THE ROLE OF AGRICULTURE IN GENERAL ECONOMIC DEVELOPMENT: A REINTERPRETATION OF JORGENSON AND LEWIS*

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ABSTRACT: In recent years there have been substantial cut-backs in real terms in resources devoted to agricultural research and in the aid given to developing countries for investments in agricultural infrastructure notwithstanding the importance of continued agricultural development to economic progress world-wide. My purpose in this paper is to show that, contrary to conventional interpretation of the classic models of dual economic development of Jorgenson and Lewis, their models strongly support the need for continued research and investment in agricultural infrastructure to maintain high rates of total factor productivity growth, especially in the agricultural sectors of developing countries. Models of dual economic growth, dating from the 1950's, emphasize the so-called "Law of the Declining Relative Importance of Agriculture"; it is in part a failure to understand the significance of the changing structure of the economy reflected in this "Law" which has led to the present situation. The paper develops Jorgenson's model to show what happens to the terms of trade between the agricultural and nonagricultural sectors and demonstrates that the rate of growth of total factor productivity in agriculture must be higher than a weighted combination of nonagricultural technical change and population growth if general economic development is not to be choked off by rising prices for food and other agricultural commodities.

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1. Introduction

During the past 30 years or so, the output of food and fiber have more than kept pace with a growing world population overall, although severe problems of distribution remain. Grains, for example, account for more than 80% of food crops consumed in developing countries directly and, of course, for a substantial part of total food consumption in developed countries indirectly through conversion into animal products. The average annual rate of growth of grain output over the last 30 years has been around 2%, more than enough to match growing world demand so that grain prices have actually fallen and are expected to continue to fall for the next 20-25 years. Much of this progress has occurred in Asian countries, particularly in the production of rice. Dire predictions of world-wide famine have not materialized, although there is plenty of hunger and malnutrition around and famines, such as have occurred in Somalia and are now occurring elsewhere in Africa, still result from war and civil disruption. Low and falling world prices, however, do not mean that poor people in poor countries will automatically have access to food and will not have to continue to produce much of what they themselves consume, nor is predicted overall world abundance for the next generation any ground for complacency in the long run. Most developing economies are relatively closed, so that the internal terms of trade between agriculture and non-agriculture matter a great deal for the course of general economic development.

In recent years there have been substantial cut-backs in real terms in resources devoted to agricultural research and in the aid given to developing countries for investments in agricultural infrastructure. Despite the improved understanding of the role of agriculture in general economic development that has emerged since the 1950's, the current view of the lack of urgency for continued support of agricultural research reflects a complacency born not only of falling food prices but also of older ideas about the nature of dual economic growth dating from the 1950's and the work of Lewis (1954, 1958), Ranis and Fei (1961) and Jorgenson (1961, 1967, 1969). My purpose in this paper is to show that, contrary to conventional interpretation of these models of dual economic growth, they strongly support the need for continued research and investment in agricultural infrastructure to maintain high rates of total factor productivity growth, especially in the agricultural sectors of developing countries. Models of dual economic growth, dating from the 1950's, emphasize the so-called "Law of the Declining Relative Importance of Agriculture"; it is in part a failure to understand the significance of the changing structure of the economy reflected in this "Law" which has let to the present situation.

Fundamental research on the changing structure of the economy in the course of development was carried out by Simon Kuznets, who summarized his findings in Economic Growth of Nations (1971). Kuznets' findings were updated by Syrquin (1988). Two of the principal findings germane to this discussion are:

(1) The shift which occurs in the relative importance of agriculture, and other primary productive activities such as mining , forestry, and fishing, vis-à-vis the rest of the economy, manufacturing and services, a shift which is almost always accompanied by increased urbanization. This is perhaps the most thoroughly documented finding about economic growth is the But many other, less apparent, structural shifts accompany development, and all structural change is necessarily disruptive to a greater or lesser degree: Groups of the population employed in, or dependent upon, slowly growing, stagnant or declining sectors, suffer deprivation to a degree necessary to induce them to move to other, faster growing sectors. Immobile factors of production may simply lose out entirely. Land may be converted to alternative uses and may ultimately be absorbed in faster growing sectors, but more usually converted to less "productive," in the sense of being less highly valued, uses. Physical capital becomes obsolete long before actual physical deterioration sets in. But the greatest tragedy of all, is the obsolescence of human capital. Human beings suddenly become worthless, or nearly so relative to their former value, are the saddest consequence of growth.[1]

(2)Kuznets also found that when an economy begins to develop there is usually a sharp increase in the rate of physical capital accumulation. In his famous paper, Lewis (1954, p.155) wrote: "The central problem in

[1] The disruptions and dislocations of the growth process have led to massive interventions and subsidies to agriculture in economically developed countries, programs which have tended to mask the continuing need for agricultural development stressed here.

the theory of economic development is to understand the process by which a community which was previously saving and investing 4 or 5 per cent of its national income or less, converts itself into an economy where voluntary saving is running at about 12 to 15 per cent of national income or more. This is the central problem because the central fact of economic development is rapid capital accumulation (including knowledge and skills with capital)." Although figures are hard to come by, I would conjecture that, even before the sharp rise in the rate of saving and investment in physical capital, there would have been a significant increase in the rate of human capital investment, not only in education and skills but in better health and nutrition. These are concomitant features of the demographic transition (Chesnais, 1992). I think it is no accident that the demographic transition and the economic development of Western Europe, North America, and Japan occurred in tandem. Society's willingness to save is not only motivated by the present generation's desire for a better future for itself, but perhaps more importantly by its hopes for the next generation.

