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AGRICULTURAL GROWTH IN DEVELOPING COUNTRIES AND AGRICULTURAL IMPORTS: ECONOMETRIC AND GENERAL EQUILIBRIUM ANALYSES

by

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1. The Possibility of Harmony of Interests Defined

During the 1960s and 1970s, the growth and welfare of U. S. agriculture became increasingly dependent on rapidly expanding foreign demand. The value of U. S. agricultural exports increased by an annual average of no less than 11.4 percent between 1960 and the peak value of export receipts in 1981. In that year, 63 percent of the production of wheat, 47 percent of that of soybeans, and 24 percent of that of corn was exported. With exports subsequently falling by an annual average of 9.7 percent between 1981 and 1986, it is no surprise that the current crisis in farm incomes and the exploding cost of farm support programs are largely due to the difficulty with farm exports.

Some of the determinants of falling export demand are policy instruments controlled by the United States, while others are exogenous. Among the first are the rising domestic loan rate and the exchange rate which, together, have been estimated to explain half of the fall in wheat exports between 1981 and 1983. Among the latter are the determinants of effective demand in the rest of the world, particularly per capita income, population, crop production, foreign exchange earnings, indebtedness, and the farm policy of, especially, the European Economic Community.

During the last 20 years, there has been a significant relocation of the origin of import demand for food and feed grains away from the more-developed countries (MDCs) and toward the centrally planned economies (CPEs), the oil-exporting and newly industrialized countries (NICs), and the less-developed countries (LDCs). As table 1 shows, between 1961-1963 and 1981-1983,

TABLE 1

Percent Distribution of Growth in Net Imports Between Geographical Areas, 1961-1963 to 1981-1983

Group	Total agricultural trade	Growth in imports of			
		Food grains[a]	Coarse grains[b]	Oilseeds[c]	Grains and oilseeds[d]
	percent				
Industrial market	24.60	3.34	23.00	43.60	19.15
Planned economies	23.49	33.68	28.19	16.83	33.63
Developing countries	51.91	62.99	48.81	39.56	47.21
Middle income	23.62	19.24	35.22	18.82	25.91
Low income	20.36	41.17	9.60	20.45	18.46
Oil exporters	7.93	2.58	3.99	0.29	2.84

[a]Includes wheat, wheat flour, and rice.

[b]Includes maize, barley, sorghum, and millet.

[c]Includes soybeans and groundnuts.

[d]Includes everything in footnotes a, b, and c.

Source: Shane, M. "Government Intervention, Financial Constraints, and the World Food Situation." U. S. Department of Agriculture, Economic Research Service, May, 1986 (mimeographed).

63 percent of the growth in net imports of food grains originated in the developing countries (DCs), of which 41 percent was in the low-income countries. For feed grains, 49 percent of the growth in net imports originated in the DCs, of which 35 percent was in the NICs. With unabated agricultural protectionism and saturation of demand in the MDCs, the future growth of food grain imports in those countries is likely to decline and that of feed grains to expand only modestly. Their share in U. S. agricultural exports has declined from 63 percent in 1961-1977 to 51 percent in 1982-1984, and it is expected to continue to decline in the future (McCalla). The CPEs are at income levels where the transition in consumption from direct food grains to animal products will sharply accelerate the demand for feed grain imports. The share of these countries in U. S. agricultural exports increased from 1.9 percent in 1965-1967 to 13.2 percent in 1984-85, but this share remains relatively modest and heavily loaded with political uncertainties.

It is the NICs and LDCs that have become the most significant sources of growth in import demand, increasing their share of U. S. exports from 35.1 percent in 1965-1967 to 40.4 percent in 1984-85. This is particularly true for food grains in the LDCs and feed grains in the NICs. Whether this growing demand will be sustained in the future depends crucially upon successful income growth and export performance in these countries. Consequently, there could exist a strong communality of interest between the U. S. farm sector and the Third World since the economic performance of the latter is an important source of effective demand creation for the former. As Mellor has argued, the strong income effects on food/feed demand created by successful economic growth in the Third World tend to outstrip the growth potential of agriculture in most of these countries and to create a rapid increase in demand for agricultural imports.

A key question is to identify the conditions for successful economic growth and for generation of foreign exchange that will allow DCs to satisfy rising food/feed demand through imports while insuring food security for their populations at nutritional risk.

Different growth strategies have been followed that have sustained a rapid growth in agricultural imports. The most evident are those with a strong component of industrial exorts (Singapore, Hong Kong, etc.), of cash crop exports (Ivory Coast), and of oil and primary-product exports (Venezuela, Saudi Arabia, etc.). Another growth path is explored in this paper, namely one that is based on a strong growth performance in food production based, in particular, on successful implementation of technological change. This is done for several reasons. One is that many countries do not have the possibility of developing their industrial exports at the stage of development at which they are without substantial additional industrial growth. For countries that do not have a strong primary export base or which do not benefit from large-scale international capital transfers, agricultural development is an important preconditon to industrial take-off.

Another reason is that recently there has emerged among U. S. farm lobbies a strong opposition to foreign assistance programs that aim at stimulating the production of food grains that compete with U. S. agricultural exports. Explored in this paper are the conditions under which there may, indeed, exist a conflict between aid and trade and the conditions under which there is not. The thesis is that there are ample opportunities for mutually beneficial agricultural development in the Third World and that this myopic Malthusian vision on the part of farm lobbies should be strongly opposed. The examples of Korea, Malaysia, Taiwan, and Thailand provide good illustrations of successful agricultural development sustaining a broad-based industrial growth which led to rapidly increasing demand for coarse grains and feedstuff imports. This approach to stimulating effective demand for U. S. agriculture is, however, not free of difficulties. Countries such as India have had successful technologial change in food grain agriculture but with little aggregate employment and income distribution effects, resulting in food self-sufficiency with continued extensive malnutrition. In all cases, substantial time lags are involved between successful technological change in agriculture and increased import demand resulting from the derived industrial growth, employment, and income effects with the likely possibility of short-run conflicts of interest between DC agricultural growth and U. S. agricultural exports even if the long-run payoffs may be substantial. Provided that MDC protectionism does not limit the exports by DCs of manufactured goods and cash crops (e.g., sugar) to their markets and provided that the United States does not price itself out of the market by high loan rates and high exchange rates or transform itself into an unreliable supplier by periodic imposition of politically motivated embargos, it will ultimately be able to benefit from successful agricultural development in the Third World. Following Paarlberg, it is also argued that a "broad based" pattern of rural development, as opposed to agricultural development with concentrated landownership and hired laborers under conditions of surplus labor, will support a larger long-run aggregate demand creation and import demand for coarse grains and feedstuffs.

