MODELS OF ECONOMIC GROWTH AND LAND AUGMENTING TECHNOLOGICAL CHANGE IN FOODGRAIN PRODUCTION

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Table of Contents

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I. Introduction

Technological change in foodgrain production as epitomized by the "Green Revolution" holds potential for substantial acceleration of overall rates of economic growth and change to a pattern of growth favorable to the low income laboring classes (33). Large additions to agricultural production increase the supply of wages goods, and hence the potential for increased employment. Furthermore, the net additions to national income expand the demand for goods and services and increase employment in the nonfoodgrains sector (42). The nature and extent of these influences depends significantly on the initial distribution of income from the increased foodgrain production, which is in turn importantly influenced by the nature of the underlying technological change. These phenomena appear sufficiently important to merit analysis in models of economic growth and sufficiently complex to appeal to the aesthetic tastes of model builders.

Growth theory and growth models would appear highly relevant to the problems of low income countries. The theory of economic growth "deals with the dynamic (time) paths of macroeconomic variables. Unlike cycle theory, growth theory concentrates only on long run trends" (64, pp. 1-2). "The primary object of the modern theory of economic growth is to explain, on the one hand, the movements in the output, employment and capital stock of a growing economy and the interrelationships among these variables, and on the other hand, to explain the movements in the distribution of income among factors of production" (56, p. 3). However, despite the apparent relevance, growth models tend to be oriented towards the regimes of high income nations. "It is apparent . . . that steady states and convergence to them have played a central role in the growth literature"

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*This paper traces from my earlier collaboration with Uma Lele (34) and benefits from her continuing suggestions and criticism. I am particularly grateful to be able to draw on her work in progress which incorporates a capital sector in our earlier model. For comparison of various models, review of literature, and substantive contributions to content and organization, I am indebted to Gillian Hart. Mohinder Mudahar, C. Ranade, Uttam Dabholkar and Bhupat Desai all commented in detail on earlier drafts and this version very much reflects their assistance.

(56, p. 7). It is probably this feature in particular which makes the literature of growth models of such limited applicability to growth of low income nations.

The property of steady state growth in practice depends on one factor of production being defined as having steady growth and the others conforming to it through the assumption of constant returns to scale. For an economy in which the labor participation ratio is constant, or highly inelastic, labor provides the key property for steady state growth by an assumption of steady rate of population and hence, labor force growth. The logic is of course circular but under some circumstances reasonable. In an economy in which labor participation has varying supply elasticity over time, it cannot provide the key, steady state, rate. Since a steady state assumption for capital is uninteresting, labor supply conditions make the dominant steady state concern of growth models inapplicable to low income countries. As we shall point out later, substitution of land plus land augmenting technological change for labor may serve the function needed for steady state growth for a period. That, however, removes from endogenous consideration one of the most interesting and important dynamics of growth in low income economies. The various "dualistic" models which explore the labor participation question are, in general, considered more limited models in terms of the variables which they explore, and often include assumption of "noneconomic" market imperfections. Thus, they are not usually considered part of the mainstream of growth models. The result has been quite limited application of mathematical models to analysis of growth in low income countries.

This paper argues that in low income countries the supply of labor or of labor services to both the agricultural or nonagricultural sectors is highly elastic with respect to the real wage rate, but that its mobilization requires an enlarged supply of wages goods. Economic growth is then perceived as a process of both productively employing more labor and of increasing the capital stock--the former achieved in part by allocating resources to producing wages goods, the latter by resource allocation to producing capital goods. This two-factor view is in sharp variance conceptually and in its policy implications to the essentially one factor Harrod-Domar (20, 12) and Fel'dman-Mahalanobis (16, 36) approaches which have been the precursors of the bulk of current mathematical planning models.

The basic approach argued in this paper is suggested by Dobb and Sen (10, 50) and of course, appears in highly abstract form in von Neumann's original formulation (63). However, a dilemma arises in application of this approach since the basic wage good in a typical low income economy is food grain which in a traditional agriculture is subject to a fixed land constraint with consequent sharply diminishing returns to other factors of production. Technological change of a land augmenting nature relaxes this constraint, opens the way to accelerated growth and suggests a large number of analytical questions.

Because of the nature and circumstances of their formulation, most models of economic growth ignore the implications of land augmenting

technological change in foodgrain production--which is itself a dramatic development in the largest sector of the economy. Most common is to exclude the agricultural sector entirely; next most common is to include agriculture marginally, but as a sector of rising costs and therefore, of increasing restraint to growth. A few models discuss technological change in foodgrains production but do so in a context of little relevance to the dynamics of the current scene. This would not be surprising if the current technologies were of small substance or were without historical precedent. The annual net direct addition to national income which they provide, however, may easily be comparable in size for example to total annual increments to national saving and investment. Such phenomena are important. The nature of the changes occurring are very similar to the technological change which took place in Taiwan in the 1950's and 1960's as well as in the 1920's; and in Japan in various periods, particularly including the post Meiji restoration decades (30, 44). The changes have certain features in common with agricultural improvements in Britain in the early stages of the industrial revolution (32). Thus, they are hardly new phenomena.

It may, of course, be argued that growth models are simply academic exercises of a highly esoteric type which neither have nor need have any connection with realities of contemporary economic growth in low income countries. Certainly that position is easily supported. I prefer, however, Solow's view of growth theory as parables--the story should of course be well told--but he also indicates that it should shed light on real economic life and be useful in analysis of economic policy (54, p. 1). Solow also notes that "there may be problems on which (the assumptions of growth theory) appears to throw light, but on which it actually propagates error," (54, p. 2). That, unfortunately, would appear to be the case generally in application of current growth models to low income countries. Unfortunately, such theories have then been built into development plans for situations in which the underlying assumptions do not hold (33). The most important effect of these assumptions is to exclude the potential multiplier effects of technological change in agriculture and therefore, to divert economic analysis and resources from the important and numerous problems related to initiating and adapting to that process. This paper reviews models of economic growth in this context and provides suggestions for adapting growth models to suit the circumstances of low income countries.