Thus, the two central "facts" which models of dual economic development seek to explain are:

- The Law of the Declining Relative Importance of Agriculture. A characteristic feature of development is a decline in the importance of agriculture, both in terms of employment of factors of production, especially labor, but also physical capital. Generally, agriculture becomes increasingly efficient with high levels of total factor productivity and high rates of growth of productivity.

- The Law of Accumulation. High rates of economic growth are universally accompanied by high rates of saving and investment in the nonagricultural sectors of the economy.

It is easy to "explain" the declining relative importance of agriculture in terms of rising per capita incomes during the process of growth and income elasticities of demand for food and agricultural products which are less than one, provided the prices of agricultural products rise little or not at all relatively to nonagricultural products. But this does not mean at all that agriculture must decline in absolute size; quite the contrary, rising incomes and population growth will inexorably increase the demand for agricultural products. The agricultural sector must grow and become more efficient in order to supply these demands at prices which do not rise greatly relatively to those of nonagricultural products lest the process of general economic development be choked off. I formalize this point in the next section.

It is also easy to explain the sharp rise in the rate of capital accumulation in the early stages of economic development by the assumption of a two-sector economy in which capital is little used in the traditional or agricultural sector and heavily used, and accumulated, in a modern, manufacturing sector.[2] The transition of the economy from traditional to modern and the declining relative importance of the agricultural sector then serve to account for the Law of Accumulation. Jorgenson(1961, 1967, 1969), Ranis and Fei (1961), and Lewis (1954, 1958), all focus on this aspect of "dual economic" development. But, consistently with the point made above, these models of dual economic development all imply that agriculture must grow absolutely and become more efficient in the course of general economic development. I show that this is the case in the context of Jorgenson's famous model of the development of the dual economy in section 3 of this paper. My principle finding evolves from a determination of the implications of long-run growth in Jorgenson's model for the terms of trade between agriculture and industry, implications which he himself drew but did not emphasize and which have been neglected by others who followed.

2. The Demand for Agricultural Products and the Relative Size of the Agricultural Sector during the Course of General Economic Development

In this section, I develop a simple framework for the sectoral shifts in demand which occur during the process of growth. I show how rising real per capita incomes and growing population affect the demand for

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[2] It is, of course, far from true that either physical capital or human capital are unimportant in agriculture, but identification of the so-called "modern" sector as capital intensive and the so-called "traditional" sector as capital nonintensive is traditional in dual economy models (see Kanbur and McIntosh, 1988).

food and other agricultural products in absolute terms and the size of the agricultural sector relative to the nonagricultural sector of the growing economy. More importantly, I show how these effects depend of the terms of trade between the agricultural and nonagricultural sectors of the economy and on the price and income elasticities of the demand for agricultural products.

Let

Y = the total income or product of an economy = total expenditure on goods and services. I will identify Y also as the total income of individuals in this society that is available to spend on goods and services, including investment.

qX = total expenditures on food and other agricultural products, denominated in units of manufactures and other nonagricultural products, where q = the price of food etc. relative to these other products. (In my subsequent discussion of Jorgenson's model, I will use p = 1/q rather than q, i.e., the terms of trade between agriculture and nonagriculture.)

N = population.

y = Y/N = per capita income.

x = X/N = the per capita demand for food and other agricultural products, which I assume to be a function of the relative price of agricultural and nonagricultural products:

(2.1)
$$x = f(q, y)\,.$$

$$\xi = -\frac{\partial \log x}{\partial \log q} = \text{ the price elasticity of demand.}$$

$$\eta = \frac{\partial \log x}{\partial \log y} = \text{ the income elasticity of demand.}$$

S = qX/Y = the share of food and agricultural products in the total output of the economy.

Now

(2.2)
$$S = \frac{qX}{Y} = \frac{qxN}{yN} = \frac{qx}{y}\ .$$

Taking logs and differentiating with respect to time, I obtain

(2.3)
$$\begin{aligned}\frac{\dot{S}}{S} &= \frac{d\log q}{dt} + \frac{d\log x}{d\log q}\frac{d\log q}{dt} + \frac{d\log x}{d\log y}\frac{d\log y}{dt} - \frac{d\log y}{dt} \\ &= \left(1-\xi\right)\frac{\dot{q}}{q} - \left(1-\eta\right)\frac{\dot{y}}{y}.\end{aligned}$$

Equation (2.3) shows how the share of agriculture in the economy as a whole depends on the rates of change of the relative price of agricultural and nonagricultural products and per capita income. If the total output of the economy is growing faster than population, per capita income will be growing at a rate

$$(2.4) \qquad \frac{\dot{y}}{y} = \frac{\dot{Y}}{Y} - \frac{\dot{N}}{N} .$$

The formula for the absolute growth of demand for agricultural products corresponding to (2.3) is

$$(2.5) \qquad \frac{\dot{X}}{X} = -\xi\frac{\dot{q}}{q} + \eta\frac{\dot{y}}{y} + \frac{\dot{N}}{N} .$$

Price elasticities of the demand for food and other agricultural products are generally thought to be low; this means that the first term in (2.3) may be quite close to the rate of increase in p, so that the terms of trade in favor of agriculture, relative prices of agricultural commodities, do not have to rise much to offset the effects of rising per capita incomes, which are, in any case attenuated by the "fact" reflected in

ENGEL’S LAW (1857): Expenditures on food decline as a proportion of total expenditures as the latter increase (i.e., holding prices constant and ignoring the relation of savings to income, $0 < \eta < 1$).

Thus (2.3) shows that the validity of the "Law of the Declining Relative Importance of Agriculture" rests on the assumption that the terms of trade do not turn too much in favor of agriculture during the process of economic growth. On the other hand, because ξ can be assumed to be small and because η has been found empirically to average about 0.5 (Houthakker, 1957), the absolute level of agricultural demand is dominated by the growth in real per capita incomes and by population growth. For many developing countries, the former is low and the latter relatively high.