This argument is developed in two steps. In the first, econometric analysis is used to show that most countries with successful agricultural growth have also been able to sustain rapid industrial growth and rapid growth of per capita income. The result in many situations has been to increase the demand for cereal imports, particulary feed grains in the NICs and the oil-exporting countries. This econometric model makes it possible to identify the levels of trade dependency and the composition of domestic agricultural growth that result in positive elasticities of import demand relative to agricultural growth. In the second step a two-sector, open-economy, general-equilibrium dynamic model is developed for archetype economies at different levels of GNP per capita to explore under what conditions and with what time lags technological change in cereal production (the Green Revolution) may create income effects that are sufficiently strong to increase the demand for food or feed grain imports. This model allows the identification of the parameter values that create this effect. It provides policy guidelines to design international aid programs complementary to technological change in food production that will allow the protection of grain export markets for the United States and other exporters. The paper concludes with recommendations as to how to maximize compatibility between foreign assistance programs and U. S. farm export interests.

2. Agriculture in Economic Development and Agricultural Imports: Economic Analysis

2.1 Agriculture as a Source of Industrial Growth

Although many countries have attempted to industrialize by taxing their agricultures, it is increasingly evident that this strategy has rarely resulted in sustained industrial growth as opposed to one that is based on strong agricultural growth. Other important determinants of industrial growth are the growth of exports, part of which may be agricultural, and the ability to contain inflationary pressures (Hwa). The growth of agriculture can be expected to stimulate industrial growth through a variety of mechanisms that include (1) the release of agricultural labor for industrial employment, which is relevant if there is labor scarcity (Jorgenson); (2) the lowering of food prices and, hence, of nominal wages and of the price of raw materials for industry (Lele and Mellor); (3) the freeing of foreign exchange by import substitution or the generation of foreign exchange through agricultural exports; (4) the generation of intermediate and final demand for industrial products (Adelman); and (5) the transfer of agricultural savings and rents for investment in the rest of the economy.

This relation between agricultural growth and industrial growth is confirmed by analyzing the determinants of manufacturing growth cross-nationally using estimated annual growth rates for 60 DCs between 1970 and 1980.[1] Countries are also split into two groups with gross national product per capital (GNPPC) below and above $600 in 1965. The estimated equations are

$$\dot{I} = \alpha_0 + \alpha_1 \dot{A} + \alpha_2 \dot{X} + \alpha_3 \dot{P},$$

where

$\dot{I}$ = growth rate of manufacturing

$\dot{A}$ = growth rate of agriculture

$\dot{X}$ = growth rate of total exports

$\dot{P}$ = inflation rate.

The results are as follows:[2]

All countries n = 60	$\dot{I} = \underset{(3.81)}{2.93} + \underset{(3.76)}{0.82\dot{A}} + \underset{(4.51)}{0.41\dot{X}} - \underset{(-3.10)}{0.05\dot{P}}, \; R^2 = .64$
GNPPC < \$600 n = 37	$\dot{I} = \underset{(1.61)}{2.91} + \underset{(2.69)}{0.94\dot{A}} + \underset{(1.95)}{0.34\dot{X}} - \underset{(-.78)}{0.08\dot{P}}, \; R^2 = .60$
GNPPC $\geq$ \$600 n = 23	$\dot{I} = \underset{(3.08)}{4.19} + \underset{(1.71)}{0.56\dot{A}} + \underset{(4.25)}{0.43\dot{X}} - \underset{(-3.85)}{0.06\dot{P}}, \; R^2 = .66.$

They show that the growth of agriculture is a significant determinant of manufacturing growth and this particularly in the poorer countries where the share of agriculture in gross domestic product (GDP) is larger. Export growth and the ability to control inflationary pressures are also important determinants of successful industrialization.

While it is clear that, over the long run, agricultural growth is itself supported by industrial growth, we establish the short-run direction of causality running from agricultural to industrial growth by using time series data between 1960 and 1981 for 42 countries for which complete information is available in The World Bank Tape of Economic Indicators. The estimated equation in table 2 is between the logarithm of manufacturing output as the dependent variable and the logarithms of agricultural and mining outputs lagged one year as the predetermined variables. The results show that 76 percent of the countries have significantly positive elasticities of manufacturing output with respect to lagged agricultural production. Among these, the average value of this elasticity is 1.38.

2.2. Patterns of Agricultural Growth and Imports

Table 3 shows the classification of the 60 DCs for which information is available between 1970 and 1980 according to two criteria: the rate of per capita

TABLE 2

Elasticity of Manufacturing Output With Respect to Lagged Agricultural Output for 42 Countries, 1960-1981[a/]

Elasticity[b/]	Number of countries	Average value of elasticity
Not significantly different from zero[c/]	10	0.25
0-1	7	0.78
1-2	23	1.39
2+	2	3.29

a/ These are the 42 countries for which complete time series data for 1960-1981 are available in The World Bank Tape of Economic Indicators.

b/ Estimated in regression: Log (manufacturing output) = a + b log (agricultural output lagged one year) + c log (mining output lagged one year) using the Cochrane-Orcutt procedure to correct for autocorrelation when needed.

c/ $t \leq 1.70$.

TABLE 3

Country Classification by Agricultural and Income Growth, 1970-1980

Growth of agricultural output per capita ≤ 0

1970-1980	Growth of gross domestic product per capita < 2 percent			Growth of gross domestic product per capita > 2 percent		
	Indicator[a]	All other countries[b]	India	Indicator[a]	All other countries[c]	Uruguay
Growth of agricultural output per capita ≤ 0	$\dot{Pop}$	2.7	2.1	$\dot{Pop}$	3.0	0.3
	$\dot{I}$	2.0	4.5	$\dot{I}$	8.3	5.2
	$\dot{X}$	-0.7	3.7	$\dot{X}$	5.6	4.8
	$\dot{P}$	14.9	8.5	$\dot{P}$	14.7	62.3
	$\dot{U}$	5.5	3.3	$\dot{U}$	4.7	0.6
	$W\dot{M}$	4.6	-29.2	$W\dot{M}$	17.3	29.0
	$Co\dot{M}$	22.9	0.0	$Co\dot{M}$	27.9	75.7
	$Ce\dot{M}$	5.2	-24.5	$Ce\dot{M}$	19.5	35.1
	Aid	36.8	35.7	Aid	1.6	0.0

Growth of agricultural output per capita > 0

1970-1980	Growth of gross domestic product per capita < 2 percent			Growth of gross domestic product per capita > 2 percent		
	Indicator[a]	High-income countries[d]	Low-income countries[e]	Indicator[a]	High-income countries[f]	Low-income countries[g]
Growth of agricultural output per capita > 0	$\dot{Pop}$	2.2	2.7	$\dot{Pop}$	2.5	2.4
	$\dot{I}$	1.7	1.5	$\dot{I}$	9.2	4.7
	$\dot{X}$	4.5	1.7	$\dot{X}$	6.4	2.3
	$\dot{P}$	109.5	9.8	$\dot{P}$	14.2	13.2
	U	2.9	4.8	$\dot{U}$	4.4	4.9
	$W\dot{M}$	5.0	3.0	$W\dot{M}$	8.1	3.3
	$Co\dot{M}$	28.1	31.7	$Co\dot{M}$	31.2	-19.3
	$Ce\dot{M}$	9.0	4.4	$Ce\dot{M}$	9.7	0.5
	Aid	5.2	21.4	Aid	12.1	29.1

[a] Annual growth rate of population ($\dot{Pop}$), of manufacturing ($\dot{I}$), of total exports ($\dot{X}$), of prices ($\dot{P}$), of urbanization ($\dot{U}$), of imports of wheat ($W\dot{M}$), of imports of corn ($Co\dot{M}$), of imports of cereal ($Ce\dot{M}$), and share of aid in total imports of cereal (Aid).