Because the current, yield increasing new technologies in agriculture increase the supply of wages goods, their most interesting relation to economic growth is contained in the assumptions about labor. Models of economic growth and development divide into two general classes in this respect: (1) those which ignore the supply of wages goods as a constraint and (2) those in which employment, within an exogenously given population, is determined partly by the supply of wages goods. The first category includes those models in which (a) labor supply is exogenously determined and limited by population growth; (b) labor supply is exogenously determined but perfectly elastic; (c) labor supply is endogenously determined by population growth. The second category of models is most relevant to yield increasing technological change in agriculture. These models are, however, in most cases quite

partial models, frequently not incorporating capital in the formulation, or they make assumptions about the agricultural production function which are not consistent with the current technological changes in agriculture.

The following pages review the models which ignore the wages goods constraint, in order to show their inapplicability to an important set of current problems of growth in low income countries. Then, in recognition of the power of the Harrod-Domar derived models and to further emphasize the role of technological change in agriculture, modifications of the basic Harrod-Domar model are suggested to increase its relevance to the closed, low income, elastic supply of labor type of economy. Next the four conditions are reviewed that give growth relevance to technological change in foodgrains production. This leads to analysis of the dualistic models. Finally, suggestions concerning a relevant synthesis are made.

II. Growth Models Which Ignore Wages Goods as a Constraint

Labor Supply Exogenously Determined and Limited by Population Growth

One Sector Models: The family of growth models directly derived from the Harrod-Domar model are single factor of production models which, at least at first glance, have no place in the growth process for agriculture, wage goods or labor. They have, however, played a key role in providing the intellectual basis for dominant planning strategies, particularly including the Second through Fourth Indian Five Year Plans. The position is best summarized by the following two quotations:

> "Modern growth models usually make capital the only endogenous factor of production, while the supply of labour at each moment of time is assumed to be given," (43, p. 34).

> "Capital occupies a position so dominant in the economic theory of production and distribution that it is natural to assume an equally important place in the theory of economic growth. In most of the recent writings . . . there is an unstated assumption that growth hinges on capital accumulation, and that additional capital would either provoke, or facilitate a more rapid rate of economic development . . ." (5, p. 75).

The most salient assumptions of the Harrod-Domar formulation are: (a) the labor force grows at a constant rate determined by demographic factors, (b) the capital/labor ratio is fixed, (c) a constant proportion of income is devoted to savings. Since there is assumed to be no technological change, it follows from (b) that there are constant returns to scale.

From these assumptions, the familiar Harrod-Domar conclusions follow--namely that steady state growth requires that:

$g = n$ where n = rate of population growth

g = highest rate of growth which is permanently maintainable

$g = s/v$ where s = constant savings ratio

v = constant capital/output ratio

$\therefore n = s/v$

Furthermore, the conclusion that the rate of growth is constrained by the rate of population increase holds even if one assumes a variable capital/labor ratio. The neoclassical models of Solow (53) and Swan (58) illustrate that if the assumptions of fixed capital/labor ratios are

relaxed, the rate of growth cannot be increased indefinitely by increasing the ratio of capital to labor because (1) constant returns to scale imply diminishing returns to capital, and (2) this is inconsistent with a constant level of s/v as the upper level of s is unity. It follows that if there is a wage goods constraint, these models are inappropriate. They are also inappropriate if the labor force can grow faster than population through increased participation rates.

Two Sector Models: Neoclassical two sector models of the Uzawa type (62, 59, 24, 13) represent an elaboration of the basic Harrod-Domar model as extended by Solow and Swan in that (1) they allow for variable capital/labor ratios, and (2) examine allocations between consumer goods and capital goods. A crucial feature of these models, however, is that they assume "the consumption good not being used as an input in the productive process" (19, p. 34). Thus, these models appear to turn more explicitly away from conditions of low income, elastic labor supply economies in which wages goods might be a constraint to employment and hence, eventually, to the rate of growth.

Labor Supply Exogenously Determined, but Perfectly Elastic at Zero Cost and No Wages Good Constraint

The logical modification of the preceding models for application to low income nations was to agree to the labor surplus assumption so prevalent in the literature, and study the implications to growth of a perfectly elastic supply of labor whose utilization was constrained only by the Harrod-Domar assumption of fixity of factor proportions. The resultant models are basically Harrod-Domar models with unemployed labor. As we shall see later, such models in fact lend themselves even less well than the basic Harrod-Domar model to incorporating analysis of technological change in the basic wages goods (foodgrains) sector. The basic models of this type assume two sectors, consumption goods and capital goods, in which capital is the only scarce resource. They also assume wages are consumed and profits saved. In the utility maximization versions which abstract from labor as a factor of production and assume fixed capital/output ratios, maximum consumption at any future point in time is achieved by investing all output, up to the time period chosen for maximizing consumption, in capital goods industries and then diverting all investment to the consumption goods sector (2, 6 (part 1), 26). Similarly, in the time minimization models (which include labor in the production function and assume fixed capital/labor ratios), full employment is achieved in minimum time by the same procedure (6 (part 2), 57).

The problems and implications of this approach are clear from Stoleru's application to Algeria. The mathematically optimal program for minimizing the time to achieve full employment involves 15 years in which all investment goes to the capital goods sector, an additional four years in which investment is in consumption goods only and from twentieth year on there is full employment and balanced growth along a von Neumann path. The economy then expands at the rate of growth of population. Strikingly, unemployment starts in this model at 40 percent and expands to a maximum of 52 percent before decreasing and con-

sumption declines by year 15 to 22 percent of its initial value! Stoleru also sets a minimum consumption level of 45 percent of the original level, in which case, all investment goes to capital goods sector for seven years, then from 7 to 20 years to both capital and consumption, from 20 to 23 years only to consumption, and then along a balanced growth path. But, of course, employment and per capita consumption decline for the first seven years.