To see what happens to the terms of trade between agriculture and industry in the course of general economic development we have to look at what happens to agriculture. It is this aspect of development which is addressed in the models of dual economic growth of Jorgenson and Lewis.

3. Implications of Models of Dual Economic Growth for the Terms of Trade between the Agricultural and Nonagricultural Sectors.

In this section I will deal with the formal apparatus of dual economic development through the model of Jorgenson (1961, 1967, 1969). I present a version of his model which is mathematically more accessible than the original and in which the changes in the terms of trade between the agricultural and the nonagricultural sectors are emphasized. The models of Lewis (1954, 1958) and of Ranis and Fei (1961) are similar to Jorgenson's in respect to their implications for the terms of trade between the agricultural and nonagricultural sectors of a dual economy.[3] For excellent surveys of models of dual economies and their importance in development economics see Dixit (1973) and Kanbur and McIntosh (1987).

Production in the Two Sectors

[3] For an alternative development of the dual economy, in which results are derived from the comparative statics of the model rather than from a dynamic analysis, such as Jorgenson gives and which I follow here, see Nerlove and Sadka (1991); there also the terms of trade between the two sectors are key to the implications of the model.

In Jorgenson's model two sectors are distinguished: The industrial or "modern" sector, and the agricultural or "traditional" sector. Agricultural commodities are produced by labor and land alone. No capital is used in agriculture or accumulated there.[4] Technical change is exogenous and "neutral."[5] Land is in fixed supply. Let A = the labor force in agriculture, which is assumed to be proportional to rural population; Y = agricultural output in units scaled to eliminate the fixed land input; α = the rate of technological change. Production is assumed to be according to a Cobb-Douglas technology, which with neutral technical change and fixed land input can be written

(3.1) $$Y = e^{\alpha t} A^{1-\beta}, \text{ where } 0 < \beta \leq 1.$$

This function implies diminishing returns to labor; the marginal product of labor in agriculture is

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

which is clearly falling as A increases. 1-β is the elasticity of output with respect to labor input.

Industrial commodities are produced by capital and labor, using no land, according to a constant-returns-to-scale Cobb-Douglas production function with neutral technical change. Let X = industrial output (manufactures); M = the labor force in the industrial sector; K = the capital stock; and λ = the rate of technical change in manufacturing. Then

(3.2) $$X = e^{\lambda t} K^{\sigma} M^{1-\sigma}, \text{ where } 0<\sigma\leq 0,$$

is the elasticity of manufacturing output with respect to capital stock. The marginal products of capital and labor in manufacturing are respectively

$$\frac{\partial X}{\partial K} = \sigma\frac{X}{K} \text{ and } \frac{\partial X}{\partial M} = (1-\sigma)\frac{X}{M}.$$

Wage Determination in the Two Sectors

The price of agricultural products is taken as the numeraire, i.e., the price of a unit of manufactures is measured in terms of the units of the agricultural commodity it takes to buy that unit of manufactures; let this price be p. This price is what I have called the terms of trade between agriculture and industry above. Then, if wages, w, in the modern sector are determined competitively,

(3.3) $$w = (1-\sigma)\frac{pX}{M}.$$

The return to capital is what is left over, i.e., r = σpX/K, which is also the marginal value product of capital. Note that both the real wage in manufacturing and the real return to capital depend on the terms of trade between agriculture and industry; if p changes so will w and r.[6]

[4] As indicated above, however unrealistic this assumption may be, it is conventional in dual economy models.
[5] Neutral technical change simply means that the isoquants are translated inwards, so that any given combination of factor inputs now corresponds to a larger output than before. In the case of a Cobb-Douglas Production Function, there is no way to distinguish factor augmenting or factor saving technological change from neutral change.
[6] The assumption of Cobb-Douglas production functions in both the modern and in the traditional sector has one awkward consequence, although it simplifies the mathematics considerably. The elasticity of substitution

The real wage in agriculture is different from w and possibly different from the marginal product of labor in agriculture. In his model Jorgenson adopts the assumption that it is proportional to w, the factor of proportionality being less than one in order to ensure a continuous flow of labor out of the agricultural sector into the industrial sector. Lewis and Ranis and Fei adopt a variety of alternative assumptions: One possibility, for example, is that total product is shared among family members, so that labor receives its average product in agriculture (which is above marginal product if the latter is falling, and certainly above a marginal product close to zero, which is implied by the assumption of surplus labor in agriculture). Another is that labor receives a subsistence wage and the landlords get the rest. In any case, the assumption that the wage in agriculture differs from the marginal product of labor there is incompatible with competition in the sector.[7]

Equation (3.3) can be used to eliminate M from the production function for the modern sector:

$$X = e^{\lambda t} K^{\sigma} \left[\frac{(1-\sigma)X}{w} \right]^{1-\sigma}$$

so that

$$X = e^{(\lambda/\sigma)t} K \left[\frac{1-\sigma}{w} \right]^{\left(\frac{1-\sigma}{\sigma}\right)} . \qquad (3.4)$$

Investment and Income Distribution

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between two factors in a two-factor production function measures the ease with which one factor can be substituted for the other. Suppose, as in the case of manufacturing, that there are two factors of production, capital and labor. The **elasticity of substitution of capital for labor**, s, is defined, holding output constant, as

$$s = \frac{\text{the \% change in the capital - labor ratio}}{\text{the \% change in the marginal rate of substitution of capital for labor}} .$$

If both factors are paid their marginal value products, the share of each factor in the total value of production (which is thereby exhausted for a constant-returns-to-scale production function) will vary with the factor price ratio in a way which depends on the elasticity of substitution:

$s < 1$ -> capital's share falls when w/r rises;
$s = 1$ -> capital's share remains constant when w/r rises;
$s > 1$ -> capital's share rises when w/r rises.