[b] Chad, Angola, Mozambique, Uganda, Ghana, Zaire, Zambia, Madagascar, Sierra Leone, Mauritania, Niger, Ethiopia, Congo, Togo, Sudan, Ivory Coast, Burkina Faso, Bangladesh, India, and Pakistan.

[c] Mexico, Algeria, Nigeria, Ecuador, Morocco, and Uruguay.

[d] Argentina, Chile, and Venezuela.

[e] Central African Republic, Somalia, Liberia, and Senegal.

[f] Korea, Brazil, Indonesia, Malaysia, Philippines, Thailand, Egypt, Tunisia, Kenya, Cameroon, Syria, Guatemala, Dominican Republic, Colombia, and Paraguay.

[g] Bolivia, Malawi, Mali, Burma, and Sri Lanka.

agricultural growth (countries with negative and positive growth rates) and the rate of growth in the gross domestic product per capita (GDPPC) (countries below and above 2 percent). Most countries fall on the first diagonal of the table indicating that there indeed exists a strong correlation between agricultural and economic growth. The four clusters of countries which this creates correspond to sharply contrasted economic performances with resulting differential demands for cereal imports.

Countries with negative agricultural growth per capita and low per capita income growth are basically the African countries and the populous Asian countries. We place India apart from the others because of her successful drive to achieve food self-sufficiency and reduce food imports sharply. The other countries all display high rates of urbanization, a poor industrial performance, and failing exports. Cereal imports have grown at an average annual rate of 5.2 percent, more than a third of it obtained through international aid (Huddleston).

Cases with high rates of agricultural growth and low income growth are few and relatively uninteresting since, like Chile, they usually correspond to instances of political failure stifling economic growth.

Countries with poor agricultural performance but high rates of income growth are, with the exception of Uruguay, exporters of oil and gas (Mexico, Nigeria, Algeria, and Ecuador) or phosphates (Morocco). They have high rates of industrial and export growth. Cereal imports are booming, both for food grains (17.3 percent) because of failures of their own agriculture and for feed grains (27.9 percent) because of strong income and urbanization effects. These countries thus provide rapidly expanding markets for food and feed exports but are numerically few and unstable owing to fluctuations in international commodity markets.

The most interesting group, from our standpoint, is composed of countries with strong agricultural and income performances. The high-income countries in that group display the highest rates of industrial and export growth. Although the performance of agriculture is strong, cereal imports are growing rapidly (9.7 percent annually), particularly those of feed for animal consumption (31.2 percent). This group of countries includes principally the NICs and a few countries with strong agriculture and primary-export bases.

2.3. Determinants of Import Demand

To establish the impact of agricultural growth on import demand, an economic model based on observed growth rates between 1970 and 1980 for 60 LDCs is constructed as follows:

$$\mathring{I} = \alpha_0 + \alpha_1 \mathring{A} + \alpha_2 \mathring{X} + \alpha_3 \mathring{P} \qquad \text{growth rate of manufacturing}$$

$$\mathring{Y} = \beta_0 + \beta_1 \mathring{A} + \beta_2 \mathring{I} \qquad \text{income equation}$$

$$\mathring{C}_i = \delta_{0i} + \delta_{1i} \mathring{Y} + \delta_{2i} \mathring{U} + \delta_{3i} \mathring{Pop} \qquad \text{consumption function}$$

$$\mathring{M}_i = \frac{C_i}{M_i} \mathring{C}_i - \frac{Q_i}{M_i} \varepsilon_i \mathring{A} \qquad \text{import equation for product i,}$$

where

$$\varepsilon_i = \frac{\mathring{Q}_i}{\mathring{A}} \qquad \text{agricultural growth structure equation.}$$

From this, we derive the elasticity of import demand for product i with respect to agricultural growth:

$$\frac{\partial \dot{M}_i}{\partial \dot{A}} = \varepsilon_i + \frac{\Theta_i - \varepsilon_i}{D_i},$$

where

$\Theta_i = \delta_{1i}(\beta_1 + \alpha_1 \beta_2) = \frac{\partial \dot{C}_i}{\partial \dot{A}}$ elasticity of consumption with respect to agricultural output

$D_i = \frac{M_i}{C_i}$ dependency ratio for product i

and

$\dot{Y}$ = growth rate of GDP

$\dot{C}_i$ = growth rate of consumption of agricultural product i

$\dot{U}$ = growth rate of urbanization

$\dot{Pop}$ = growth rate of population

$\dot{Q}_i$ = growth rate of output of agricultural product i

$\dot{M}_i$ = growth rate of net imports of agricultural product i.

The growth rates of I, A, X, P, Y, C_i, U, Pop, and Q_i are estimated by loglinear regression over the period 1970-1980.

Table 4 shows the estimated parameters of the model for all 60 countries as well as for the LDCs (GDPPC less than $600 in 1965) and NICs (GDPPC above $600). The elasticities of manufacturing output with respect to agricultural output and of consumption with respect to income are highly significant. The derived elasticity of consumption with respect to output is high for wheat in the LDCs and for corn (feed) in the NICs.

TABLE 4

Parameters, 1970-1980

Gross domestic product per capita	Number of countries	α_1	β_1	β_2	δ_{1i}			Θ_i			ε_i		
					Cereals	Wheat	Corn	Cereals	Wheat	Corn	Cereals	Wheat	Corn
dollars, U. S.													
<600	37	.94[a]	.56[a]	.31	.26[a]	1.01[a]	.27	.22	.86	.23	1.20	1.43	1.39
>600	23	.56[a]	.50[a]	.46	.35[a]	.36	1.34[a]	.26	.27	1.01	1.62	-.35	1.24
All	60	.82[a]	.53[a]	.37	.33[a]	.80[a]	.93[a]	.28	.67	.78	1.33	.79	.78

[a]Significant at the 95 percent confidence level.

Whether the resulting elasticity of import demand with respect to agriculture is positive or negative depends on Θ_i but also on the level of dependency ($D_i = M_i/C_i$) and on the structure of agricultural growth (ε_i), namely the growth rate of product i relative to that of agriculture in general. Table 5 shows the frontier of compatibility of interest between agricultural growth (LDC interests) and growth of import demand (U. S. interests). Compatibility exists for cereals in 27 percent of the countries, for wheat in 90 percent, and for corn in 48 percent. In the case of wheat, compatibility is dominated by the African countries which are, in general, not producers of wheat themselves. In the case of corn, it is dominated by the NICs due to strong income effects and shifting consumption patterns towards meat products.