Although such an economy would be a politician's nightmare, Chakravarty points out that it does follow from the assumptions that the supply of capital is the major bottleneck. He poses the question:

> "What happens when we supplement the . . . one-constraint model with a separate constraint based on the incremental minimum consumption demand that accompanies the process of development leading to the conversion of unemployed labor into an employed labor force with higher consumption requirements per worker? In a fully planned economy, where consumption can also be effectively controlled, such a discrepancy may not be allowed to arise. But even there, a rising consumption floor may have to be imposed for no other reason than that of maintaining per capita consumption with a strongly rising population level. With this additional constraint, our model would lose some of its openness, inasmuch as there would be a value attached to consumption as an exogenous constraint, quite apart from its role as an indicator of welfare," (6, p. 136).

Thus, the assumptions of these models provide little or no place in growth for allocation of resources to agriculture. It is only required by short run welfare considerations. Technological change in agriculture is of course welcome if it is costless, as it relieves short run welfare problems without a cost to long run growth, but in this view of development it contributes no more. The key assumptions in these models are labor surplus which (a) can be employed with no further payment to the labor and (b) only at constant capital/labor ratios. The one assumption allows no cost to labor, the other allows no return except as complemented with the exact amount of capital.

These assumptions are not likely to hold and as a consequence the models are probably irrelevant. First, if the labor market is in equilibrium initially then increased labor input could still be highly elastic but nevertheless have a real cost. That cost will reflect itself in increased demand for consumer goods with consequent effects on resource allocation and savings rates. Second, given some cost of labor, if there is any substitutability of labor for capital in production it becomes necessary to explore the optimal allocation of resources between capital goods and consumer goods. The path to maximum employment or consumption at a point in time is then not one of investing all resources in capital goods up to that point in time.

The framework for the Second and subsequent Indian Five-Year Plans forms part of the same intellectual stream as the previous models. The theoretical framework for the Second Plan was developed by Mahalanobis (36) in a model very similar to that of Fel'dman (16). The attention was on physical allocation of resources to capital goods, with a minimal employment and consumption constraint. Except for this "social" constraint, labor is in effect viewed as costless. Although the Plans did not explicitly urge a low employment content in growth, they indirectly achieved it. First, they focused on investment in capital goods as the prime constraint to growth. This in practice seems to foster high capital/labor ratios and hence low employment growth. It was in recognition of this that Mahalanobis placed a minimum employment constraint. Second, the Plans recognize investment as requiring savings, and wages as not providing savings, thereby providing a long run rationalization for growth which happens to provide little in wages and leaves narrow distribution of benefits of growth. Thus, there is little economic basis for investment in agriculture--(a) because it is not a capital goods sector, contributing directly to growth, (b) because the Plan in fact provided little additional employment and hence little added demand for wages goods.

Brahmanand and Vakil (4) attacked the Second Five-Year Plan exactly on these grounds--that a much larger supply of wages goods would be required, that they must come largely from agriculture and that insufficient concern and allocation were being provided to that sector. It is not clear to what extent they viewed agriculture as did Sen (50) and Dobb (10) as a sector of diminishing returns. In that view the supply of wages goods is inelastic, and hence increased employment raises the price of that set of goods and diverts to the consumption goods sector an increasing proportion of investment at diminishing returns. That of course poses a development dilemma.

From the preceding comment, it can be seen that the set of models discussed above are not misleading if there is not technological change in foodgrain production--that is, in economies with an elastic labor supply, but in which the principal wages goods are constrained by a fixed land input and rapidly diminishing returns to other inputs. In such an economy, the maximum level of both employment and income at some future point in time occurs if short term employment and consumption is minimized or kept very low, and hence capital formation is maximized or receives a high proportion of resources and those resources are invested largely in the nonagricultural sector. It may seem strange that a similar conclusion follows from alternative assumptions of free labor (3, 6, 26, 57) and increasingly costly labor (i.e., if the supply of food grains is inelastic). The reasons are the assumption of constancy in C/L ratios, the view of additions to capital stock as the only endogenously determined factor of production, and capital formation an inverse function of the payment to wages. With these assumptions, one maximizes growth by minimizing wage payments and maximizing capital formation.

In practice, these views and models have favored investment in capital intensive production processes even in situations in which

additionally employed labor might have had a sufficiently high marginal product to cover its wages and thus not to consume at the net expense of capital formation. These models also divert attention from analysis of potentials for technological change in agriculture which would then give very different results to a model which allowed a real cost to increased employment. We shall return to that question in part IV.

Labor Supply Endogenously
Determined by Population Growth

It is aesthetically tempting to make both capital and labor endogenous to a system of economic growth. Indeed the von Neumann formulation has precisely that elegance (63).

The Harrod-Domar and Solow-Swan formulations do not distinguish labor supply and labor use (assuming full employment and ignoring the niceties of labor-leisure choices) and assume they grow with population. In high income countries rates of population growth appear to be more functions of social values than direct economic forces; hence the assumption of exogenous determination. However, a low income economy is of course more likely to be subject to Malthusian restraints. Growth in the labor force could then be a function of production of consumer goods.

Hahn and Matthews point out that, "Induced change in population may be admitted to the (one sector) model without going to the Malthusian extreme of treating population as in perfectly elastic supply at a given real wage," (19, p. 24). Several economists have devised more complex population functions based on the assumptions that (1) the rate of growth of the labor force (N) is identical with the rate of population growth, and (2) is an increasing function of the real wage (W). Niehans (43) for example, uses a population function of the form:

$$\frac{\dot{N}}{N} = \alpha \, (W - \bar{W})$$

i.e., the proportionate increase in population per unit of time depends linearly on the difference between the actual wage and the minimum subsistence wage ($\bar{W}$). Haavelmo (18) suggests that the law of growth of population is given by:

$$\frac{\dot{N}}{N} = \alpha - \beta \frac{N}{X}$$

where α and β are positive constants and X the total flow of means of subsistence available to the population. (α may be interpreted as the birth rate and $\beta \frac{N}{X}$ the death rate).

