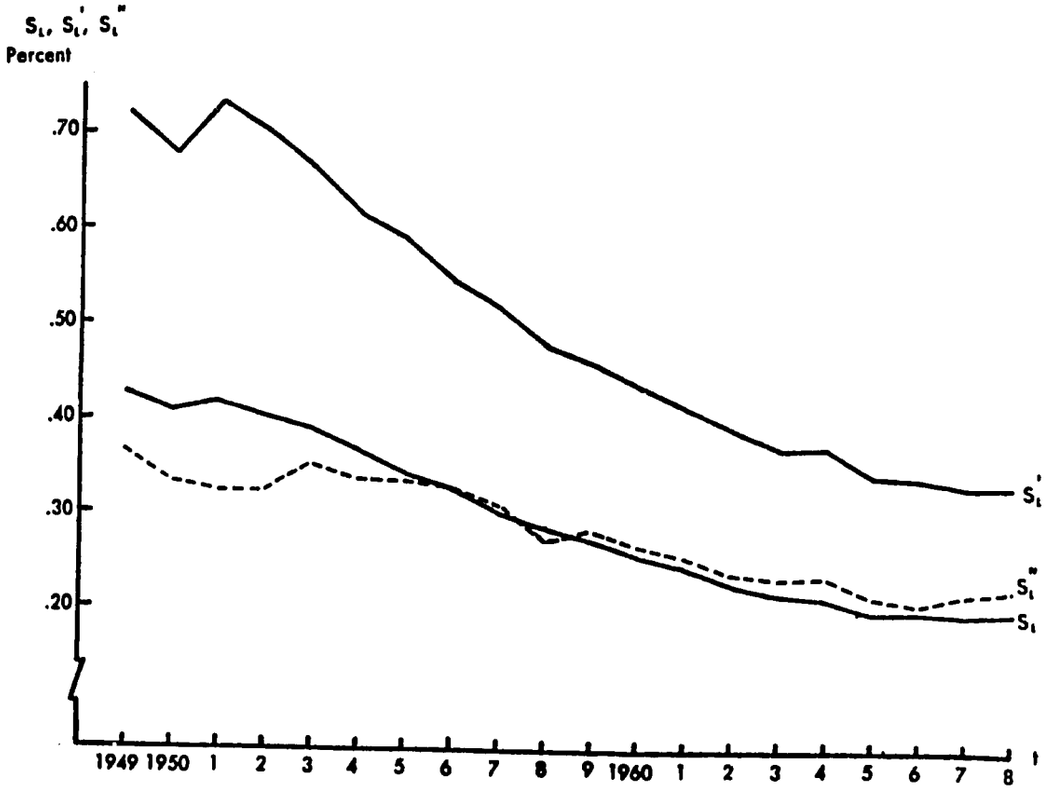

Figure 1. Relative share of labor in U.S. agriculture

Source: Theodore P. Lianos, "The Relative Share of Labor in U.S. Agriculture, 1949-69," AJAE, 53:412 (August 1971).

Table 10. Estimates of the Relative Share of Labor: U.S. Agriculture, 1949-68.

Year	S_L 1/	S_L' 2/	S_L'' 3/
1949	.4271	.7223	.365
1950	.4052	.6787	.333
1951	.4153	.7337	.322
1952	.3979	.7036	.321
1953	.3880	.6652	.351
1954	.3606	.6131	.336
1955	.3416	.5783	.334
1956	.3279	.5451	.327
1957	.3027	.5147	.306
1958	.2820	.4754	.271
1959	.2718	.4601	.280
1960	.2579	.4361	.266
1961	.2442	.4102	.254
1962	.2294	.3909	.238
1963	.2177	.3712	.233
1964	.2152	.3733	.237
1965	.1996	.3441	.215
1966	.1989	.3420	.206
1967	.1970	.3323	.219
1968	.1999	.3337	.224

1/ (Wage rate) (man-hours) ÷ value of total output, with wage rate deflated by the index of prices paid by farmers, and value of total output deflated by the index of prices received by farmers.

2/ (Wage rate)(man-hours) ÷ value added in agriculture, deflated as described in footnote 1.

3/ (Wage rate)(man-hours) ÷ gross output, all in current prices.

Source: Theodore P. Lianos, "The Relative Share of Labor in U.S. Agriculture, 1949-68," AJAE, 53:413 (August 1971).

Summary and Concluding Remarks

We have developed a model embodying production, demand, human capital, and asset ownership -- a model that illuminates some of the influences on income distribution that are felt during the process of agricultural development in a developed country. An even more important goal was the development of a model that will provide insights into these influences on income distribution and serve as a conceptual framework for measuring their effects. In particular, we developed a model that can be made to reveal an agenda of research needed for a better understanding of the income distribution effects of agricultural development, and ultimately for attempts to modify income distribution in directions desired by society.

From a Cobb-Douglas aggregate production function, we derived a steady-state expression of the important variables on which depend the three growth rates in which we are interested -- agricultural output, and the marginal products of labor and land. The influential variables include growth rates in: (1) land cultivated, (2) land-augmenting capital, (3) agricultural labor force, (4) human capital, and (5) labor-augmenting capital. The effects of changes in these factors on the three target variables are illustrated. By using empirically dervied rates of change, the difficulty of limiting agricultural output by controlling land cultivated is shown. If clamped down hard enough, acreage limitations can be effective in holding the rate of output growth down to an acceptable level, but have an unvarying tendency to raise returns to land and to lower returns to labor.