The most interesting cases are the countries that had positive growth of agricultural output per capita and high growth of per capita GNP in Table 3, nonnegative growth rates of product i relative to the growth rate of agriculture (ε_i) in Table 5, and positive elasticities of import demand with respect to agricultural growth. They include Korea (cereals and corn), Brazil (wheat and corn), Malaysia (cereals and corn), Egypt (wheat), Tunisia (cereals and corn), Kenya (wheat), Guatemala (wheat), Colombia (corn), and Paraguay (wheat). These success stories combine strong agricultural growth, strong economic growth, and growing agricultural imports in specific cereals in spite of the fact that the output of these cereals has grown at a rate at least equal to the overall growth rate of agriculture.

TABLE 5

Elasticities of Import Demand with Respect to Agricultural Growth, All Countries[a/]

D_i \ ε_i	≤ -2.0	-1.5	-1.0	-.5	0	.5	1.0	1.5	≥2.0
Cereals, θ_i = .28									
.1	Chad 20.80	16.30	Uganda 11.80	7.30	2.80	Kenya -1.70	Indonesia -6.20	India -10.70	Nigeria -15.20
.25	7.12	Morocco 5.62	4.12	2.62	Korea 1.12	Brazil -.38	Colombia -1.88	Pakistan -3.38	Ivory Coast -4.88
.50	2.56	Egypt 2.06	1.56	Algeria 1.06	Malaysia .56	Tunisia .06	Senegal -.44	-.94	Venezuela -1.44
.75	1.04	.87	.71	.54	.37	.21	0.04	-.13	Mauritania -.29
.90	.53	.48	.42	.37	.31	.26	.20	.14	Jamaica .09
1.00	.28	.28	.28	.28	.28	.28	.28	.28	.28
Wheat, θ_i = .67									
.1	Ethiopia 24.70	20.20	15.70	11.20	6.70	2.20	-2.30	-6.80	India -11.30
.25	8.68	7.18	5.68	4.18	2.68	Kenya 1.18	Syria -.32	Mexico -1.82	Burma -3.32
.50	3.34	Morocco 2.84	Chile 2.34	Algeria 1.84	1.34	Paraguay .84	Brazil .34	-.16	Sudan -.66
.75	Ecuador 1.56	1.39	1.23	Bolivia 1.06	.89	.73	Guatemala .56	.39	Egypt .23
.90	Korea .97	Niger .91	Colombia .86	.80	.74	Angola .69	.63	Zambia .58	Nigeria .52
1.00	.67	.67	.67	.67	Sahel .67	.67	.67	.67	.67
Corn, θ_i = .78									
.1	Chad 25.80	21.80	Ecuador 16.80	Morocco 12.30	Colombia 7.80	Brazil 3.30	Indonesia -1.20	El Salvador -5.70	Ivory Coast -10.20
.25	Niger 9.12	7.62	6.12	4.62	3.12	Mexico 1.62	.12	Panama -1.38	Egypt -2.88
.50	3.56	3.06	2.56	Dominican Republic 2.06	1.56	Venezuela 1.06	.56	.06	Syria -.44
.75	1.71	1.54	1.37	1.21	1.04	.87	.71	.54	.37
.90	1.09	1.03	.98	.92	.87	Malaysia .81	.76	.70	Korea .64
1.00	.78	.78	.78	.78	Tunisia .78	.78	.78	.78	.78

a/ θ_i = elasticity of consumption of product i with respect to agricultural output, ε_i = growth rate of product i relative to growth rate of agriculture, and D_i = dependency ratio for product i (imports over consumption).

3. Impact of Technological Change on Cereal Imports: Simulation Models

3.1. General-Equilibrium Open-Economy Archetype Models

To explore further the location of the harmony frontier between agricultural growth in DCs and demand for food- or feed grain imports, the temporal dimension must be added and the role of specific technological and structural parameters must be identified. To do this, a dynamic two-sector model is constructed for several archetype developing economies at different levels of GNP per capita, and the impact of land-saving technological change in agriculture on the demand for food- and feed-grain imports is studied. The equations of the model are given in Appendix 1, and the parameter values for three archetype economies are given in Appendix 2. The model incorporates a number of features taken from Lele and Mellor. Both that model and the model in this paper trace out the growth effects of technological change in food grains, but the causal logics are markedly different. In the former, the causal linkage is through lower food prices and lower nominal wages in a closed economy; in the latter, it is through foreign exchange savings and higher import of capital goods.

The agricultural sector produces with two inputs, land and labor. Land is in fixed quantity, and there is surplus labor. Employment is determined by equating marginal productivity with a fixed real wage. Unemployment (or underemployment) in the economy is located in the agricultural sector, and the income earned by employed agricultural workers is shared in the agricultural population. Per capita income in agriculture is thus a direct function of the rate of employment.

Inputs in the nonagricultural sector are labor and an aggregate capital stock made of imperfectly substitutable domestic and imported capital goods. Imported capital goods are more productive than domestic capital goods, and the productivity of the stock of capital increases with its size.[3] Workers are employed at a wage rate which differs from per capita income in agriculture by an additive constant.

Consumption behavior for cereals and meat is specified for each of the four social classes (workers and landlords in agriculture and workers and capitalists in nonagriculture) by an income share and an income elasticity. Price elasticities are irrelevant because prices are constant in this open economy. Total grain demand is made up of direct food grain consumption and derived demand for feed grains. Net imports of grains, calculated from the difference between domestic production and demand, require that a certain proportion of industrial production be exported to generate the needed foreign exchange.

The dynamics of the model is confined to the only impact of a one-time technological change in agriculture. Therefore, the dynamic path it generates should be compared to a steady-state reference path in which the base-year situation is repeated throughout the years.

In the first period, technological change increases land productivity and thus agricultural production, which stays constant at that higher level from then on. The foreign exchange saved in each period after satisfying the demand for food and feed imports is used to import capital goods that increase the stock of capital in the nonagricultural sector and production in the next period. This use of foreign exchange savings is based on the assumption that, of the two gaps (foreign exchange and domestic savings) which potentially constrain economic growth, the former is the effective one.

Empirical values in the model typify three economies at different levels of economic development, very low, low, and medium income. The low-income economy corresponds to the higher half of the World Bank low-income group with a GNP per capita of $250 to $400 in 1983 which includes India, China, Sri Lanka, Pakistan, Kenya, and the Sudan. The very low-income group corresponds to the lower half of the World Bank low-income group with a GNP per capita of between $120 and $250. It includes countries such as Bangladesh, Nepal, Burma, Ethiopia, and Tanzania. Finally, the middle-income countries have a GNP per capita of between $500 and $1,000 and include Indonesia, the Philippines, Thailand, Egypt, Morocco, and El Salvador. The structural characteristics and parameter values for each of these three archetype economies are given in Appendix 2. They are derived inasmuch as possible from average observed values for these three groups of countries.

3.2 Simulation of Time Path

Table 6 gives indicators of growth, income distribution, the structure of consumption, and the structure of imports associated with the base run and a number of alternative experiments.