These models are, however, open to question for two reasons. First, for most contemporary situations the rate of growth of population seems more a function of public organization to reduce death rates than

of income. Second, and more important, where incomes are so low that population growth is a direct function of income it seems likely that the supply of labor from the existing population would be elastic, for the reasons cited earlier. From the point of view of social policy, it would seem more useful and interesting to focus on the question of greater and more productive utilization of the existing labor force, and the substantial exogenously determined growth in that labor force.

III. Harrod-Domar Type Models and Low Income Countries

The models outlined above bear close resemblance to the basic Harrod-Domar formulation; indeed Wan has commented that "one should never overlook the roles played by the models of Harrod and Domar and their similarities with later models . . ." (64, p. 14).

The Harrod-Domar type approach, which regards growth of capital stock as the only endogenously determined factor of production, may be sensible in the context of high income countries within which the models were constructed because: (1) growth under conditions of full employment is an important and immediate problem which can usefully be analyzed separately from the problem of cyclical unemployment; (2) the supply of consumer goods and real wages have little or no aggregate effect on the supply of labor and hence are considered only in their relation to the objective function.

The Harrod-Domar models do, however, draw attention to features which, with modification, could give perspective to the role of technological change in agriculture in low income countries and shed light on a number of questions of growth, as they do for high income countries.

Modifications of the Basic Harrod-Domar Model to Incorporate Technological Change in Agriculture

In the Harrod-Domar type models the rate of steady state growth is, in effect, set by the exogenously determined rate of population growth. The model can be made relevant to low income countries with an elastic supply of labor and inelastic supply of wages goods (food grains) by simply substituting an exogenously determined, land augmenting rate of technological change in foodgrains production--presumably handled in the same manner as by Solow for labor augmenting technological change (54, p. 35). The determinant of the labor supply is not population growth but the supply of wages goods which is inelastic because of the fixity of the land base; land augmenting technological change relaxes that constraint. Consistent with Harrod-Domar type models, the economy is closed, which eliminates trade as a means of relaxing the land constraint. For a high rate of growth, one prays exogenously for a high rate of land augmenting technological change in agriculture; with that given, one can then analyze the full range of problems explored by Harrod, Domar, Solow, Swan, et. al. Steady state growth--in this context of course--has relevance only to the rather long, but finite, period until the labor supply becomes sufficiently inelastic with respect to the relative price of wages goods so that it, rather than the supply of wages goods, is the limiting factor.

The adaptation of the Harrod-Domar type model to low income countries through this device is clarified as follows:

(A) Assume that the crucial features distinguishing high income from low income countries are:

(i) the elasticity of the labor supply;

(ii) the structure and elasticity of demand for agricultural and nonagricultural commodities.

(B) For both high and low income countries, assume (as is typical in Harrod-Domar derived models):

(i) less than perfect substitutability of capital for labor;
(ii) no technological change;
(iii) wages consumed and profits saved;
(iv) closed economy;
(v) constant returns to scale.

(C) For a high income country assume:

(i) labor supply inelastic;
(iia) consumption of food grains a small proportion of laborers' expenditure and demand inelastic with respect to income;
(iib) consumption of manufactured consumer goods large and demand elastic with respect to income;
(iii) assumption (iia) implies that land is not a significant factor of production; hence there are two relevant factors of production--labor and capital.

Under these conditions, increase in the capital supply at a more rapid rate than the labor supply will:

(i) increase demand for labor relative to capital;
(ii) increase the relative wage rate--i.e., wages increase relative to profits;
(iii) increase the demand for nonagricultural consumer goods;
(iv) decrease the savings rate.

Thus, growth is primarily constrained by rate of increase in labor supply. Per Solow, labor supply may be defined in productivity units to accommodate technological change and rising real income.

(D) For a low income country assume:

(i) labor supply perfectly elastic;
(ii) consumption of food grains a high proportion of laborers' expenditure, and elastic with respect to income;
(iii) land is an important factor of production for food grains, imperfectly substituted for by capital;
(iv) from the above and the assumption of constant returns to scale, it follows that land is limiting to labor input and hence there are two factors of production, land and capital;[1]

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[1]See (34) for an exposition of the view of separate labor and food-grain markets and the implications of their interaction.

(v) that the supply of land to food grains is inelastic with respect to relative price and hence is exogenously determined. The latter assumption then leaves a model very much like Harrod-Domar, but with land replacing labor.

Under these conditions, an increase in the supply of capital at a rate more rapid than the rate of increase of the supply of land to food grains will:

(i) increase the demand for labor relative to capital;
(ii) increase the relative demand for food grains;
(iii) increase the relative price of food grains; therefore,
(iv) increase wages relative to profits;
(v) decrease the savings rate.

Thus, growth is primarily constrained by the rate of increase of agricultural land. Per Solow, the land supply may be defined in productivity units to accommodate technological change, increasing labor utilization and hence rising real income per capita.

IV. The Role in Growth, of Technological Change in Foodgrain Production--Assumptions and Evidence

The foregoing exposition facilitates an explicit statement of the conditions which are required if land augmenting technological change in the foodgrains sector is to contribute to a dynamic process of economic growth rather than making a simple addition to national income. Those conditions are that (1) the aggregate supply of food grains be inelastic with respect to relative price, (2) that laborers have a high marginal propensity to consume food grains and that the rate of substitution of food grains for other consumption commodities be inelastic, (3) that the supply of labor be highly elastic with respect to the real wage rate and (4) that the substitutability of capital for labor in the industrial sector be less than perfect or that there be an absence of technological change in the industrial sector. This is a stringent set of conditions, which nevertheless, appear to hold for many low income countries.