In developed countries, both the price and income elasticities of demand for agricultural products are low. The effects of output increases on prices, total revenue, and total revenue per worker are shown for different growth rates in agricultural output. For given combinations of relative output increase and rates of change in acreage cultivated, the outmigration rates required to keep marginal product of labor (or gross revenue per agricultural worker) increasing at a specified rate are worked out. As far as agricultural labor incomes are concerned, lowering agricultural prices increases the volume sold, but the quantity effect is swamped by the price effect.

When the production and demand models are used together it is apparent that the twin goals of supply control and labor income growth require a balance between acreage reduction and labor transfers out of agriculture. In the existing political climate, failure of labor to migrate at an acceptable rate requires greater reliance on acreage reductions, which in turn exert strong downward pressures on the marginal product of labor. Research is needed on the possibility of using some of the other influences on agricultural output as instrumental variables. Besides land cultivated and agricultural labor, these potential instrumental variables include land-augmenting technology, labor-augmenting capital, and human capital. Reducing the growth rate of human capital would be an ineffective instrument of raising labor incomes in agriculture because a lower rate of human capital formation in the agricultural population which would presumably lower the rate of output increase might also be expected to depress the outmigration

rate from agriculture. Labor-augmenting capital formation is subject to social control, if interest rates are subsidized or if publicly financed research plays an important role in developing the underlying technology. Direct means of depressing this rate do exist in the form of taxation, for example. Public research funds could be diverted into the development of labor-intensive technology, if that is technically feasible.

Public funds are important in the generation of land-augmenting technology. Increased use of land-augmenting inputs increases the effective supply of land; this makes it necessary to reduce further the land acreage cultivated to hold down output. In turn this reduction does the following: raises the marginal product (and value) of the land still in cultivation; enhances still more the profitability of using land-augmenting inputs; and lowers the marginal product of labor. If agricultural prices are permitted to fall, than society benefits from the technological change due to land-augmenting technology. Careful investigation is needed to compare the gains in efficiency to society with the adverse effects on the income distribution operating through land and labor returns. If the gains to society are great enough than some of the gains might be used to redress the income distribution effects. If the gains to society are not that large, then another means of controlling the rate of output growth might be through reducing (or managing) the flow of public funds into the development of land-augmenting technology. The use of land-augmenting inputs could also be influenced by direct taxation of the inputs.

Even if these additional means of limiting the rate of output growth prove to be effective and feasible, the rate of labor outmigration from agriculture will still play a key role in maintaining a supply-demand balance and an acceptable rate of growth in agricultural labor incomes. The probability that redundant agricultural labor will transfer to gainful employment outside agriculture depends to considerable extent on two factors: (1) growth of nonfarm employment opportunities, and (2) the volume of human capital embodied in the redundant labor. The first factor is controlled by the federal managers of monetary and fiscal policies, and incomes policy. As for the second factor, it is argued in this study that there is a chronic tendency for rural areas and rural people to underinvest in human capital. In combination with less than full employment, this underinvestment holds down outmigration from agriculture and not only intensifies the difficulty of keeping supply and demand in balance but also intensifies the downward pressure on labor returns in agriculture. Support for this hypothesis is found in evidence that the returns to farm labor are comparable to the returns to nonfarm labor when account is taken of skill levels. It is also argued that human capital not only influences the average earnings rates, but, in an economy not always fully employed, also affects the income distribution through the hours worked.

Finally, we turn briefly to the influence that ownership of farm assets has on the distribution of income. Agriculture is shown to be increasingly an asset-intensive activity, with real estate accounting for nearly 80 percent of the value of all assets used in agriculture, and 80 percent of farm operators' equity capital (assets owned by farm operators).

The price of farm real estate rose 195 percent from 1950 to 1971 (14, p. 9) and much of this increase can be attributed to two facets of agricultural development -- rapid growth in land-augmenting technology, and the use of acreage reductions to control supply. The gains from these value accretion have, of course, been larger for the larger land owners. The magnitude of the effects of capital gains on income distribution can be inferred from the fact that the ratio of capital gains to farm income averaged .425 for six selected years during the 1948-68 period. The decline in the relative share of labor in U.S. agricultural income was dramatic during this same period. Quite likely the distribution of human capital is also one of the important determinants of the distribution of earning assets, and the asset distribution contributes to the mean, variance, and skewness of incomes.

The agricultural development process in the U.S. has created strong downward pressures on average farm incomes. Some of the programs designed to deal with these pressures have skewed income distribution toward assets and against labor. The programs required to neutralize the income distribution effects of technological change, of low price and income elasticities of demand for rural products, and of low income elasticity of demand in rural areas for human capital have not been forthcoming. The policies and programs used in agriculture have undoubtedly increased the contribution of the agricultural sector to over-all income inequality.

At the same time additional research is needed to spell out more accurately the degree of rural underinvestment in human capital, the role

of human capital in migration, the characteristics of the distribution of assets among farm operators, and the effect on over-all income distribution of other influences emanating from agriculture. Design of agricultural programs should include more careful attention to equity effects, in addition to efficiency effects. It should also be clearly understood that equity considerations require attention to a much broader set of programs than those usually considered in looking at the aggregate welfare of agriculture.

References and Bibliography

(1) Gary S. Becker, Human Capital and the Personal Distribution of Income: An Analytical Approach, Ann Arbor, Institute of Public Administration and Department of Economics, The University of Michigan, 1967.

(2) Kul B. Bhatia, "On Estimating Capital Gains in U.S. Agriculture," AJAE, 53:502-506 (August 1971).