Technological change is represented by a 15 percent increase in land productivity. Since the reference path is a steady state with growth of neither population nor capital, this change should be understood as an increase in per capita production. If it is spread over 10 years, a 15 percent increase corresponds to an average annual growth rate of 1.4 percent, which is a median value for the countries with successful agriculture during the 1970s. Indeed,

TABLE 6

Results of 10-Year Simulations

Experiments	Cumulated growth rates: Gross national product	Nonagricultural employment	Agricultural workers' per capita income	Nonagricultural workers' wage	Nonagricultural inequality a/	Workers' average income	Consumption: Food	Consumption: Feed	Food in consumption increase	Elasticity of agricultural consumption with respect to: Agricultural production	Elasticity of agricultural consumption with respect to: Gross national product	t_M b/
	percent											years
Low-income countries												
1. Base run	18.8	9.5	20.6	10.3	9.5	17.8	8.6	25.9	50.5	.86	.68	8.2
2. Capital bias	18.8	-5.2	18.0	9.0	11.4	14.9	7.4	25.9	46.7	.80	.63	10.0
3. Labor bias	18.6	12.9	22.8	11.4	5.0	20.3	9.6	25.8	53.4	.91	.73	6.9
4. Imported capital, less productive	16.5	7.1	19.1	9.6	7.1	16.1	7.9	22.7	51.7	.77	.70	> 10.0
5. Imported capital, more productive	20.5	11.2	21.7	10.9	11.2	19.1	9.1	28.4	49.7	.92	.67	6.9
6. Peasant agriculture	17.9	6.9	18.9	11.8	6.8	16.9	8.6	25.9	53.4	.83	.69	8.0
Very low-income countries	17.9	10.8	18.2	9.1	10.8	17.0	12.1	29.9	71.4	.97	.81	7.1
Middle-income countries	15.8	5.3	20.3	10.1	5.3	15.6	6.1	19.5	27.5	.81	.77	9.2

a/ Defined by the ratio of per capita income of capitalists and workers.

b/ Time at which agricultural imports are equal to initial value.

among the 60 countries studied (table 3), 32 experienced a negative growth rate of per capita agricultural production, 9 had a growth rate of between 0 percent and 1 percent per year, 10 had a growth rate of between 1 percent and 2 percent per year, and 9 had a growth rate of more than 2 percent per year. Only 23 percent had a growth rate superior to that simulated here.

In this first series of experiments, technological change is assumed to occur quickly and is represented as a one-time change in land productivity in the first year. This generates employment in agriculture, a reduction in total unemployment, and thus an increase in per capita income. The cost of labor in nonagriculture, which has to keep in line with rural per capita income, increases and induces a loss of employment and a reduction in non-agricultural production in the first year.

Parameter t_M is the time at which cereal imports are back to their initial level before agricultural technological change took place. It locates in time the frontier of harmony between DC agricultural development and U. S. agricultural export interests. Key parameters to the growth process and the location of this frontier are the share of labor in value added in the non-agricultural sector, the productivity of imported capital goods, the structure of landownership, and the size of the agricultural sector in the economy.

Agricultural imports decrease dramatically in the first year both because the shift of unemployed industrial workers back to the rural lower income group partially compensates for the higher level of agricultural employment and because of the increase in agricultural production. The result is that only 30 percent of the incremental agricultural output is consumed while 70 percent is exported. The foreign exchange saved from lower cereal imports is used to import capital goods which, in the following years, enhance nonagricultural production, reduce unemployment, and raise the per capita income of workers in both sectors.

This growth process is somewhat slowed down by two mechanisms: The rate of employment growth is reduced by an increasing labor cost brought about by the reduction of unemployment itself, and import savings are reduced by increasing consumption induced by increasing incomes. However, foreign exchange availability has been increased by nonagricultural growth and exports. The result is that the initial momentum given by the release of foreign exchange from decreased food imports is sustained even after the agricultural balance of trade has again reached its initial value.

This base-run path is represented in figure 1. It illustrates the importance of the time scale in appraising the impact of technological change in agriculture on agricultural imports. In this case, agricultural imports return to their initial level eight years after the occurrence of technological change in agriculture.

In the base run, the share of labor is kept at 40 percent of value added, which implies that an increase in labor cost is compensated by lower employment. Consumption increases with both higher income within classes and a shift of agricultural workers to higher paid nonagricultural jobs. Feed consumption increases with income more than food consumption and, after 10 years, accounts for almost half of incremental consumption when it represents only 25 percent of total cereal consumption in the base year.

Comparison of experiments 2 and 3 with the base run shows the key role of employment policy. If, in the industrialization process, labor loses its share from only 40 percent to 38 percent of value added in 10 years (capital bias), growth is somewhat faster but inequality increases dramatically.

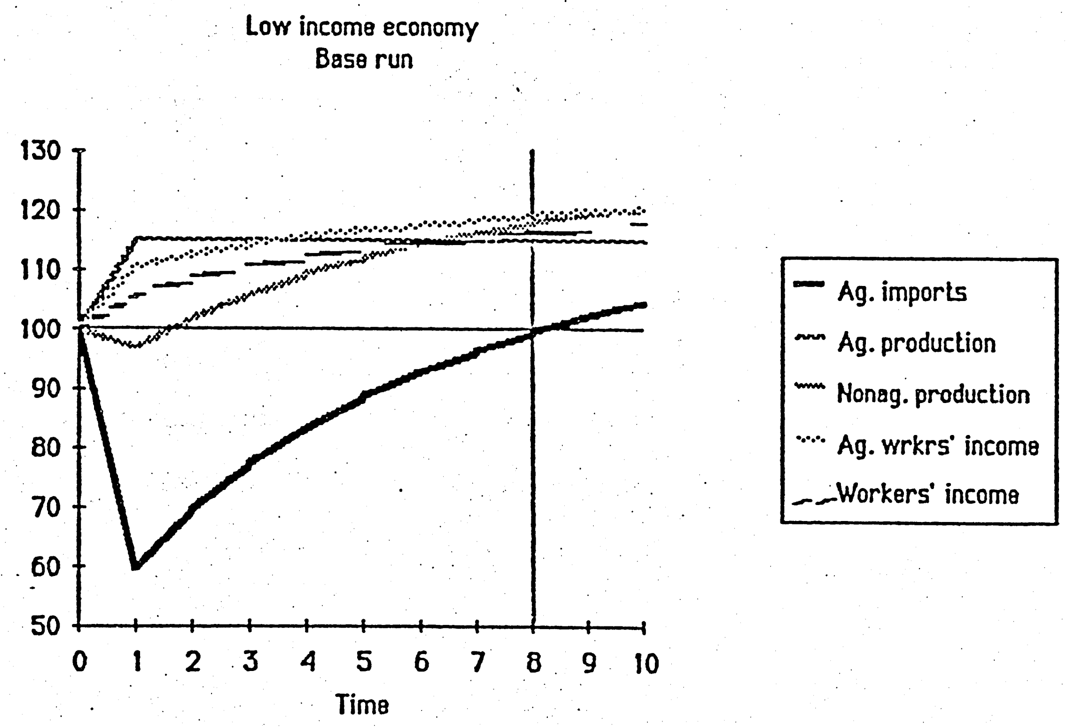


Figure 1. Base-run path

Workers lose from both reduced employment and lower wages. With this structural change in income distribution, food consumption increases less rapidly, and feed accounts for 53 percent of the total increase in grain consumption. The overall increase in grain consumption is, however, slower, and t_M is retarded to 9.7 years.