Inelastic Aggregate Supply of Food Grains

The more elastic the supply of food grains with respect to relative price, the less crucial is technological change, as a shifter of the production function, to the supply of wages goods and growth of labor input. In the case of a highly elastic supply of food grains, small increase in relative price and diversion of resources from capital goods to wages goods would allow growth with relatively constant capital/labor ratios.

There appears to be an instinctive tendency among economists to refuse to accept that the aggregate supply of food grains is highly inelastic in a traditional agriculture (e.g., 38, 49). This is substantially the result of misuse of evidence gathered for very different purposes. Over a decade ago, there was debate as to whether or not farmers in low income nations acted in an "economically rational manner" (48). At that time, farmers' response in shifting acreage among crops which were close substitutes in use of land in response to shifts in relative price changes was taken as a reasonable test of the economic rationality argument. From this period, came a series of studies, Raj Krishna (28), Falcon (14) and others, which showed the acreage for individual crops quite responsive to relative price change. These studies in no way showed, or were intended to show, an elastic aggregate supply. First, these studies normally showed acreage of even individual commodities at least somewhat inelastic (14, 28). The test was apparently to show that acreage shifts were less inelastic to relative price changes than for similar situations among "economically rational" farmers of say, the United States. Second, they were, in keeping with the hypothesis being tested, studies of situations purposefully chosen because of the expectation of normally high elasticities of substitution of land from one commodity to another--e.g., cotton in the Punjab (28, 14). Third, they were specifically micro studies of acreage transfer response and so were in no way intended to measure elasticities of aggregate response.

Inelastic aggregate supply response is expected in traditional agriculture for the reasons Ricardo developed so fully in analysis of a

similar economy. Land is a significant factor of production. Since it is relatively fixed and other inputs are not perfect substitutes, they are subject to diminishing returns, per unit costs rise and so supply is inelastic. To Ricardo this was an important restraint on growth. His means of relieving it was through imports.

Measurement of the aggregate response of foodgrains output to change in the terms of trade between agriculture and nonagriculture is, of course, exceedingly complex. The available evidence suggests highly inelastic aggregate supply. Study of supply response for individual commodities which occupy a high proportion of a nation's land area usually shows a highly inelastic supply, (e.g., Raj Krishna (28) for wheat in India, Ruttan et. al. (47) for rice in the Philippines). Robert Herdt's careful, direct effort to measure aggregate supply elasticity for agriculture in the Punjab of India provides elasticities of 0.1 to 0.2 (22). Barnum, with an indirect measure, estimates aggregate supply elasticity of food grains of about 0.1 (1).

These results would appear typical for countries with the bulk of potentially cultivatable land already in intensive use. For such countries, foodgrains supplies can be increased by imports or by technological change of a yield increasing sort. For some countries, land area may be underutilized as a result of institutional factors--as in much of Latin America. In such circumstances, change in institutions may have effects quite analogous to technological change of a yield increasing nature. Imports may, of course, solve the problem for individual countries of modest size, as argued by Ricardo for Britain. But for the aggregate of all low income countries, or individual large ones such as China and India, imports may only convert a domestic inelasticity into an international one.

Since the inelasticity of supply arises from the fixity of the land base, it follows that agricultural products which use little land, due to their relative unimportance or due to intensity of cultivation will not evidence inelastic supply for this reason. Fruits and vegetables, livestock produced on imported feed, indeed a high proportion of the agricultural commodities with elastic demand fit in this category. It is the food grains, which provide the basic calorie source for the bulk of mankind, which evidences the inelastic aggregate supply. For these commodities domestic production increase other than through a rapidly rising per unit cost must depend on technological change of a land augmenting nature or institutional changes having a similar effect.

High Marginal Propensity of Laborers to Consume Food Grains

Inelastic supply of food grains would not be limiting to labor input if laborers' marginal propensity to consume food grains is low or if the elasticity of substitution is high between food grains and other consumer goods with more elastic supply. Under these conditions, technological change in industry could compensate for diminishing returns in agriculture. To hold real wage rates constant the required rate of technological improvement in industry would have to equal or exceed the

rate of decline in agricultural productivity due to diminishing returns to land multiplied by the weighted proportion of food grains in total consumption. Thus, the proportionate burden on technological change in industry is greater when agriculture represents a high proportion of consumption. Also, the more inelastic the cross-elasticities of demand, the greater will have to be the rate of technological change in industry to balance diminishing returns in foodgrains production.

As Engel observed, low income people spend the bulk of their incomes on food. The basic, land produced, calorie sources bulk particularly large for the low income consumer. For India, defining the laboring class as the lower 20 percent in the income distribution, 54 percent of laborers' total income is spent on food grains alone and 76 percent on all food commodities; in this income class, at the margin, 59 percent and 79 percent of increments to income is spent respectively on these commodities (7). Comparative data on income elasticities of demand for other low income countries suggest a comparable importance of food and food grains as wages goods (25, p. 74).

The evidence with respect to cross-elasticities is of course much less substantial. One may hypothesize that a major commodity group, of continued biological importance to low income people, would have relatively inelastic cross-elasticities. The more reliance is on the cheapest source of calories the less scope there is for substitution. Circumstantial evidence of relatively rapid increases in relative foodgrain prices when demand increases moderately more rapidly than supply is consistent with this hypothesis (e.g., Lele and Mellor (33) for evidence from India in the early 1960's).

Elastic Supply of Labor

Inelasticity in the supply of wages goods will not restrain labor input unless the supply of labor itself is more elastic.[2] In a high income country such as the United States, labor force participation in the sense of hours worked per year has been declining as real wages have risen, suggesting a backward bending supply curve and justifying the usual growth model assumption of a highly inelastic supply of labor. With this assumption, ignoring labor input as an endogenous growth variable seems reasonable and thus wages goods, including food grains, have no endogenous role as determinants of the growth rate.