(3) James T. Bonnen, "The Distribution of Benefits from Cotton Price Supports," Problems in Public Expenditure Analysis, ed. Samuel B. Chase, Jr., Brookings Institution, Washington, D.C., 1968, pp. 213-254.

(4) James T. Bonnen, "The Distribution of Benefits from Selected U.S. Farm Programs," Rural Poverty in the United States: A Report of the President's National Advisory Commission on Rural Poverty, Washington, D. C., 1968, pp. 461-505.

(4a) G. E. Brandow, Interrelations Among Demands for Farm Products and Implications for Control of Market Supply, Bulletin 680, Agricultural Experiment Station, Pennsylvania State University, University Park, August 1961.

(5) Changes in Farm Production and Efficiency -- A Summary Report, Stat. Bull. No. 233, Economic Research Service, U.S. Department of Agriculture, Washington, D. C., June 1971.

(6) Laurits Christensen, "A New Look at Farm Income in the United States," University of Wisconsin, Social Systems Research Institute, EME 7112, June 1971.

(7) Economic Tables, Economic Research Service, U.S. Department of Agriculture, Washington, D. C., January 1971.

(7a) Farm Population, Series Census-BAE, No. 16, Washington, D. C., March 9, 1953.

(7b) Farm Population, Series Census-AMS (P-27), No. 29, Washington, D. C., April 18, 1961.

(7c) Farm Population, Series Census-ERS, (P-27), No. 42, Washington, D. C., August 16, 1971.

(8) H. Thomas Frey, Orville E. Krause, and Clifford Dickason, Major Uses of Land and Water in the United States -- Summary for 1964, Agri, Econ. Report No. 49, Economic Research Service, U.S. Department of Agriculture, Washington, D. C., November 1968.

(9) Bruce L. Gardner, "An Analysis of U.S. Farm Family Income Inequality: 1950-1960," unpublished Ph.D. thesis, University of Chicago, 1968.

(10) Bruce L. Gardner, "Determinants of Farm Income Inequality," AJAE, 51:753-769, November 1969.

(11) Handbook of Agricultural Charts, 1964, Agriculture Handbook No. 275, Economic Research Service, U.S. Department of Agriculture, Washington, D.C., September 1964.

(12) Handbook of Agricultural Charts, 1967, Agriculture Handbook No. 348, Economic Research Service, U.S. Department of Agriculture, Washington, D. C., October 1967.

(13) Handbook of Agricultural Charts, 1968, Agriculture Handbook No. 359, Economic Research Service, U.S. Department of Agriculture, Washington, D. C., November 1968.

(14) Handbook of Agricultural Charts, 1971, Agricultural Handbook No. 423, U.S. Department of Agriculture, Washington, D. C., November 1971.

(15) Yujiro Hayami and Vernon W. Ruttan, Agricultural Development: An International Perspective, Baltimore and London, The Johns Hopkins Press, 1971.

(16) Yujiro Hayami and Vernon W. Ruttan, "Induced Innovation and Agricultural Development," University of Minnesota, Department of Agricultural and Applied Economics, Staff Paper P71-1, January 1971.

(17) Robert W. Herdt and Willard W. Cochrane, "Farm Land Prices and Farm Technological Advance," Journal of Farm Economics, 48:243-263, May 1966.

(18) Earl F. Hodges, Livestock-Feed Relationships, 1909-1963, Stat. Bull. No. 337, Economic Research Service, Washington, D. C., November 1963.

(19) Dale W. Jorgenson, "The Development of a Dual Economy," Economic Journal, 71:309-334, June 1961.

(20) L. Don Lambert and Donald D. Durost, "Productivity: Index of Total Farm Input and Productivity, for Each Farm Production Region, 1939-70," Supplement V to Changes in Farm Production and Efficiency, Economic Research Service, U.S. Department of Agriculture, Washington, D. C., September 1971.

(21) Theodore P. Lianos, "The Relative Share of Labor in United States Agriculture, 1949-1968," AJAE, 53:411-422, August 1971.

(22) Vernon C. McKee and Lee M. Day, "Measuring the Effects of U.S. Department of Agriculture Programs on Income Distribution," Rural Poverty in the United States; A Report by the President's National Advisory Commission on Rural Poverty, Washington, D. C., May 1968.

(23) J. E. Meade, Efficiency, Equality and the Ownership of Property, London, George Allen and Unwin, 1964.

(23a) Jacob Mincer, "On-the-Job Training: Costs Returns, and Some Implications," October 1962 Supplement to The Journal of Political Economy, 70, No. 5, Part 2: 50-79.

(24) Jacob Mincer, "The Distribution of Labor Incomes: A Survey with Special Reference to the Human Capital Approach," Journal of Economic Literature, 8:1-26, March 1970.

(25) Richard F. Muth, "The Derived Demand Curve for a Production Factor and the Industry Supply Curve," Oxford Economic Papers, NS16: 221-234, July 1964.

(26) T. Paul Schultz, "Long Term Change in Personal Income Distribution: Mythology, Fact and Explanations," American Economic Review, Papers and Proceedings, 60, No. 2, May 1971.

(26a) Theodore W. Schultz, "Reflections on Investment in Man," Supplement to The Journal of Political Economy, 70, No. 5, Part 2: 1-8, October 1962.

(27) Theodore W. Schultz, "Our Welfare State and the Welfare of Farm People," The Social Service Review, 38, No. 2:123-129, June 1964.

(28) Allen G. Smith, "Comparative Investment per Worker in Agriculture and Manufacturing Sectors of the Economy," AJAE, 53:101-102, February 1971.