$s = 0$ is the case in which it is impossible to substitute one factor for the other (fixed proportions) and $s = \infty$ is the case of perfect substitutability (one factor is just a "renamed" version of the other). A Cobb-Douglas production function is characterized by always having $s = 1$, which means that under competitive conditions, when each factor is paid its marginal value product, factor shares are always constant. It is this fact which makes it impossible to distinguish neutral technological change from other types, such as factor-saving change, for the Cobb-Douglas technology.

[7] A much more interesting way to model this phenomenon, and one which would be more realistic to boot, would be to introduce a relationship between the flow of labor from the agricultural to the nonagricultural sector, the rate of which would depend on the size of the difference between the marginal productivity of labor in agriculture and w. Provided the flow was not instantaneous, this would permit us to assume competitive determination of wages in the agricultural sector and to find, under the right conditions, a positive outflow of labor from that sector. The dynamic analysis, however, would involve a planar system, the mathematics of which is considerably more complicated than the mathematics of the one-dimensional Jorgenson model. See Nerlove (1993).

In Jorgenson's model, as in one-sector growth models more generally, savings = gross investment = net capital formation in the absence of depreciation is assumed to depend upon income.[8] In Jorgenson's model, however, the way in which capital accumulation depends on the income of society is through profits in the industrial sector; it is all of capital's share.

If there were capital used in agriculture, and therefore the possibility of investment in the agricultural sector existed, a mechanism for the allocation of investment between the two sectors would have to be formulated. Moreover, if laborers as well as capitalists saved or if capitalists consumed some of their profits, a further formulation of the way in which income in each sector is divided between savings and consumption would be necessary. And such a formulation would make clear the importance of people's preferences in determining how an economy grows, preferences which are almost universally neglected in discussions of growth.[9] Jorgenson avoids all this by simply assuming all profits are invested, an assumption which is common to the Lewis model and to the Ranis-Fei extension of it, but this means that the role of preferences, particularly those for present versus future consumption which play such a crucial role in Schultz's (1964) characterization of traditional agriculture, are essentially suppressed.[10]

Thus in the Jorgenson model:

(3.5) $$\dot{K} = K\left[\frac{\sigma pX}{K}\right] = \sigma pX, \text{ where } \dot{K} = \frac{dK}{dt}.$$

In a one-sector growth model (3.4) and (3.5) lead to the conclusion that in the steady state of equilibrium growth output and the capital stock must both grow at the same rate. But this is true in Jorgenson's model only when wages in the agricultural sector and in the manufacturing sector are the same and there is no relative movement of population out of agriculture (population and labor force must be growing at the same rates in both sectors).[11] This result becomes important since, in the limit Jorgenson's model tends to a one-sector model as agriculture becomes a negligible sector of the economy.

Population Growth

The key assumption in Jorgenson's model is his assumption about the way in which population grows. In the initial phase of growth, agriculture is the only sector and the rate of growth of total population is also the rate of growth of the agricultural labor force, $\frac{\dot{A}}{A}$. Let N = total population and let y = Y/N = per capita food output. When agriculture is the only sector in the economy N = A. Jorgenson makes an assumption which is almost Malthusian; he assumes that above some minimal level δ, which can be identified as the death rate,

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[8] See section 2 of Nerlove and Raut (1995) on the structure of one-sector growth models.

[9] Consumer preferences more generally, however, play a fundamental role in the comparative-static model of dual economy growth elaborated by Nerlove and Sadka (1991)

[10] See Nerlove (1994).

[11] Proof: From (3.5) $\frac{\dot{K}}{K} = \frac{\sigma pX}{K}$. In a steady state, $\frac{\dot{K}}{K} = \text{constant}$, so that if the terms of trade between agriculture and industry are also constant, as they must be in the steady state, $\frac{X}{K} = \text{constant}$; hence, $\frac{\dot{X}}{X} = \frac{\dot{K}}{K}$.

population grows at a rate proportional to per capita food consumption but that, as per capita food consumption reaches a sufficient level, population then grows at the maximal rate ε:

$$(3.6) \qquad \rho = \frac{\dot{N}}{N} = \min\begin{cases} \gamma y - \delta, & \text{population grows endogenously,} \\ \varepsilon, & \text{population grows exogenously.} \end{cases}$$

Equation (3.6) defines the minimum level of income, y*, for which ρ attains its maximal level ε:

$$y^* = \frac{\varepsilon + \delta}{\gamma}.$$

Agricultural surplus is defined as y - y*; any positive agricultural surplus can be used to support industrial growth. In the first phase of economic development, there is no nonagricultural sector; N = A; Jorgenson's model reduces to a pure Malthusian model. From (3.1)

$$\frac{\dot{y}}{y} = \alpha - \beta\frac{\dot{A}}{A} = \alpha - \beta(\gamma y - \delta).$$

Hence, in this phase growth of output is characterized by the quadratic equation

$$(3.7) \qquad \dot{y} = (\alpha + \beta\delta)y - \beta\gamma y^2,$$

which has two stationary solutions, $\frac{\dot{y}}{y} = 0$, one at $y_1 = 0$ and another at $y_2 = \frac{\alpha + \beta\delta}{\beta\gamma} > 0$. This relation is graphed in Figure 1.