Intuitively, the situation seems sharply different in low income countries. Certainly the current concern with secular unemployment suggests this. In practice the evidence and the logic are highly complex and require careful new study. Unfortunately, much of the past effort which might have gone to comprehensive study of labor supply schedules went instead to study this misconceived problem of whether or not the marginal product of labor in agriculture is zero or higher.

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[2]For this reason, it is analytically useful to separate the foodgrain supply and the labor supply into two separate but mutually related markets as Lele and I have done in our earlier model (34).

A substantial body of literature (35, 15, etc.) argues the availability of "unlimited" supplies of low productivity labor in the rural sector--implying a highly elastic labor supply. The marginal productivity of labor in agriculture need not be zero to provide a highly elastic labor supply; nor does one even have to assume labor market imperfection, as does so much of the literature on low income countries (39).

Two factors suggest a highly elastic supply of labor in low income countries. First, the rate of growth of population and hence of labor force, even with constant participation rates, is rapid relative to the rate of growth of capital stock. Second, even if labor absorption is more rapid than natural increase in labor force, it appears that the conditions of employment in agriculture are such that increased employment opportunity at only small increases in real wage rate will elicit a large increase in supply. This could arise from drawing down stocks of completely idle labor. More likely, agricultural labor is seasonally fully employed but small expenditures on mechanization or reorganization of production could save large quantities of labor at seasonal peaks and provide an elastic supply for large increments in demand.

Thus, the schedule of supply elasticities for aggregate labor supply from agriculture depends on (a) the relative size of the agricultural sector; (b) the technical conditions of agricultural production with the seasonality of agricultural employment a potentially important variable, and (c) the family labor-leisure function (39). These factors are complex in agriculture because of the seasonality of labor demand. For example, the quantity of employment taken and the wage rate and presumably the marginal productivity vary greatly by season. It is thus difficult to know what it is that is to be equated among sectors--the wage rate at what season; the annual income; or more likely, some combination of these. It seems likely, therefore, that a number of complex factors influence decisions to migrate between and within sectors, resulting in behavior patterns which appear different from those in high income economies. The use of market imperfections as an explanation is clearly unsatisfactory; what is needed is a far more comprehensive understanding of the operation of labor market mechanisms than exists at present.

What little empirical evidence there is seems consistent with a highly elastic supply of labor to the nonagricultural sector--at least in the sense of adjustments being possible which allow a large increase in the supply of labor with little increase in the real wage rate. In the case of Japan, Umemura (61) shows real wages rising relatively little between 1885 and 1911, although the labor force participation rate rose sharply--more hours per worker and more workers per family. Thus, real income of laborers rose while wage rates held relatively constant.

Similarly, T. H. Lee (31, Table 3, p. 38) shows for Taiwan relatively small increases in real wages while participation rose sharply. In both Japan and Taiwan, labor productivity rose sharply in agriculture concurrent with land augmenting technological change. In Taiwan, net agricultural production increased at an average annual growth rate of 3 percent between 1911 and 1960. The increase in labor productivity was 1.8 percent per annum (30, p. 17). According to Ohkawa and Rosovsky (44, pp. 46-56),

the average annual growth rate of net agricultural output in Japan averaged 2.3 percent between 1878 and 1917, and labor productivity increased annually by 2.6 percent. From 1918 to 1940, both net output and labor productivity grew at annual rates of less than one percent.

Thus, although the processes may be complex, it appears that labor supply can increase rapidly in low income countries if jobs and wage goods are available. Thus, supply of wage goods can conceivably play a direct role both in growth and contributing to utility.

The assumption should be made explicit that increased labor utilization requires increased wage payments--i.e., that there is no forced labor. Some of the "labor surplus" postulations in effect assume forced labor--previously unutilized labor put to work and still subsisting on the previous source of subsistence, whatever and wherever it came from. In practice, it appears that such forced labor schemes are infrequent.

Less Than Perfect Substitutability of Capital for Labor

To the extent that capital and labor are less than perfect substitutes, restraint on labor supply will require an increasingly high rate of savings simply to maintain a given rate of growth. This is then a key assumption to a large class of growth models. The Harrod-Domar type models assume fixed capital labor ratios; modified versions at least assume less than perfect substitutability between the two factors. Perfect substitutability of capital and labor is of course an uninteresting case.

The empirical evidence is difficult to appraise; the difficulty, of course, partly arises because changes in capital/labor ratios are achieved through manipulation of the structure of domestic demand and trade as well as by choice of technology within a given structure (33). The literature, however, clearly indicates that the elasticities of substitution of capital and labor are generally low (8, 52). Indeed, it seems likely that emphasis on capital in growth plans may have resulted in uneconomically high capital intensity such that restructuring of growth towards labor may increase high returns (33).

Thus, we set a very stringent--but apparently not unrealistic--set of conditions which must be met if agriculture is to play a substantial role in economic growth and hence to be relevant in models of economic growth. The data do suggest that wages goods may be a significant restraint to growth in low income countries and that technological change in foodgrains production is likely to be the primary means of relaxing the wages goods constraint. In view of this we proceed to examination of models which include a wages goods constraint and then give special attention to the incorporation of technological change.

V. Dualistic Models

Dualistic models in general lack elegance. Like the more capital oriented steady state models, the dualistic models are also oriented towards only one endogenous factor of production--in their case, labor. But, by the very nature of the phenomena with which they deal they cannot exhibit steady state growth. In addition, the dualistic models are often stated to depend on market imperfections of an "uneconomic" nature which is by definition inelegant economics. However, the dualistic models do focus on change in labor participation rates, which may well be the key factor differentiating the growth processes of high income and low income economies. The supply of labor in low income countries is probably highly elastic but becoming less elastic over time. Such circumstance offers short run potential for employment growth more rapid than population growth. Under these conditions, the capital oriented, fixed rate of growth of labor, steady state growth models are inapplicable. Similarly, if labor force participation rates are an important part of economic growth in low income countries, then a focus on that aspect seems as reasonable an analytical simplification as a focus on capital. Thus, if one must choose rather than combine, the dualistic, labor oriented models perhaps offer more potential to increase understanding of growth in low income economies than do the capital oriented models.