(29) Luther Tweeten and Dean Schreiner, "Economic Impact of Public Policy and Technology on Marginal Farms and on the Nonfarm Population," Benefits and Burdens of Rural Development, Iowa State University Press, Ames, Iowa, 1970, pp. 41-76.

(30) Fred Tyner and Luther Tweeten, "Optimum Resource Allocation in U.S. Agriculture," Journal of Farm Economics, 48:613-631, August 1966. Also in the AEA Readings in the Economics of Agriculture, 1969.

(30a) U.S. Bureau of the Census, "Estimates of the Population of the United States and Components of Population Change, 1944 to 1962," Current Population Reports, Series P-25, No. 250, Washington, D. C., July 3, 1962.

(30b) U.S. Bureau of the Census, "Estimates of the Population of the United States to January 1, 1972," Current Population Reports, Series P-25, No. 476, Washington, D. C., February 1972.

(31) U.S. Bureau of the Census, Statistical Abstract of the United States, 1956, U.S. Department of Commerce, Washington, D. C., 1956.

(32) Finis Welch, "Some Aspects of Structural Change and the Distributional Effects of Technical Change and Farm Programs," Benefits and Burdens of Rural Development, Iowa State University Press, Ames, Iowa, 1970, pp. 161-193.

(33) Finis Welch, "Education in Production," Journal of Political Economy, 78:35-59, January-February 1970.

(34) Hugh H. Wooten, Karl Gertel and William C. Pendleton, Major Uses of Land and Water in the United States -- Summary for 1959, Agri. Econ. Report No. 13, Economic Research Service, U.S. Department of Agriculture, Washington, D. C., July 1962.

APPENDIX

The empirical information shown earlier in Table 1 was developed largely from actual time series. The seventeen series considered in arriving at Table 1 are shown in Table A.1, where the sources are given. The five-year rates of change (1946-50 to 1951-55, 1951-55 to 1956-60, 1956-60 to 1961-65, and 1961-65 to 1966-70), and the twenty-year rate of change (1946-50 to 1966-70) are given for nearly all of the seventeen series in Table A.2. The average annual rates of change for each period and for the whole twenty-year period are given in Table A.3.

For many of the desired rates, time series that are direct measures of the magnitudes of interest were readily available, largely from the Economic Research Service of the U.S. Department of Agriculture. Rates of change could be estimated directly from these data.

Among the annual series available from 1946 through 1970 are "Index of total farm output" (shown in Column 4 of Table A.1, and used to estimate $\dot{Y}$); "Population of the United States, as of July 1," (shown in Column 2, and used to estimate $\dot{N}$; "Average value of farmland per acre" (Column 7, used to estimate change in marginal product of land $\left(\frac{\partial Y}{\partial L}\right)^{\cdot}$); "Farm Population as of April1." For the farm population series, a change in the definition of rural farm and rural nonfarm was made in 1960, and we have to deal with two series, shown in Column 5. In Column 5a we converted the two series in Column 5 into index numbers, using 1960=100 for each series. We obtained our estimates of $\dot{A}$ from the resulting index number series. This is not a perfect adjustment for the discountinuity in the series, but it is believed that this adjustment would minimize the distortion in the annual rates.

Table A.1a. Annual Data Used in Testing Model.

Year	(1) Personal Disposable Income per capita (Current dollars)	(2) Population of the United States as of July 1 (thousands)	(3) Average farm wage rate per hour w/o board or room (dollars)	(4) Index of total farm output (1967=100)	(5) Farm population as of April 1 (thousands)	(5a) Index of farm population as of April 1 (1960=100)	(6) Cropland used for crops (million acres)
1944	1,057	138,916					379
1945	1,074	140,468	0.58	69	25,295	123.14	372
1946	1,132	141,936	0.63	71	26,483	128.93	369
1947	1,178	144,698	0.67	69	27,124	132.05	373
1948	1,290	147,208	0.71	75	25,903	126.10	378
1949	1,264	149,767	0.68	74	25,954	126.35	387
1950	1,364	152,271	0.69	73	25,058	121.99	377
1951	1,469	154,878	0.77	75	24,160	117.62	381
1952	1,518	157,553	0.81	78	24,283	118.22	380
1953	1,583	160,184	0.82	79	22,679	110.41	380
1954	1,585	163,026	0.81	79	22,099	107.58	380
1955	1,666	165,931	0.82	82	22,438	109.24	378
1956	1,743	168,903	0.86	82	22,362	108.86	369
1957	1,801	171,984	0.88	80	21,606	105.18	358
1958	1,831	174,882	0.92	86	21,388	104.12	355
1959	1,905	177,830	0.95	88	21,172	103.07	358
1960	1,938	180,667	0.97	90	20,541	100.00	355
1960	--	--	--	--	*15,635	100.00	--
1961	1,984	183,672	0.99	90	*14,803	94.68	340
1962	2,066	186,504	1.01	91	*14,313	91.54	331
1963	2,139	189,197	1.05	95	*13,367	85.49	337

(Continued)

Table A.1a. Annual Data Used in Testing Model -- continued

Year	(1) Personal Disposable income per capita (Current dollars)	(2) Population of the United States as of July 1 (thousands)	(3) Average farm wage rate per hour w/o board or room (dollars)	(4) Index of total farm output (1967=100)	(5) Farm population as of April 1 (thousands)	(5a) Index of farm population as of April 1 (1960=100)	(6) Cropland used for crops (million acres)
1964	2,288	191,833	1.08	94	*12,954	82.85	335
1965	2,436	194,237	1.14	97	*12,363	79.07	336
1966	2,605	196,485	1.23	96	*11,595	74.16	331
1967	2,751	198,629	1.33	100	*10,875	69.56	343
1968	2,946	200,619	1.44	102	*10,454	66.86	339
1969	3,130	202,599	1.58	103	*10,307	65.92	334
1970	3,358	204,800	1.64	102	* 9,712	62.12	336
1971		207,006	1.73	109			347**

*New Series ** Preliminary

Source: See end of Table A.1

Table A.1b. Annual Data Used in Testing Model.