It is easy to see that the equilibrium at $y_1 = 0$ is unstable; any small displacement of per capita output will result in further increases at an increasing rate, due to increasing returns to labor applied to the fixed factor land, until the point y_0 is reached; after that point per capita output will continue to increase but at a decreasing rate as decreasing returns set in. The economy is entirely agricultural and population growth is governed by the Malthusian first line of (3.6). If the level y* at which an agricultural surplus is generated exceeds y_2, the economy will never take off into nonagricultural growth; instead, a stable Malthusian equilibrium will be attained at a level $y_2 = (\alpha + \beta\delta)/\beta\gamma$ at which population continues to grow only if there is a positive rate of neutral technological change in agriculture, $\alpha > 0$, at a rate α/β which leaves everyone at a level of well-being corresponding to the level of per capita income y_2 which does not change. This point has been called the low level equilibrium trap (Nelson, 1956); population growth is exactly balanced by technical change in agriculture. If $y^* < y_0$, output, and therefore population, can continue to grow only if the rate of technological progress in agriculture is exceedingly high.[12] It is therefore plausible to assume that $y_0 < y^* < y_2$.

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[12] $\frac{\dot{y}}{y} < \frac{\alpha - \beta\delta}{2} \leq 0$ when $\alpha \leq \beta\delta$. For example, suppose that labor's relative share of agricultural output, *were agricultural laborers to be paid their marginal product,* would be 0.5 and that the crude death rate was about 25 per 1000 population, not out of line with the poorest countries in 1990. Then, if the rate of neutral technical change in agriculture were below 1.25% per annum, no growth in per capita income in agriculture would occur.

Suppose that this is the case. Then

$$y^* < y_2 \text{ implies that } \frac{\alpha + \beta\delta}{\beta\gamma} > \frac{\varepsilon + \delta}{\gamma} \text{ or } \frac{\alpha}{\beta} > \varepsilon$$

so that $\alpha - \beta\varepsilon > 0$ is a necessary and sufficient condition for the eventual emergence of an agricultural surplus in Jorgenson's model. Before a surplus emerges population grows at the rate

(3.8) $$\frac{\dot{N}}{N} = \frac{\alpha + \beta\delta}{\beta\gamma} - \delta = \frac{\alpha}{\beta} > 0 .$$

Once the surplus emerges, population grows at the rate ε, at which point per capita agricultural output grows at

(3.9) $$\frac{\dot{y}}{y} = \alpha - \beta\varepsilon > 0 .$$

This is depicted in the figure as the straight line segment taking off from the quadratic function at y*. Jorgenson calls the phase of growth up to this point classical and after this point neoclassical.[13] In the neoclassical phase a growing agricultural surplus is available to support a nonagricultural labor force assuming everyone consumes exactly y* food per capita. In effect this means that the income elasticity of demand for food is infinite up to the point y* and then abruptly drops to zero.[14]

Take-Off into Nonagricultural Growth. The "Neoclassical" Phase.

• A necessary condition for a "Jorgensonian" take-off into nonagricultural growth is a sufficient rate of increasing efficiency in agriculture and a sharply falling income elasticity of demand for food, which, taken together, permit the emergence of an agricultural surplus available to support a nonagricultural population.

Once an agricultural surplus emerges, y - y* is available per capita population in agriculture to support nonagricultural growth and a part of the total population M may be freed to produce manufactures:

(3.10) $$N = A + M .$$

If everyone consumes just y* food (the income elasticity now being zero in Jorgenson's model),

(3.11) $$\text{Total food production} = \text{Ay} = \text{Total food consumption} = \text{Ny*};$$

whence, A/N = y*/y ≤ 1, so that

(3.12) $$\text{M} = \text{N}(1 - \frac{y^*}{y}) .$$

[13] Obviously, the demographic transition, which is quite crucial to the continuance of economic development once it has begun, is ignored.

[14] Jorgenson's assumption, while superficially quite unrealistic, is a way of modeling the empirical finding of a fall in the income elasticity of the demand for food at high levels of real per capita income. Since it simplifies the mathematics of his model very considerably it is best not to quibble.

By (3.6), once an agricultural surplus emerges population must be growing exogenously at its maximal rate ε, i.e., solving $\frac{\dot{N}}{N} = \varepsilon$, with initial population N(0),

(3.13) $$N(t) = N(0)e^{\varepsilon t} \ .$$

From (3.11), (3.13) and the agricultural production function (3.1), it follows that total agricultural output is

(3.14) $$N(0)y^* e^{\varepsilon t} = Y(t) = e^{\alpha t} A(t)^{1-\beta},$$

or

(3.15) $$A(t) = \left[N(0)y^*\right]^{\frac{1}{1-\beta}} e^{\left[\frac{\varepsilon-\alpha}{1-\beta}\right]t},$$

which is the total population in agriculture.

Growth in the Neoclassical Phase

If we now take t = 0 to be the moment when the agricultural surplus first emerges, setting t = 0 in (3.15) yields

$$N(0) = \left[N(0)y^*\right]^{\frac{1}{1-\beta}},$$

since at that moment A(0) = N(0); whence $y^* = N(0)^{-\beta}$. Replacing y* in (3.15) by this value gives us

(3.16) $$A(t) = N(0)e^{\frac{\varepsilon-\alpha}{1-\beta}t} \ .$$

It follows from (3.16) and (3.13) and (3.10) that

(3.17) $$M(t) = N(0)\left\{e^{\varepsilon t} - e^{\frac{\varepsilon-\alpha}{1-\beta}t}\right\},$$

or

(3.18) $$\frac{M(t)}{N(t)} = 1 - e^{-\left[\frac{\alpha-\beta\varepsilon}{1-\beta}\right]t}$$

is the proportion of total population (labor force) engaged in nonagricultural pursuits. This proportion tends to one over time, i.e., the Jorgenson model of dual economic growth in the neoclassical phase tends to a one-sector model of growth for an economy in which agriculture is negligible, because $\frac{\alpha - \beta\varepsilon}{1-\beta} > 0$, since 0≤β<1 and since $\alpha - \beta\varepsilon > 0$ is a necessary and sufficient condition for the emergence of an agricultural surplus and thus for the take-off into sustained growth. Of course, the corresponding share of agriculture in the total population (labor force) is

$$(3.19) \qquad \frac{A(t)}{N(t)} = e^{-\left[\frac{\alpha - \beta\varepsilon}{1-\beta}\right]t},$$

which tends to zero with t.