Conversely, a labor-intensive industrialization with the share of labor increasing to 42 percent of the value added in 10 years reduces slightly the overall growth but increases equality. The shift of income distribution towards workers induces higher food consumption, which now accounts for 53 percent of the total cereal consumption increase. This more equitable growth path accelerates the growth of imports, and t_M is brought forward to only 6.9 years.

In experiments 4 and 5, the relative productivity of imported capital goods is, respectively, decreased and increased. If the imported capital goods are not used in highly productive industries, release of the foreign exchange constraint by technological change in agriculture does not stimulate the economy. Income, consumption, and import needs all grow more slowly. Conversely, an industrialization process that makes a more efficient use of the foreign exchange released accelerates income growth, increases consumption and the shift to meat consumption, and brings forward the harmony frontier.

Another aspect of the role of income distribution in these growth strategies is illustrated by simulating the impact of technological change in agriculture when it is organized on a family farm basis. In this case, there is no landlord class and all agricultural income (rather than 80 percent) goes to the labor force. Paarlberg and others have, indeed, argued that a "broad based" pattern of agricultural development is more likely to harmonize agricultural development in the Third World and U. S. export interests because it enhances cereal consumption. The results in this paper do show that, compared to the base run, rural development results in a slightly lower overall growth but in a more equal distribution of income. Elasticities of grain consumption, both food and feed, with respect to GNP and agricultural growth, are higher, and the harmony frontier is brought forward. While the qualitative results are instructive, the order of magnitude in changes relative to the base run is small since, in the original economy, landlords captured only a small share of the product as rent.

The impact of technological change in agriculture is different in countries at different levels of per capita income. A key factor explaining these differences is the size of the agricultural sector. In a very low-income country where agriculture accounts for 50 percent of GNP, a 15 percent increase in agricultural production has a larger growth effect than in a middle-income country where agriculture is only 25 percent of GNP. This is reinforced by the fact that the capital-output ratio is also lower in the very low-income country, so the same amount of foreign exchange has a stronger growth effect. The increase in capital productivity is, however, higher at a higher level of development. The net effect is that it is the low-income countries which benefit the most from technological change in agriculture (a growth in GNP of 18.8 percent), followed by the very low-income countries (17.9 percent).

It is also in the low-income countries that the aggregate elasticity of consumption for food and feed grains with respect to income is the lowest (0.68). This is because, in the very low-income countries, a large segment of the population essentially relies on food grains for direct consumption with a high income elasticity (close to one). In the middle-income countries, the share of meat in consumption has increased. Since it has an income elasticity greater than one, the aggregate elasticity for cereals is high again (.77).

Combination of the rate of economic growth and the income elasticity of cereal consumption determines the import needs and the time (t_M) at which imports are back to their original level. With fairly high growth and income elasticty of consumption, the very low-income countries are the first to absorb completely the increased production (7.1 years), followed by the low-income (8.2) and the middle-income countries (9.2).

In terms of volumes of imports, as opposed to growth rates, it is in the middle-income countries that the impact is the greatest. The increase in cereal consumption during the 10-year period more than doubled in the middle-income, as opposed to the low- and very low-income, countries. Compatibility of interests between DC agricultural development and U. S. exports thus is at a peak in the middle-income countries. In those countries, the agricultural sector is still sufficiently large to allow technical change to enhance economic growth, and the aggregate income elasticity is very high due to transition to meat consumption.

The impact of the level of technological change is twofold. On the one hand, higher productivity growth releases more foreign exchange and induces a higher growth of the economy, although with a decreasing elasticity, and higher increases in income and consumption. On the other hand, higher growth in cereal production displaces a higher volume of imports. The overall effect is that the time, t_M, at which agricultural imports are back to their original level increases with the level of productivity growth (figure 2), but the absolute level of imports after 10 years reaches a peak for a one-time productivity growth of 10 percent.

The issue of the length of time over which the diffusion process takes place is illustrated by figure 3. For a given 15 percent increase in per capita agricultural output, the impact on the economy is far greater if this technological change is implemented rapidly. At one extreme, when it is completely done in the first year, maximum foreign exchange is freed and nonagricultural growth is induced, which itself adds to the momentum for further growth. At the other extreme, a steady growth of 1.4 percent per year over 10 years does not give enough acceleration to nonagricultural growth and to overall income for consumption increase to catch up with production increase. Agricultural imports decrease regularly over the 10 years and can only stabilize and start to grow again when the diffusion process has been completed. In figure 3, t_M^* represents the year in which imports start to grow again.

We conclude, therefore, that, while there is a short-run conflict of interest between DC agricultural development and U. S. export interests, this conflict is resolved in the medium run when t_M is reached. Maximum compatibility is reached for an average growth in productivity which induces enough growth of the whole economy without sufficiently satisfying the consumption needs of the population. For agricultural productivity growth to generate enough acceleration to the nonagricultural sector and, thus, to reconcile domestic growth and U. S. exports, the diffusion process has to be rapid. More importantly, significant increases in import demand can be achieved in the long run when very low-income and low-income countries are transformed into middle-income countries--in large part under the impetus of successful technological change in agriculture.

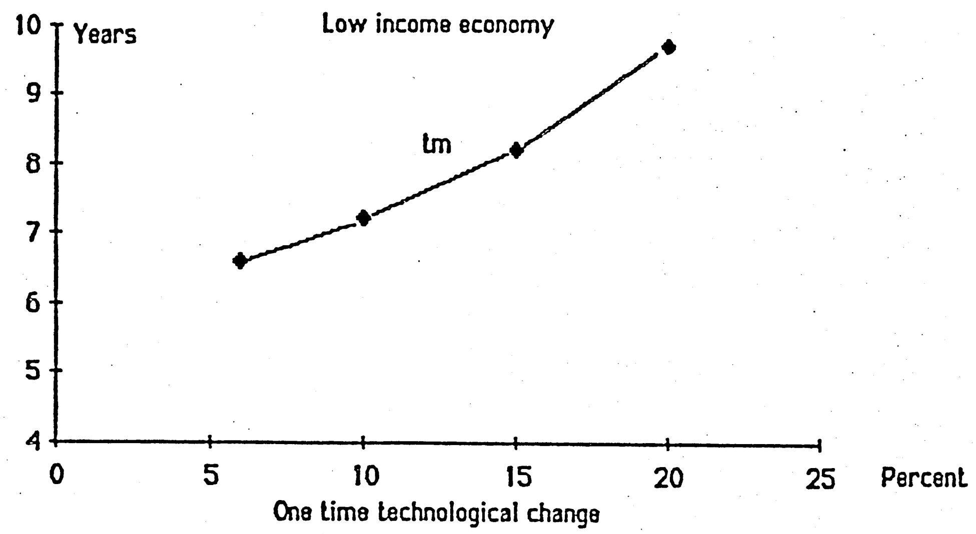
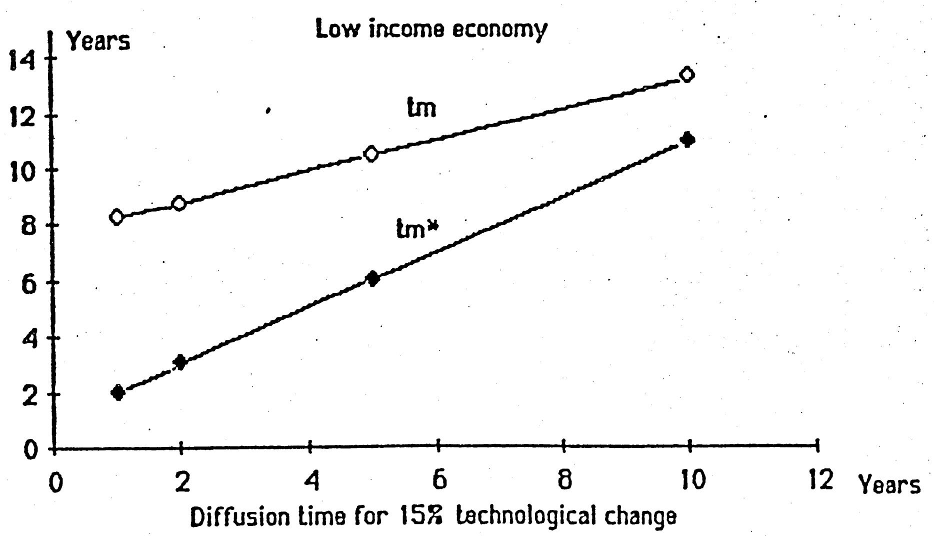