Year	(7) Average value of farmland per acre (dollars)	(8) Index of total farm inputs: mechanical power and machinery (1967=100)	(9) Total concentrates fed (million tons)	(10) Index of total farm inputs: fertilizer and liming materials (1967=100)	(11) Prices received by farmers for food products (1950=100)	(12) Index of civilian food consumption per capita (1960=100)	(13) Consumer price index: food (1950=100)
1944		55	126.7	23	77.0	99.1	66.6
1945	33.8	56	130.2	23	80.9	100.0	68.1
1946	38.2	55	119.3	24	92.2	102.7	78.1
1947	43.2	61	107.7	28	107.8	100.8	94.7
1948	46.1	68	115.9	29	112.1	97.6	102.9
1949	46.9	75	122.5	31	97.7	97.6	98.8
1950	46.2	79	121.7	32	100.0	98.9	100.0
1951	53.2	84	124.1	36	115.0	97.1	111.2
1952	58.2	89	114.0	39	111.5	99.0	113.2
1953	59.8	90	116.6	42	103.1	100.0	111.4
1954	62.0	90	116.2	43	97.5	99.9	111.2
1955	62.0	91	121.9	45	91.4	100.5	109.6
1956	66.4	91	119.7	44	90.2	101.7	110.4
1957	71.8	90	129.0	46	92.9	99.7	114.0
1958	77.2	91	139.5	48	99.7	98.4	118.8
1959	84.4	92	144.7	54	92.3	100.4	116.9
1960	88.2	91	149.8	54	93.6	100.0	118.2
1960	--	--	--	--	--	--	--
1961	92.0	90	151.8	58	93.1	99.6	119.6
1962	96.7	91	150.3	62	94.0	99.9	120.7
1963	101.4	92	148.3	70	91.6	100.2	122.5

(Continued)

Table A.1b. Annual Data Used in Testing Model -- continued

Year	(7) Average value of farmland per acre (dollars)	(8) Index of total farm inputs: mechanical power and machinery (1967=100)	(9) Total concentrates fed (million tons)	(10) Index of total farm inputs: fertilizer and liming materials (1967=100)	(11) Prices received by farmers for food products (1950=100)	(12) Index of civilian food consumption per capita (1960=100)	(13) Consumer price index: food (1950=100)
1964	109.0	93	145.3	76	91.5	101.2	124.0
1965	116.8	96	161.0	80	100.0	100.8	126.8
1966	125.6	100	160.7	90	108.5	102.0	133.1
1967	133.6	100	161.8	100	101.4	103.7	134.3
1968	144.2	102	172.2	107	106.6	105.0	139.0
1969	151.5	103	181.3	110	117.0	105.3	146.3
1970	156.3	103	179.5	113	117.6	106.2	154.3
1971	166.0	103	137.0	118	122.7	107.2	159.8

Source: See end of Table A.1.

Table A.1c. Annual Data Used in Testing Model.

Year	(14) Irrigated land in Farming (thousand acres)	(15) Cropland used only for pasture (million acres)	(16) Grassland pasture (million acres)	(17) Forest land used for pasture and range (million acres)
1939	21,170			
1940		68	655	342
1944	20,539	48	650	345
1945				
1946				
1947				
1948				
1949	25,787	69	631	319
1950		69	631	320
1951				
1952				
1953				
1954	29,552	66	633	301
1955				
1956				
1957				
1958				
1959	33,023	66	633	245
1960		65		
1961		65		
1962				
1963				
1964	37,552	57	640	225
1965	38,586	58		
1966	39,657	57		
1967	40,768	59		
1968	41,923			
1969	43,126			
1970		49		
1971				

Source: See end of Table A.1.

Table A.1d. Annual Data Used in Testing Model

Sources of data:

Column 1: 1944-56, (12, Figure 27).
1957-59, (13, Figure 3).
1960-70, (14, Figure 2).

Column 2: 1944-49, (30a).
1950-71, (30b).

Column 3: 1949-71, directly and 1945-48, computed from data provided by C. Kyle Randall, Economic Research Service, U.S. Department of Agriculture, Washington.

Column 4: (20, Table 12).

Column 5: 1945-50, (7a); 1951-60, (7b); 1960-70, (7c).

Column 5a: Computed from Column 5.

Column 6: 1945-49, (34, Table 21); 1950-70, (5, Table 4); 1971, (Randall)

Column 7: Computed from data provided by C. Kyle Randall, Economic Research Service, U.S. Department of Agriculture, Washington.

Column 8: (20, Table 1).

Column 9: 1944-49, (18); 1950-59, (11, Figure 73); 1960-70, (14, Figure 121); 1971, (Randall)

Column 10: (20, Table 1), 1971, (Randall)

Column 11: 1944-49, estimated from data found in (13, Figure 5); 1950-71, (14, Figure 41).

Column 12: 1944-49, estimated from data found in (11, Figure 18); 1950-59, estimated from data found in (13, Figure 32); 1960-71, (14, Figure 36).

Column 13: 1944-49, estimated from data found in (31, p. 324); 1950-71, (14, Figure 41).