Note that, in the limit the Jorgenson model is the same as the Solow/Swan one-sector neoclassical growth model with exogenous population growth at the rate ε and neutral technical change at the rate λ. However, in the Jorgenson model the proportion of nonagricultural income saved is equal to capital's share of income in the nonagricultural sector. Moreover, some population growth and technical change in the agricultural sector is necessary to ensure that y* per capita food supplies are available to feed the nonagricultural population. So agriculture must grow absolutely even though it declines into insignificance relatively.[15]

• In Jorgenson's model of dual economic growth, once an agricultural surplus emerges that permits sustained nonagricultural growth, the agricultural sector declines relative to the overall economy but continues to expand absolutely.

Saving and Investment in the Neoclassical Phase

There is one important problem with respect to sustained nonagricultural growth which has not yet been addressed; that is how the stock of physical capital which is essential for production of manufactures is determined. Indeed, the problem is more serious in Jorgenson's model than one might at first imagine because in a Cobb-Douglas technology every factor of production is essential. No production is possible in the nonagricultural sector without some initial stock of capital no matter how small and that has to come from somewhere. Jorgenson simply assumes that it is there when needed and shows that then growth is self-sustaining under his assumptions. A more plausible alternative is to assume that production technology in manufacturing is not quite Cobb-Douglas in the very initial phase so that some output can be produced by those agents who get things started and who also save.

From (3.2) and the assumptions that capital owners are paid the marginal product of capital and save and reinvest it all and that there is no depreciation, we have

$$(3.20) \qquad \dot{K} = \sigma X = \sigma K^{\sigma} M^{1-\sigma} e^{\lambda t} = \sigma K^{\sigma} e^{\lambda t} N(0)^{1-\sigma} \left\{ e^{\varepsilon t} - e^{\left[\frac{\varepsilon - \alpha}{1-\beta}\right]t} \right\}^{1-\sigma} > 0,$$

provided that, when an agricultural surplus first emerges at t=0, K(0)≠0, since the term in curly brackets is always positive for t>0. K(t) follows a path which is the solution of the differential equations (3.20) and $\dot{N} = \varepsilon N$. There are two initial conditions: N(0) the size of the population when the agricultural surplus first emerges and K(0) the size of the initial capital stock at that time. Eventually neither matters to the economy which behaves as a one-sector nonagricultural growth model after a sufficient lapse of time. As shown, output and capital stock must then grow at the same rate:

[15]See Nerlove and Raut (1995, section 2) on one-sector growth models with more general *endogenous* population growth.

(3.21) $$\frac{\dot{X}}{X} = \frac{\dot{K}}{K} = \frac{\lambda}{1-\sigma} + \varepsilon .$$ [16]

Movement of Labor Out of Agriculture during Neoclassical Growth

Once nonagricultural growth begins, it can be sustained only by a continual movement of labor out of agriculture even if fertility and mortality are identical in the two sectors. Of course, in the limit, the agricultural sector is negligible; nonetheless, in the Jorgenson formulation it must continue to decline relatively, a problem which would be resolved by a more realistic formulation of the determination of relative wages in industry and agriculture and a proper dynamic model of the movement of labor out of agriculture in response to a wage differential. From (3.16), it is easy to see that the rate of growth of the agricultural labor force (= rural population) must be less than the rate of overall labor force (population) growth in the neoclassical growth phase:

(3.22) $$\frac{\dot{A}}{A} = \frac{\varepsilon - \alpha}{1-\beta} < \varepsilon = \frac{\dot{N}}{N} .$$ [17]

In order to ensure that labor moves out of agriculture in the neoclassical phase, Jorgenson assumes that agricultural wages are a fraction of the wage rate in the industrial sector, $\mu<1$, but he doesn't say anything about how this comes about. In the classical, preindustrial phase of growth, real wages on average must be real per capita food consumption y, if farmers also own the land that they farm. If there are landlords, however, and if returns to labor input are decreasing, labor would get $1-\beta$ as a fraction of total agricultural output and landlords the rest, or β, if agricultural laborers were paid their marginal product. Then we would have to formulate separate theories of the determination of population growth for agricultural laborers and for landlords. Perhaps it's best not to be specific as Jorgenson is wisely not. Once neoclassical growth begins, however, competition for labor in both modern and traditional sectors would ensure that the marginal value product of agricultural laborers and that of manufacturing workers would be equalized in equilibrium. A delayed adjustment in the movement of labor out of agriculture in response to a higher marginal value product in the modern sector would do the job, however, without having to invoke exploitation by the land owning class. Such a class would essentially be irrelevant to the further growth of the economy; as long as competitive conditions prevailed, landowners could not act in such a way as to impede the absolute growth of agricultural output through technical change in agriculture or the growth of the agricultural labor force, which is necessary in order to permit the growth of the nonagricultural sector.

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[16] Determined by differentiating the log of the production function with respect to t to obtain

$$\frac{\dot{X}}{X} = \lambda + \sigma\frac{\dot{K}}{K} + (1-\sigma)\frac{\dot{M}}{M} .$$

Substituting $\frac{\dot{M}}{M} = \varepsilon$ and $\frac{\dot{X}}{X} = \frac{\dot{K}}{K}$ then yields (3.21).

[17] Recall that $\frac{\alpha}{\beta} > \varepsilon$ is a necessary condition for the agricultural development to the point of the take-off into nonagricultural growth, i.e., the emergence of a nonagricultural sector. Some manipulation of this inequality yields $\varepsilon-\alpha<(1-\beta)\varepsilon$ which implies (3.22).