Dualistic models touch upon three aspects of increased labor utilization rates--labor transfer among sectors; wages goods production; and wages goods transfers among sectors. Various models emphasize different aspects.

Labor Transfer

The early dualistic models emphasized the growth stimulating effects of labor transfers from agriculture to nonagriculture (35, 46). To simplify they assumed that the rules of operation of labor markets differed in different sectors and often assumed imperfect markets.

The original formulation by W. Arthur Lewis was intended to emphasize potentials for creating capital by mobilizing low productivity labor from the agricultural sector (35). The Lewis model is termed a "classical" model in that it assumed laborers in agriculture received incomes greater than their marginal product. This seemed reasonable from the casual observation of considerable idleness in agriculture and had desirable growth implications in that the labor supply for productive work would be highly elastic and offered potential of a high rate of savings if labor productivity in the nonagricultural sector could be raised above the wage at which the supply was so elastic. If labor receives more than its marginal product in agriculture and if wages and marginal product in nonagriculture are equal, then aggregate production increases with transfer of labor between sectors, while labor's income remains constant. The Lewis model is more formally elaborated by Fei and Ranis (15) with of course, the consequence of underlining the implications of a number of the assumptions.

The most important deficiency of the labor market assumption in the classical model is its tendency to divert attention from the role of technological change in agriculture. If labor is already free, what need to produce more wages goods at lower cost? Seen in a more complex manner, the classical model attaches sole importance to transfer of labor from agriculture to industry on grounds of differences in marginal productivity. If, however, there is an operable labor market, labor productivity must at least be maintained and probably at least slightly increased if more labor is to be utilized. Economic development requires an economic transformation with an increasing proportion of the labor force in industry, but the rationale lies not with an initial discrete difference in labor productivity in the two sectors, but with differences in demand elasticities for products of the two sectors. That factor, in turn, is operative primarily in an environment of rising per capita incomes, perhaps modified by the demand effects of redistribution of income.

Jorgenson, (27), in a "neoclassical" model, lessens the dependence of dualistic models on an assumption of imperfect markets by assuming (1) that agricultural labor produces and receives a positive marginal product and (2) transfers to the nonagricultural sector when the wage rate in that sector provides an income equal to the average income in agriculture, and (3) the wage rate in nonagriculture is equal to labor's marginal product in that sector. These are essentially the same assumptions made by Lele and Mellor (34). However, Jorgenson in essence, carries his view of the agricultural labor market no further than to say that agricultural labor is productively employed at the margin and that removing it would reduce agricultural output with the effect of a real wage cost to society of transferring labor from agriculture to industry. Although this argument is probably correct (45, 48) the point of a real cost of labor could also be made by arguing an economic labor market in which laborers would demand payment for additional labor. This latter argument is developed in detail by Mellor (39) and by Sen (51), but is not fitted into the dualistic model context.

If indeed intersectoral labor transfers and changes in labor participation rates are an important aspect of growth in low income nations, then models must go beyond the "neoclassical" assumptions of Jorgenson and Lele and Mellor and deal with the great complexities of labor markets in such economies. The current simplistic assumptions are part of the long tradition of viewing behavior in low income countries which seemed different to that of high income countries in terms of market imperfections. The work by Mellor (39) and Sen (51) with respect to rural household labor-leisure preferences sheds some light on these questions. Todaro (60) shows clearly how apparently aberrent behavior in rural-urban labor markets is explained not by imperfect response by laborers but by imperfect capital markets and public regulations. Beyond this, an emphasis on labor mobilization and transfer of labor must recognize the intense seasonal fluctuations not only in employment, but in wage rates and the implications of those to the nature of the labor supply function. Such analysis will then indicate the extent to which the effect of a highly elastic labor supply in low income countries is the

result of the point of operation on the labor-leisure function, overt unemployment, or low cost of labor augmenting technological change and institutional reorganization of agriculture. That in turn will affect the form of a useful analytical model.

Wages Goods Production

The classical models of course ignore the need to increase wages goods production because of the nature of the labor supply function they assume. An emphasis on increasing the supply of wages goods may take two courses: (1) incorporation of technological change within the model (27, 34) or (2) increased production through higher prices or greater investment without technological change (9, 23).

By assuming a positive marginal product of labor, a rigid wage rate at the subsistence level, and perfectly inelastic supply of wages goods, Jorgenson demonstrates the crucial role of technological change in agriculture to transfer of labor to other sectors. Jorgenson assumes no capital in agriculture, fixed land supply and "full employment" of labor. Thus, the only means by which production can be maintained with labor transfer is through technological change which increases output per man. And, although technological change in agriculture plays a key role in the Jorgenson model, he assumes neutral technological change. This is in sharp contrast to the reality of the current high yielding varieties (42). Thus, the Jorgenson analysis fails to deal with important aspects of land augmenting technological change of the current types.

In contrast, both Dixit (9) and Hornby (23) deal with increasing production of wages goods, but view the question in the context of no change in technology and therefore, as a response to changes in relative prices and public investment policy. This approach, however, leads to the position discussed earlier, diminishing returns, rising prices of wages goods and hence of increasing labor costs and substitution of capital for labor.

Lele and Mellor's analysis does emphasize land augmenting technological change. It does not, however, go the next step of dealing with the factors determining technological change in agriculture. From the Lele-Mellor analysis a logical extension would be to incorporate technological change endogenously (see 21).