Column 14: 1939-64, (8, Table 15); 1965-69; (7, Table 12)

Column 15: (5, Table 1).

Column 16: (5, Table 1).

Column 17: (5, Table 1).

Table A.2. Rates of Change for Five-Year Averages of Annual Data Used to Test Model.

Column a/	1946-50 to 1951-55	1951-55 to 1956-60	1956-60 to 1961-65	1961-65 to 1966-70	1946-50 to 1966-70
1	25.58	17.86	18.34	35.58	137.48
2	8.93	9.07	8.14	6.10	36.32
3	19.23	13.65	15.07	37.00	113.61
4	8.56	8.40	9.62	7.71	38.95
5a	-11.39	-7.42	-16.81	-21.92	-46.71
6	0.80	-5.48	-6.46	+0.24	-10.67
7	33.82	31.44	32.96	37.86	222.39
8	31.36	2.48	1.54	9.96	50.30
9	00.87	15.28	10.84	13.16	45.85
10	42.36	20.00	40.65	50.29	261.11
11	1.71	-9.605	0.32	17.205	8.10
12	-0.02	0.75	0.30	4.09	5.14
13	17.28	3.90	6.10	15.22	49.00
14	na	na	na	14.84 b/	79.72 c/
15	na	na	na	na	-27.94 d/
16	na	na	na	na	-2.29 e/
17	na	na	na	na	-34.21 e/

a/ Refer to Table A.1 for identification of each series designated here by number.
b/ 1964 to 1969.
c/ 1944 to 1964.
d/ 1944 to 1970.
e/ 1940 to 1964.
na Not available.

Source: Computed from Table A.1.

Table A.3. Annual Average Rates of Change for Five-Year Averages of Annual Data Used to Test Model

Column a/	1946-50 to 1951-55	1951-55 to 1956-60	1956-60 to 1961-65	1961-65 to 1966-70	1946-50 to 1966-70
1	4.66	3.36	3.42	6.28	4.42
2	1.73	1.75	1.56	1.09	1.56
3	3.58	2.59	2.85	6.50	3.87
4	1.66	1.63	1.85	1.50	1.66
5a	-2.39	-1.53	-3.61	-4.83	-3.10
6	0.16	-1.12	-1.33	0.05	-0.56
7	6.00	5.62	5.86	6.63	6.03
8	5.61	0.49	0.31	1.92	2.06
9	0.17	2.89	2.08	2.50	1.91
10	7.32	3.71	7.06	8.49	6.63
11	0.34	-2.00	0.07	3.23	0.39
12	-0.005	0.15	0.06	0.80	0.25
13	3.24	0.77	1.19	2.87	2.01
14	na	na	na	2.81 b/	2.97 c/
15	na	na	na	na	-1.09 d/
16	na	na	na	na	-0.10 e/
17	na	na	na	na	-1.74 e/

a/ Refer to Table A.1 for identification of each series designated by number.
b/ 1964 to 1969.
c/ 1944 to 1964.
d/ 1944 to 1970.
e/ 1940 to 1964.
na Not available.

Source: Computed from Table A.1.

In effect, we are using changes in the farm population as a proxy for changes in the farm labor force. This introduces biases whose nature is unknown, but this procedure appeared to be more acceptable for our purposes than any other available.

For a measure of the land input, we used "Cropland used for crops" (Column 6) to estimate $\dot{L}$. Besides cropland used for crops, there is cropland used only for pasture (Column 15), grassland pasture (Column 16), and forest land used for pasture and range (Column 17). Table A.3 shows that all four categories of land use recorded 20-year declines of the same order of magnitude. The predominant importance of cropland used for crops as a land input made us feel some confidence in an estimate based on the changes in cropland used for crops.

Another rate estimated directly was based on "Average farm rate per hour w/o board and room." As is evident from the source for Column 3, the early years of this series had to be estimated from a closely related series by using the average ratio between the two series for the ten years following the missing years; the ratios seemed to be reasonable, exhibiting little secular trend. Changes in this series were used as a proxy for the changes in marginal product of labor $\left(\dot{\frac{\partial Y}{\partial A}}\right)$.

"Personal disposable income per capita," measured in current dollars, was available for the whole period and is shown in Column 1. This series was the basis for estimates of $\left(\dot{\frac{Z}{N}}\right)$. "Consumer price index: food" could be obtained for the whole period only by splicing three series together,

but the procedure appeared to give acceptable results. Shown in Column 13, this series was used to measure $\dot{P}'$, where $\dot{P}$ was obtained from "Prices received by farmers for food products," given in Column 11. $\dot{P}$ was regressed against $\dot{P}'$ for the years 1946-70. The regression

$$(44) \quad \dot{P}' = 2.20 + 0.61\,\dot{P}$$

yielded an R^2 of .6835. $\dot{P}$ and $\dot{P}'$ were expressed in percentages. This regression enables us to relate changes in food consumption per capita to changes in prices paid farmers through the relationship between retail food prices and prices paid farmers.

Rates of change in the three forms of agricultural capital were much more difficult to estimate. As a proxy for the rate of change in the use of labor-augmenting capital, we used the "Index of total farm inputs: mechanical power and machinery," shown in Column 8. It is obvious that developing a weighting procedure and taking adequate account of quality changes are very difficult. Among the different proxies that were available and might have been used, this series seemed to be preferable. It was used to estimate $\dot{K}_3$.