The Terms of Trade between Agricultural and Nonagricultural Products

In the previous section, I stressed that the agricultural sector must grow absolutely even as it declines relatively in order that agricultural prices not rise so much relative to the prices of nonagricultural goods as to choke off general economic development. It is possible to work out just what does happen to the terms of trade between agriculture and manufacturing in the context of the Jorgenson model. Now I will show how the direction in which the terms of trade turn depends on the elasticities of output with respect to labor input and the rates of technical change in industry and agriculture, and on the rate of exogenous population growth.

Above I wrote p as the ratio between the price of manufactures and the price of agricultural products, taking the latter as the numeraire, i.e. equal to 1. In these terms:

$\frac{\dot{p}}{p} > 0,$ represents a turning of the terms of trade against agriculture

and is favorable to general economic development;

$\frac{\dot{p}}{p} < 0,$ represents a turning of the terms of trade in favor of agriculture

and is unfavorable to general economic development.

If, following Jorgenson, we assume that capitalists save and invest all profits, which are manufactured goods, and that landowners consume all rents, which are agricultural goods, then total net output (net of investment by capitalists and consumption by landlords) in the two sectors must equal the total receipts of labor in the two sectors:

(3.23) $$(1-\sigma)pX + Y = wM + \mu wA\,.$$

Manufacturing technology is assumed to be constant returns to scale in labor and capital; hence, by Euler's Theorem, paying each factor its marginal product will exactly exhaust the total product:

(3.24) $$wM + rK = wM + \sigma pX = pX\,.$$

From which it follows that $wM = (1-\sigma)pX$ so that from (3.24):

(3.25) $$Y = \mu wA\ ,$$

where μ is assumed to be constant. Taking logs and differentiating with respect to time

(3.26) $$\frac{\dot{y}}{y} = \frac{\dot{w}}{w} + \frac{\dot{A}}{A}\,.$$

Since labor receives its marginal product in manufacturing, $w = (1-\sigma)\frac{pX}{M}$,

we find also by taking logs and differentiating with respect to time that

(3.27) $$\frac{\dot{p}}{p} + \frac{\dot{X}}{X} = \frac{\dot{w}}{w} + \frac{\dot{M}}{M}\,.$$

From (3.26-27)

(3.28) $$\frac{\dot{p}}{p} = \frac{\dot{Y}}{Y} - \frac{\dot{A}}{A} - \left(\frac{\dot{X}}{X} - \frac{\dot{M}}{M} \right).$$

From the agricultural production function (3.1), again by taking logs and differentiating with respect to time

(3.29) $$\frac{\dot{Y}}{Y} = \alpha + (1-\beta)\frac{\dot{A}}{A}.$$

From (3.16)

$$\frac{\dot{A}}{A} = \frac{\varepsilon - \alpha}{1-\beta}.$$

In the long run, from (3.21) M must grow at the rate of population growth, ε,

$$\frac{\dot{M}}{M} = \varepsilon,$$

and capital stock and manufacturing output must grow at the same rate

$$\frac{\dot{X}}{X} = \frac{\lambda}{1-\sigma} + \varepsilon..$$

Substituting all these results in (3.28), we arrive finally at an expression for the change in the terms of trade in terms of the parameters of the problem:

(3.30) $$\frac{\dot{p}}{p} = \alpha - \lambda\left(\frac{1-\beta}{1-\sigma}\right) - \varepsilon,$$

which is positive or negative according as

(3.31) $$\alpha - \lambda\left(\frac{1-\beta}{1-\sigma}\right)\begin{Bmatrix} > \\ < \end{Bmatrix}\varepsilon.$$

4. Conclusions

Equations (3.30-31) say that the terms of trade between agriculture and industry turn against agriculture or in favor of agriculture according as:

$$\text{The rate of technical change in agriculture} - (\text{the rate of technical change in industry}) \times \left(\frac{\text{the elasticity of output with respect to labor input in agriculture}}{\text{the elasticity of output with respect to labor input in manufacturing}}\right)$$

is greater or less than the rate of population growth.

A reasonable approximation to the adjustment to the rate of technical change in industry would be to take the ratio of the share of labor in total output in the two sectors. This would presumably be less than one, but perhaps not too much less.

The importance of the terms of trade to the process of general economic development is not to be found in Jorgenson's model itself, for he assumes that the wage in agriculture is always a fraction of the industrial wage sufficient to induce movement of labor from agriculture to industry. But clearly the real industrial wage depends on the prices of agricultural products relative to manufactures (from equation (3.3) $\frac{\partial w}{\partial p} = (1-\sigma)\frac{X}{M} > 0$). If the former rises relative to the latter, real wages in industry will fall relative to real wages in agriculture and the movement of labor into the industrial sector will be impeded or even choked off and the process of general economic development will be thereby slowed or halted.

Thus,

- Improving agricultural efficiency, technical change in agriculture, and agricultural modernization are an integral part of the process of general economic development. High rates of improvement in total factor productivity in agriculture relative to rates in industry and relative to the general rate of population growth can prevent or impede the turning of the terms of trade between agriculture and industry in favor of agriculture, a turn which might otherwise slow or choke off the process of general economic development.