Figure 2- tm as a function of the intensity of technological change



tm* time at which imports starts to increase

Figure 3- tm and tm* as functions of the diffusion time of technological change

4. Conclusion

Rapid income growth in DCs has been identified as the most important potential source of increased demand for U. S. agricultural exports. While this is obvious for situations where the leading sectors of economic growth are export oriented (primary products, cash crops, or industry), claims have also been made that it could be achieved by a strong growth performance in food production induced, in particular, by diffusion of land-saving technological change. If this is the case, international assistance to food production in the DCs would be compatible with the promotion of U. S. exports of food and feed grains. We call the "frontier of harmony" the limiting conditions under which this compatibility of interests exists. The purpose of this paper was to explore the location of this frontier and the policy instruments that can enlarge the area where harmony prevails.

We approached this problem through both intercountry econometric analysis and simulation analysis in archetype general-equilibrium models. The first gives the long-run structural determinants of the location of the frontier while the second gives the short-run time dimension and the role of specific technological and distributional parameters.

The main conclusion is that harmony of interests is not automatic. It can, indeed, prevail in many, but far from all, situations; and there exist a number of policy instruments that can be used to enhance the chance of harmony. This provides us with guidelines to enhance the consistency between foreign assistance (U. S. Agency for International Development) and export-promotion (U. S. Department of Agriculture) programs.

Across countries and over time, the analysis has identified a number of determinants of a larger elasticity of cereal imports with respect to agricultural production. They include:

1. A lower elasticity of cereal output with respect to agricultural production (ε). This is particularly evident for wheat in the tropical countries as well as for countries that have implemented cheap food policies toward the cereals sector.

2. A higher level of cereal dependency (D). This is, again, most visible for the African countries in wheat and for the Asian NICs in corn.

3. A higher elasticity of industrial growth with respect to agricultural growth (α_1). This depends on the strength of the different contributions of agriculture to industrial growth: foreign exchange generation, lower wage-food prices, intermediate and final demand effects, and savings-investment effects. This elasticity is higher in the low-income developing economies because of the sheer size of the agricultural sector in the economy.

4. A higher elasticity of consumption with respect to income (δ_{1i}). While the income elasticities of both food and feed grains decrease with income, the latter is much larger than the former, and the aggregate elasticity of cereal consumption first decreases and then increases with income. Expectedly, the area of harmony is, thus, greater for wheat in the low-income countries and for corn in the medium-income countries. More progressive patterns of income distribution and, in particular, a more egalitarian land-tenure system increase total consumption of food/feed imports at a given level of per capita income. Promoting a broad-based pattern of rural development is thus more amenable to harmony of interests than one with landlords and wage labor.

5. A higher share of labor in total output. While the rate of economic growth is lower, food/feed imports are higher. Policies that stimulate employment creation and increase the share of labor are, therefore, important to increase the likelihood of harmony of interests.

6. A more productive use (Π) of imported capital. In this case, the import multiplier is larger, and import substitution in agriculture has higher growth and income effects.

7. A technological change in agriculture that is happening more rapidly. This allows the benefits of greater availability of foreign exchange to create strong growth and income effects, restoring the balance of agricultural trade to its initial level within 10 years even with one-time technological changes that reach 20 percent and more. By contrast, a slow but continuous pace of technological change postpones growth effects and prevents restoring the balance of cereal imports. Programs of technological assistance to Third World agriculture should, therefore, attempt to concentrate their impact over a short period of time.

This analysis showed that there do exist short-run conflicts of interest between technological programs in DC agriculture and U. S. farm exports. Foreign assistance to that agriculture must be seen with a medium- and long-run perspective of mutual gains. In the medium run, the growth and income effects created by agricultural growth eventually increase food/feed imports after the threshold t_M. In the long run, successful agricultural development in the very low- and low-income countries increases the level of cereal imports per capita, particularly of feed, as these countries reach the middle-income status. It is important to recall that successful agricultural growth increases total import demand even if it decreases the demand for agricultural imports. Technological change in agriculture thus always generates gains from trade which are partially captured by the nonagricultural exporting sectors of other nations.

The results have shown that harmony can indeed exist between DC agricultural development and U. S. export interests. The situations of harmony identified in this paper would probably be further extended when derived from a model that accounts for intermediate and final demand effects and for sources of economic growth additional to technological change in agriculture.

Appendix 1

Model Equations

1. Static Relations (time argument omitted)

For $i = A, NA$ agricultural (food and feed grains) and nonagricultural sectors

$k = F, M$ food grains and meat

Production

$$X_i = a_i L_i^{\lambda_i} (t_{Ki} K_i)^{1-\lambda_i}$$

or

$$X_i = a_i \left[\lambda_i L_i^{-\rho_i} + (1 - \lambda_i)(t_{Ki} K_i)^{-\rho_i}\right]^{-1/\rho_i} \text{ with } \rho_i = (1/\sigma_i) - 1$$

Capital Aggregation

$$K_{NA} = b[\mu KM^{-\rho^*} + (1 - \mu) KD^{-\rho^*}]^{-1/\rho^*} \text{ with } \rho^* = (1/\sigma^*) - 1$$

Technological Change

$$t_{K,NA} = t_0 K_{NA}^{\varepsilon}$$

$$t_{K,A} = \bar{t}_{K,A}$$

Labor demand

$$\partial X_i / \partial L_i = w_i$$

Wages

$$w_A = \bar{w}_A$$

$$w_{NA} = y_A + d$$

Income

$y_i = w_i L_i / Pop_i$ for workers in sector i

$YK = \Sigma_i (X_i - w_i L_i)$ for capitalists

Population Distribution

$$Pop_{NA} = L_{NA}$$

$$Pop_A = Pop - Pop_{NA}$$

Consumption

$C_{ik} = Pop_i \; c_{ik} \; y_i^{\eta_{ik}}$ by workers in sector i

$C_{Kk} = c_{Kk} \; YK^{\eta_{Kk}}$ by capitalists

Food and Feed Imports

$M_{FF} = \Sigma_i \; C_{iF} + C_{KF} + \gamma_{FM}(\Sigma_i \; C_{iM} + C_{KM}) - X_A$