It was not possible to find a series to represent directly the human capital embodied in the agricultural labor force, or even an annual series to represent the volume of human capital in the total population. To test our model, we used a rate obtained from estimates by T. W. Schultz (26a, p.6). Professor Schultz estimated the value of the educational capital in the labor force for 1929 and 1957, and using some estimates of Mincer (23a), developed "guesses" for 1939 and 1957 of the human capital embodied in

on-the-job training of males in the labor force. By interpolation and combination, I obtained an annual growth rate of 4.58 percent in the growth of human capital in the labor force (defined here as educational capital and capital embodied in the on-the-job training of males in the labor force). Using 4 percent as an approximation involves the heroic assumptions that estimates based on the 1929-57 and 1939-57 periods would also be valid for the 1960-70 decade, and that growth rate estimates for the male labor force could be applied without adjustment to the agricultural labor force. If forced to guess, I would surmise that the Schultz estimate of the on-the-job training component might be too high for the agricultural labor force, the estimate of the educational capital of the labor force might be too low. Because of the substantial disparities in 1960, the growth rate in the rural areas may be higher even if the median years of schooling are still well below the urban areas. I would also surmise that the rates of the 1960's would be higher than for 1939-57. Our judgment is that the rate chosen is a reasonably conservative estimate for the 1946-70 period.

For changes in the importance of land-augmenting technology, no proxy -- or combination of proxies -- seemed to be satisfactory. Three series were examined: "Index of total farm inputs: fertilizer and liming materials" (Column 10), "Total concentrates fed" (Column 9), and "Irrigated land in farms" (Column 14). It was my hope that the fertilizer series might represent the changes in land-augmenting technology as applied to crop production, that the concentrates series might serve as a proxy for changes in land-augmenting technology as applied to livestock production, and that the

irrigated land series might represent changes in irrigation investments. Making assumptions heroic enough to justify using these series as a basis for estimating changes in the use of land-augmenting capital still leaves open the question of how to weight their contributions. The only attractive alternative was to weight each series according to the proportions that crop production (less irrigated crop production), livestock production, and irrigated crop production were of total agricultural production measured in value terms.

Table A.3 shows that, over the 20-year period, the average annual rate of change in the fertilizer index was over 6 1/2 percent, in irrigated land in farms nearly 3 percent, and in total concentrates fed nearly 2 percent. I took the coward's way out and used .06 as an estimate for $\dot{K}_1$ without any additional sleight-of-hand with the numbers.

One brief comment on the estimated rates should be made at this point. Some of the rates used were not particularly stable over time, as Table A.3 illustrates. Inflation undoubtedly influenced the 1961-65 to 1966-70 rates for personal income, and farm wages. Population growth rates showed a tendency to decline over time. Unstable outmigration rates tended to make for uneven rates of change in the farm population. Rates of change in the cropland used, in mechanization, and in concentrates fed, also varied considerably over the period of interest. The rapid rate of growth in the use of fertilizer was interrupted during the 1956-60 period. Rates of change in farm prices, retail food prices, and food consumption per capita were also irregular over the period. One of the next items on the writer's agenda is to test the explanatory power of the model for the change rates for shorter periods of time.

Testing the model required estimates of the elasticities listed in Table 2 -- β, α, δ_1, δ_2, η_{yp}, and η_{yz}. For the two demand elasticities (η_{yp} and η_{yz}), we used the estimates published in 1961 by Brandow and generally applicable to the last half of the 1950-60 decade. For η_{yp}, we used Brandow's estimate of -.2278 for the farm-level price elasticity of demand for all food (4a, Table 10). For η_{yz}, we used Brandow's estimate of .162 for the income elasticity of demand for all food consumed at home by nonfarm families (4a, p. 20). One would anticipate that continued growth since the 1950's in personal disposable income per capita would have driven the absolute values of price elasticity of demand and income elasticity of demand below Brandow's estimates. Thus these estimates would appear to be on the conservative side.

Estimates of the other elasticities -- β, α, δ_1, and δ_2 -- were obtained by means of informal procedures from Table A.4. From the table it can be seen that these elasticities have been undergoing drastic changes since 1945. That is to say, the importance of each input group but farm real estate has changed sharply. While farm labor has declined in importance by almost two-thirds and farm real estate has barely increased in importance, fertilizer and lime have quadrupled, mechanical power and machinery, and feed, seed and livestock have each almost doubled, and "all others" has increased in importance by one-half. A next test of the model is to apply it to five-year periods, allowing the production elasticities to change from one period to another, as in fact they seem to have done.

One final evaluation can be made of the rates of change (based largely on annual data) and the production elasticities (less firmly based on empirical

Table A.4. Total Farm Inputs: Percent Distribution of Input Groups for Specified Groups,

Input group	1945	1950	1955	1960	1965	1970
Farm labor	47.9	38.4	32.2	26.5	21.1	16.9
Farm real estate	18.5	19.9	20.0	20.0	20.3	19.8
Mechanical power and machinery	14.9	21.0	23.8	25.0	25.6	26.2
Fertilizer and lime	2.0	2.8	3.8	4.8	7.0	9.3
Feed, Seed and livestock	6.7	7.9	8.9	10.6	11.3	12.8
All other a/	10.0	10.0	11.3	13.0	14.7	15.0
Total	100.0	100.0	100.0	100.0	100.0	100.0

a/ Includes taxes, interest on inventory, pesticides, insurance, containers, binding materials, dairy supplies, irrigation O & M charges, veterinary, telephone, and ginning charges.