This point is clearly recognized by Ranis and Fei (1961) who attempted to correct what they thought was a defect in the Lewis model. They wrote (p.534): "Lewis ... has failed to present a satisfactory analysis of the agricultural sector. It seems clear that this sector must also grow if the mechanism he describes is not to grind to a premature halt." But, in fact Lewis (1954, pp. 172-173) himself makes the same point: "Anything which raises the productivity of the subsistence sector (average per person) will raise real wages in the capitalist sector, and will therefore reduce the capitalist surplus and the rate of capital accumulation, unless it at the same time more than correspondingly moves the terms of trade against the subsistence sector. [Emphasis supplied.] ...if the capitalist sector produces no food, its expansion increases the demand for food, raises the price of food in terms of capitalist products, and so reduces profits. This is one of the senses in which industrialization is dependent upon agricultural improvement; it is not profitable to produce a growing volume of manufactures unless agricultural production is growing simultaneously. This is also why industrial and agrarian revolutions always go together, and why economies in which agriculture is stagnant do not show industrial development." Yet much of the development literature and the policy implications drawn there from since Lewis wrote have focused on the idea that resources can be withdrawn from agriculture almost without cost in terms of reducing agricultural output to feed a dynamic, growing industrial sector and thus account for the sharp rise in the rate of capital accumulation in the initial phases of economic development, which Lewis said (p.155) was "... the central problem in the theory of economic development...."

Why have policy makers and development theorists misread the implications of the models of Jorgenson, Lewis, and Ranis and Fei? As I pointed out in section 2, it is quite possible for the relative size of the agricultural sector to decline in the course of general economic development while at the same time the absolute size of the sector, at least in terms of output actually expands. Indeed, as we now see, it is one of the major implications of these models that the agricultural sector must expand and become more efficient in order that general economic development proceed. As Nicholls (1963, p. 2) wrote in an early critique, It seems "...that most Western policy-planners and theorists have misread the Law of the Declining Relative Importance of Agriculture, tending to emphasize the existence of a labor surplus in agriculture while taking a surplus of food output (except in a very long-run context) for granted. They have thus reinforced the predilections of economic planners in underdeveloped countries for all-out emphasis on industrial development."

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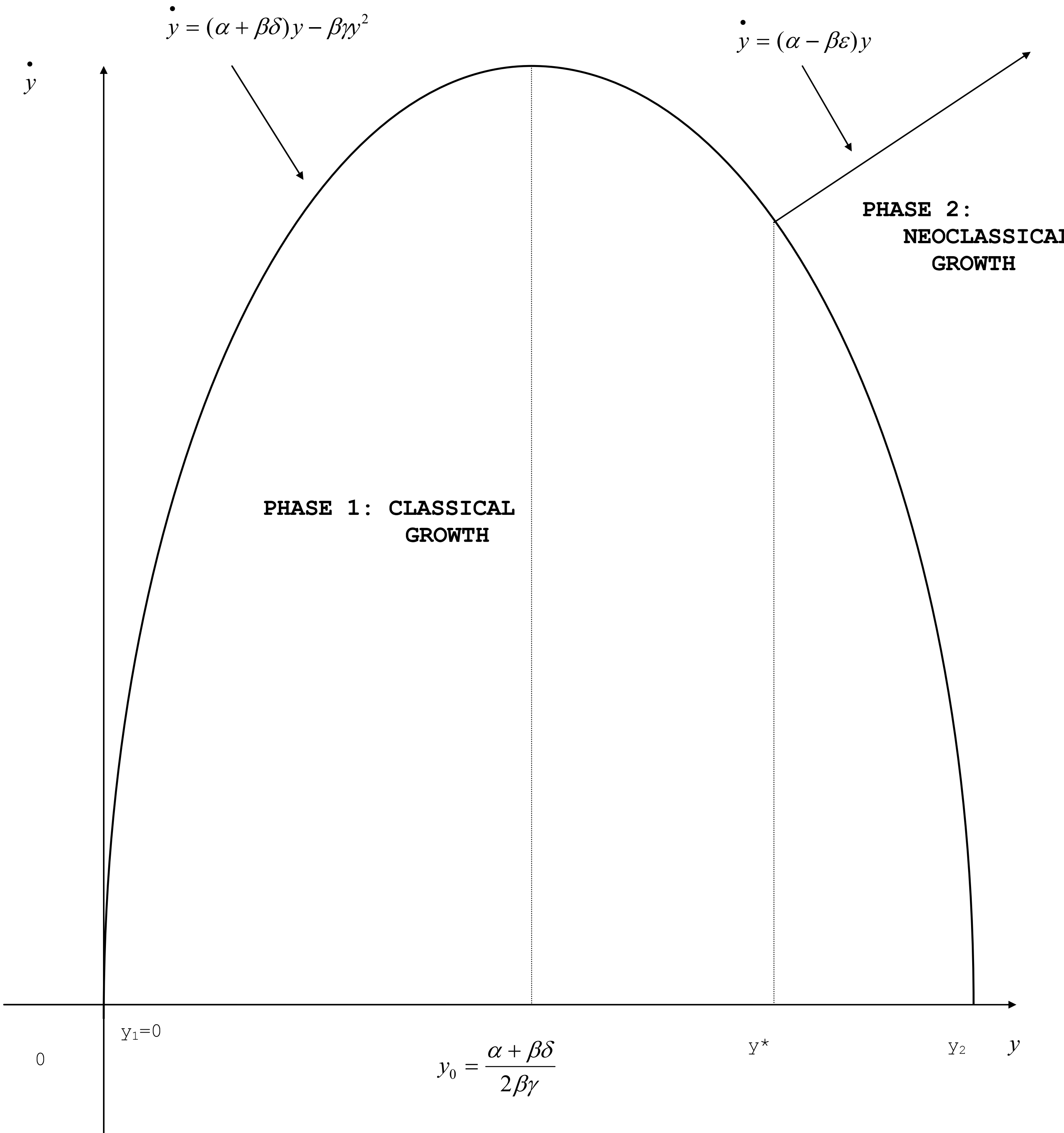

FIGURE 1: DIAGRAMATIC EXPOSITION OF JORGENSON'S MODEL OF ECONOMIC GROWTH OF A DUAL ECONOMY