Capital Goods Imports

$M_{KM} = e_{NA} \; X_{NA} - M_{FF}$

2. Dynamic Relation for Imported Capital Accumulation (t = time)

$KM(t + 1) = KM(t) + M_{KM}(t)$

3. List of Symbols

Parameters Derived from Initial-Year Values

$a_i \; \lambda_i$	Shift and share parameters in production function
b, μ	Shift and share parameters in capital aggregation with μ derived from $\partial K_{NA}/\partial KM = \Pi \; \partial K_{NA}/\partial KD$ in initial year
c_{ik}	Consumption parameter
e_{NA}	Share of nonagricultural production exported to cover food and feed inputs derived from $M_{KM} = 0$ in initial year
d	Difference between nonagricultural wage and agricultural income per capita

Parameters Defined in Appendix Table 1

σ, σ^*	Elasticities of substitution in production function and capital aggregation
Π	Relative productivity of imported capital compared to domestic capital

η_{ik}, η_{Kk} Income elasticities of consumption of food grains and meat (k = F and M), respectively, for workers i and capitalists

γ_{FM} Value share of feed in meat production

ε Elasticity of technological change in nonagriculture with respect to the stock of capital

Exogenous Variables

KD Domestic capital in nonagriculture

K_A Land

Pop Total population

$\bar{w}_A$ Real wage in agriculture

Endogenous Variables

X_i Production

L_i Employment

KM, K_{NA} Imported and aggregate capital in nonagriculture

t_{Ki} Productivity of land/capital

w_i Wage

y_i Per capita income of workers of sector i

Pop_i Population in sector i

YK Capitalists' income

C_{ik}, C_{Kk} Consumption of food and meat by workers of sector i and capitalists, respectively

M_{FF} Imports of food and feed grains

M_{KM} Imports of capital goods

Appendix 2

Specification of the Archetype Economies

1. Low-Income Economy: $250 to $400 GNP Per Capita

In this economy the agricultural sector produces one-third of GNP and supports two-thirds of the population.

The nonagricultural sector is not very capital intensive and has an incremental capital-output ratio of 2.2. Foreign exchange plays a crucial role in the industrialization process with imported capital goods amounting to 20 percent of the total capital and having a marginal productivity four times higher than that of an equivalent value of domestic capital. The elasticity of capital productivity in relation to that of the capital stock is .2. (Evidence on this, other than the share of imported capital, is found in Chenery et al.)

Remuneration of labor absorbs 80 percent of the value added in the agricultural sector and 40 percent in the nonagricultural sector. The agricultural workers spend 60 percent of their income on cereals and 6 percent on animal products, nonagricultural workers spend 42 percent and 13 percent, respectively, and capitalists spend 19 percent and 14 percent, respectively. Income elasticities of cereal consumption are .9, .55, and 0 for the agricultural workers, nonagricultural workers, and capitalists, respectively; and the elasticity of meat or feed consumption decreases from 2 to 1.5 and 1.1 for these three groups. [The consumption structure is derived from Indian data (Mellor; Radhakrishna; de Janvry and Subbarao; and National Sample Survey) with a higher share of the food budget given to meat than is found for India based on scattered empirical evidence from other countries.] Meat production is still fairly extensive with feed accounting for half of the value of production.

2. Very Low-Income Economy: $120 to $250 GNP Per Capita

In this type of economy, agriculture supports 80 percent of the population and produces 50 percent of GNP. The nonagricultural sector is more labor intensive, the capital-output ratio is lower, and the productivity of capital increases less with new capital (an elasticity of .1). For foreign capital, the share and relative productivity of foreign goods are kept the same to see, in the comparison of the two archetypes, the sole effect of the share of agriculture in the economy, of the labor intensity (both of which increase the growth impact of a given productivty growth in agriculture), and of the consumption structure due to lower income (with higher elasticities). With lower income, food grain consumption takes a higher share of income while meat consumption has a lower share and all of the elasticities are higher.

3. Middle-Income Countries: $500 to $1,000 GNP Per Capita

In this type of economy, 25 percent of GNP is generated in agriculture and 55 percent of the population is in the agricultural sector. The capital-output ratio and the growth of capital productivity with growth are slightly higher. Because of the higher income levels, the budget share of animal products is higher, and the elasticities of both food and feed demand are lower. Meat production is more intensive in feed and requires a 40 percent higher input of feed.

The parameter values of the three archetype economies are given in Appendix table 1.

APPENDIX TABLE 1

Parameters for Archetype Economies

		Countries		
		Very low income	Low income	Middle income
Production				
Agricultural	X_A	230	230	500
Nonagricultural	X_{NA}	230	450	1,500
Employment				
Agricultural	L_A	230	160	140
Nonagricultural	L_{NA}	92	120	165
Wages				
Agricultural	W_A	0.8	1.15	2.5
Nonagricultural	W_{NA}	1.0	1.5	3.5
Capital				
Agricultural	K_A	345	345	750
Nonagricultural, domestic	KD	368	800	2,760
Nonagricultural, imported	KM	92	200	690
Elasticity of substitution between KM and KD	σ^*	0.4	0.4	0.4
Relative productivity of KM	Π	4.0	4.0	4.0
Elasticity of capital productivity	ε	0.1	0.2	0.3
Agricultural Population		368	245	200
Income per capita	Y_A	0.5	0.75	1.75
Share on food		0.6	0.55	0.39
Income elasticity of food	$\eta_{A,F}$	0.9	0.7	0.6
Share on meat		0.08	0.12	0.2
Income elasticity of meat	$\eta_{A,M}$	2.0	2.0	1.7
Nonagricultural population				
Income per capita	Y_{NA}	1.0	1.5	3.5
Share on food		0.45	0.37	0.22
Income elasticity of food	$\eta_{NA,F}$	0.6	0.5	0.4
Share on meat		0.16	0.21	0.22
Income elasticity of meat	$\eta_{NA,M}$	1.7	1.5	1.3
Capitalists				
Share on food		0.35	0.16	0.08
Income elasticity of food	$\eta_{K,F}$	0.4	0.0	0.0
Share on meat		0.22	0.25	0.2
Income elasticity of meat	$\eta_{K,M}$	1.4	1.1	1.0
Value share of feed in meat	γ_{FM}	0.5	0.5	0.7

Elasticity of substitution between capital and labor in nonagriculture, σ, is 0.6 for labor bias and 1.5 for capital bias.

Footnotes

[1]The data are taken from The World Bank, World Development Report, 1982 (Washington, D. C., 1982).

[2]n is the number of countries. Data in parentheses are t-ratios.

[3]Empirical support for these two specifications is given is Chenery, Robinson, and Syrquin.

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