Source: Data provided by C. Kyle Randall, Economic Research Service, U.S. Department of Agriculture, and by Donald Durost of the same organization.

data). We have observed values of $\dot{Y}$, $\left(\frac{\partial \dot{Y}}{\partial A}\right)$, and $\left(\frac{\partial \dot{Y}}{\partial L}\right)$ based on annual series. We also have the following expressions:

$$(11) \quad \dot{Y} = \alpha(1-\beta)\dot{K}_1 + \beta\delta_1\dot{K}_2 + \beta\delta_2\dot{K}_3 + \beta(1-\delta_1-\delta_2)\dot{A} + (1-\beta)(1-\alpha)\dot{L}$$

$$(17) \quad \left(\frac{\partial \dot{Y}}{\partial A}\right) = \alpha(1-\beta)\dot{K}_1 + \beta\delta_1\dot{K}_2 + \beta\delta_2\dot{K}_3 + \beta(-\delta_1-\delta_2)\dot{A} + (1-\beta)(1-\alpha)\dot{L}$$

$$(21) \quad \left(\frac{\partial \dot{Y}}{\partial L}\right) = \alpha(1-\beta)\dot{K}_1 + \beta\delta_1\dot{K}_2 + \beta\delta_2\dot{K}_3 + \beta(1-\delta_1-\delta_2)\dot{A} + [(1-\beta)(1-\alpha)-1]\dot{L}$$

If we substitute our estimates of the variables in Table 1 and the elasticities in Table 2 for the items on the right hand side of equations (11),

We obtain computed values of $\dot{Y}$, $\left(\frac{\partial \dot{Y}}{\partial A}\right)$ and $\left(\frac{\partial \dot{Y}}{\partial L}\right)$. The observed and computed values are shown in table A.5.

Table A.5. Observed and Computed Values of the Following Rates of Change: Index of Total Farm Output, Average Farm Wage Rate Per Hour and Average Value of Farmland Per Acre.

Item	Index of total output ($\dot{Y}$)	Average farm wage rate per hour $\left(\frac{\partial \dot{Y}}{\partial A}\right)$	Average value of farmland per acre $\left(\frac{\partial \dot{Y}}{\partial L}\right)$
Observed value	.0165	.039	.06
Computed value	.02342	.03644	.02942

Source: Table 1 for observed values.

As far as $\dot{Y}$ is concerned, our model says that the actual rates of change of the five inputs -- $\dot{K}_1$, $\dot{K}_2$, $\dot{K}_3$, $\dot{A}$ and $\dot{L}$ -- should have generated an annual rate of increase in $\dot{Y}$ of 2.34 percent, rather than the observed annual increase of 1.65 percent. Some of this shortfall is due to several kinds of inefficiencies, including the effects of supply management programs and the failure of resources (especially labor) to adjust into more efficient utilizations. In 1966, Tyner and Tweeten conducted a study designed to determine "the optimum level and combination of resources in U.S. agriculture that would have (1) minimized the cost of production, and (2) made marginal value products for all resources equal to their earnings in alternate uses." (30, p. 287). In part, they concluded:

> Adjustment of farm resources [in 1952-61] to an equilibrium level, with all variable resources earning an opportunity cost return, would have entailed a reduction of 4.2 billion 1947-49 dollars, or 12.5 percent of the actual input volume. The cost of excess capacity was approximately $2.2 billion or 6.6 percent of the resource volume: the cost of a nonoptimal input mix was $2 billion, or 5.9 percent of the resource volume. (30, p. 303)

This seems to say that the resources actually committed to agricultural production could -- if combined efficiently -- have produced more than was actually produced. From the Tyner-Tweeten analysis, it would appear that the actual resources committed could have produced as much as 14.3 percent more than actual agricultural output. The influence of this adjustment upon the growth rate is not so clear. We conclude that an accurate adjustment would have reduced somewhat the discrepancy between the observed and the computed growth rate. In effect, we are arguing that the actual growth rate was a disequilibrium rate, for the reasons mentioned above.

For the marginal product of labor $\left(\frac{\partial \dot{Y}}{\partial A}\right)$, the computed value is much closer to the observed value. A discrepancy this large (or even larger) could be accounted for by disequilibria in labor use, except that improvements in the allocation of labor would presumably increase the observed value and also increase rather than reduce the discrepancy.

The largest discrepancy between the observed and computed values arises for the marginal product of land $\left(\frac{\partial \dot{Y}}{\partial L}\right)$, where the observed value is more than twice the computed value. Two major reasons can be suggested for this large discrepancy. First, changes in the selling prices for land include a great deal of "franchise value," or the capitalization into the land value of the value of the crop allotment attached to the land. For some crops, such as tobacco, the franchise value of the land is much higher than the opportunity value of identical land without a tobacco allotment.

The second reason is found in a previously noted characteristic of land-augmenting technology. The farmer using the services of some forms of land-augmenting technology does not bear their full cost. Examples are seeds of new, productive crop varieties, or improved disease, insect or weed control measures, or improved feed rations, particularly those produced under conditions of elastic supply. These increases in productivity, almost costless to the farmer, become embodied in the value of the land, as would any other increase in the "net product of land". Another example is development of gravity irrigation systems which provide water to the farmer at a charge less than the cost of producing the water (and less than the opportunity

value of the water). As before, this subsidy becomes capitalized into the value of the land.[15/]

Whether the discrepancy between observed and computed value of land is accounted for by the "franchise value" of acreage allotments, by the rapid growth in the availability of land-augmenting technology, and by irrigation and other subsidies is an important subject for further research. It is clear that other variables would be needed to make equation (21) useful as a predictor of the average value of farm land.

15/ In their study of changes in land prices, Herdt and Cochrane (17) obtained results that appear to be consistent with our hypothesis.