Wages Goods Transfer

Wages goods not only must be produced but they must also be transferred with labor to the point of increased employment. This is usually assumed to occur automatically. Fei and Ranis provide an extensive discussion of transfer mechanisms but do not formally incorporate it in their model (15). Jorgenson does not treat the question. Various others (29, 2) treat the question of marketable surplus but do not incorporate it formally in models of growth or relate it to labor supply. Zarembka (65) does treat the question but views the labor and food markets as operating simultaneously.

The Lele-Mellor model makes a dual addition to previous models by: (1) refining the analysis of separate food and labor markets and (2) pointing out and incorporating income distribution in the foodgrains sector as a prime determinant of (a) marketings and hence of transfer of wages goods and (b) level of wages. The distribution of income is linked to the nature of technological change in agriculture. The Lele-Mellor model does allow increased per capita laborer's incomes and hence a basis for absorbing an increase in per capita foodgrain supplies. Less than perfectly elastic labor supply could be incorporated. The model then allows exploration of a wide range of phenomena and shows how quite different values may be taken for terms of trade, capital/labor ratios and other variables depending on the initial assumption.

Capital Formation and Transfer

The Lele-Mellor model, as the Fei-Ranis and Jorgenson models, treats capital formation only in the nonagricultural sector. This is a significant deficiency in these models. Generation of technological change in agriculture may itself require capital and is in practice embodied in varying amounts of capital.[3] Concurrently, absorption of additional labor released to the nonagricultural sector requires added capital. Thus the pressure on capital supplies may increase, raising a complex problem of allocation of resources between wages goods production and capital goods production and of allocation of capital between sectors.

The current work of Uma Lele extends the Lele-Mellor dualistic model to explore the effect of biased technological change in agriculture on capital formation and intersectoral capital flows as well as its effects on the food and labor markets. This effort leads logically to a synthesis of the Harrod-Domar type model and the dualistic models.

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[3]In this respect, Marty (37, p. 439), has commented that, "The Jorgenson model illustrates, in its most extreme form, the separation of technical progress from the rate of investment. In the agricultural sector, we are asked to conceive a constant rate of technological change which somehow can be influenced by social policy and yet is totally devoid of embodiment in capital formation." Fei and Ranis (15, p. 217) justify their exclusion of capital on the grounds that, "Agricultural productivity change may be mainly related to the success in insuring mass participation in the search for indigenous technological change, with relatively little need for new capital formation . . ." The analysis of technological change in agriculture by Hayami and Ruttan (21) lends itself to incorporation in a model which includes both capital and labor.

VI. Towards a Relevant Synthesis

The Harrod-Domar derived models emphasize capital and capital allocations, and ignore labor participation rates and wages goods as endogenous elements of growth. Dualistic models tend to the opposite position. Synthesis requires a merging of the positions. The allocational problem for a low income economy is then stated as the allocation of resources between wages goods and capital goods.

The literature does contain a few efforts in this direction. Von Neumann of course, dealt with the problem in a highly abstracted context. Dobb (10, 11) clearly understood the problem.[4] A. K. Sen (50) also noted the problem and indeed, in the context of study of choice of technology developed a model which treats allocation between wages goods and capital goods. Findlay (17) presents a similar model for examining allocations between consumer and capital goods with the size of the labor force in the industrial sector determined by consumer goods production.

None of these models seem to have sparked substantial interest, leading to improvements and elaborations. The reasons are probably related to the actual and believed conditions of the principal consumer goods sector--agriculture.[5] Both Dobb and Sen saw agriculture as highly and increasingly capital intensive. This, of course, means that the real cost of labor increases over time. This eventually drives one to the same emphasis in obtaining growth through capital alone as the models which ignore labor. Thus, there seems little sense in having a more complex model to arrive at the same end. The view of Dobb and Sen is consistent with the view expressed earlier about aggregate supply elasticity in traditional agriculture. It is the presence of land augmenting technological change which alters the conditions sufficiently to make the more complex case interesting. Thus the necessity of incorporating such technological change into a view of the growth of low income economies. Since such technological change may play such a key role attention must be given to its actual attributes, particularly the highly varying factor bias.

Viewing the growth problem in these terms will have important implications to (a) placing the role of agriculture in economic development, (b) the processes of labor mobilization, (c) choices of factor proportions, and (d) international trade.

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[4]He comments that although the relative priority attached to wages goods and capital goods "may very well vary in different cases as well as change at different stages of development . . . there is no conflict between their respective implications, which can be regarded as constituent elements of any planning policy designed to maximize growth," (11, p. 111).

[5]It may also be that the capital oriented models provided intellectual support for large scale, modern, public sector industry, which was politically desirable in India, the largest consumer of the economics of growth models and planning. Thus, the economists following that approach prospered, spawned students, schools of thought and many books which the others did not.

The view set forth here of course gives a primary place to agriculture in determining both the role and the path of economic growth. Attention must be given to inducing land augmenting technological change and adjusting to it. Particular attention must be given to determinants of marketable surplus.

With both capital and labor as economic variables the question of factor proportions becomes important. With relaxation of the wages good restraint, interest must center on means of reducing capital intensity and raising savings rates including changes in scale of production, changes in consumption patterns and international trade. Since, by definition, in this approach increased labor input involves increased consumption, the structure of growth will appropriately move towards consumer goods also. The range in choice of technology may be greater in consumer goods than in capital goods. It should be emphasized that the types of technological change in agriculture now being experienced are adding substantially to national income. How that income is expanded is of great importance to the rate and pattern of growth. Lele and I trace these "linkages" in some detail in a forthcoming paper (42).

Reduction of a wages good restraint will require much more emphasis than in the past on precise definition of labor supply functions. Particularly in agricultural economies, the complexity of the subject has led to the assumption of market imperfections and noneconomic behavior as explanations of labor market behavior. Such short cuts are likely to lead to serious error in the types of formulations suggested here. The approach to the analysis of growth outlined above also provides scope for analyzing international differences in factor proportions in growth and therefore, a basis for Hechscher-Ohlin type trade. It will be noted that most existing approaches to growth do not provide that scope.

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