THE DISCREPANCY BETWEEN SOCIAL AND PRIVATE RETURNS TO MECHANIZATION IN THE EARLY PHASE OF ECONOMIC DEVELOPMENT

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The technical problems that are encountered in the mechanized production of tropical root crops are likely to divert attention from certain economic considerations that cast doubt on the wisdom of applying scarce resources of capital to the mechanization of root crop production. Increasing attention is being given, perhaps most vociferously in the United States, to a "world food crisis" resulting from rapid growth of demand for food which in a number of less developed countries is not being matched by equally rapid growth of domestic production. Although unprecedentedly rapid growth of population is the major component of this growth of demand, the increase in demand for food associated with rising per capita incomes is also an important factor.

The other conspicuous feature of the attention being given to the world food crisis is the growing recognition that expansion of agricultural output "depends predominantly," in Schultz's terminology, "upon the availability and price of modern (nontraditional) agricultural factors".[1] Closely associated with this emphasis on the need for farmers to make use of "a profitable new set of factors" is the conviction that agriculture has been assigned too low a priority in developing countries with resulting underinvestment and inadequate price incentives for farmers. Heady has even suggested that it would be a good policy to maintain "producer prices which favor growth and output but subsidize consumers at lower prices. . ."[2]

Although neglect of measures to foster increased agricultural production can unquestionably have serious consequences, there is also a danger in focusing too exclusively on the food supply implications of rapid population growth. The purpose of the present paper is, first of all, to emphasize that rapid growth also has important implications with respect to the process of economic transformation whereby the overwhelming importance of agriculture in an underdeveloped economy is modified by growth of the nonfarm sectors. The interrelationships between the transformation of the productive structure of an economy and the development of the agricultural sector is stressed because the possibility of creating a highly productive agricultural economy is so heavily dependent upon the process of economic transformation. And finally, it will be suggested that the degree of structural transformation that has taken place in a national economy has strong influence in determining *which* "modern agricultural factors" are most appropriate for achieving expanded production. Although farm machinery is often regarded as the hall-

1 W. T. Schultz, **Transforming Traditional Agriculture**, New Haven, Connecticut, 1964 p. 145.

2 E. O. Heady, **A Recipe For Meeting The World Food Crisis,** Iowa State University, Report 28, Ames, 1966. p. 7.

mark of a modern agriculture it will be argued that investment in mechanization is likely to be uneconomic from a social point of view until considerable structural transformation has taken place.

Just as tractors are commonly regarded as the symbol of a modern agriculture, industrialization is often viewed as an overriding goal because it symbolizes a modern economy. Excess zeal in pursuing the goal of industrialization has often been self-defeating, particularly when a high and unbalanced tariff structure has fostered the creation of high-cost domestic industries and resulted in such distorted price relationships that "import substitution" has actually resulted in increased dependence on imports.[3] Nevertheless, sound industrial development is an essential component of economic growth ; agricultural and industrial development are goals that must be pursued simultaneously.

Three aspects of the interaction between agricultural and industrial development are of critical importance to the modernization of agriculture and raising the productivity of a nation's farmers. First of all, the expansion of the market for cash sales of agricultural products as a growing percentage of the population comes to depend on purchased food is of profound importance to the agricultural sector. Secondly, the enlarged use of purchased inputs, a fundamental characteristic of a progressive agriculture, depends to a considerable extent on increased local production of new and improved inputs — higher yielding plant material, fertilizers, insecticides, improved tools, equipment for drying or grating, etc. — as well as the enlarged money income that makes such purchases possible. And finally, the growth of nonfarm employment is a critical requirement for increasing labour productivity in agriculture since it is the availability of alternative job opportunities that initially slows the increase in the size of the farm labour force and eventually makes possible a reduction in its absolute size. Moreover, the growth of nonfarm employment provides the income base for the nonfarm population dependent on purchased food that increases both in absolute size and in relation to the size of the farm labour force.

The bearing of international trade on these interactions must be noted. The possibilities that exist for exporting agricultural products obviously represent an additional means whereby farm cash incomes can be increased, a possibility that is particularly significant in the early phase of development. And imports of certain types of farm inputs are likely to be highly beneficial to developing countries. Domestic production of farm requisites such as nitrogen fertilizers and heavy farm machinery is likely to be much more costly because the local market is too small to realize economies of scale, and the lack of capital, professional and technical personnel, and complementary industrial activities also increase the cost of local manufacture. For most developing countries the possibilities opened up by international trade qualify but do not by any means nullify the dependence of agricultural development on the process of structural transformation.

The nature of these interactions between agriculture and the rest of the economy clearly depends upon the degree of structural transformation that has taken

3 For discussion of this problem and additional references, see R. I. McKinnon, "Intermediate Products and Differential Tariffs : A Generalization of Lerner's Symmetry Theorem," **The Quarterly Journal of Economics**, November 1966.

place, measured most simply by agriculture's share in the total population and labour force. Agriculture's existing weight in a country's total labour force also has a powerful influence on the rate and direction of change in the size of the farm labour force. Countries that are classified as "underdeveloped" differ markedly in the extent to which the occupational composition of their labour force has been modified. Whereas most of the less developed countries in Asia and Africa still have some 70 to 80 per cent of their labour force in agriculture, in some of the countries of Latin America this percentage has fallen to 50 per cent or less.

Projections of the growth of the total, farm, and nonfarm labour force of a country are highly sensitive to agriculture's initial share in the total labour force as well as to the rate of growth of the total labour force. The influence of these factors can be shown most concisely by the following identity :

$$P'_A \equiv \frac{P_T}{P_A} P'_T - \frac{P_N}{P_A} P'_N$$

in which P_T, P_A, and P_N stand for the total, farm, and nonfarm labour force respectively and the primed variables represent annual percentage rates of change. Given the rate of growth of the total labour force and the rate of increase in nonfarm employment, the rate of change in the farm labour force obviously depends upon the ratio of total population to the farm labour force and the ratio of nonfarm employment to the farm labour force. If we consider three hypothetical countries — Earlyphasia in which 80 per cent of its total labour force is in agriculture, Middlephasia with 50 per cent in agriculture and Latephasia with only 25 per cent of the total labour force in agriculture — the strong influence of agriculture's initial share in the rate of change in the farm labour force can be illustrated easily. The two weighting coefficients and the relationship between them is summarized in the following tabulation for each of the three hypothetical situations :

		P_T/P_A	P_N/P_A	Coefficient of P'_T divided by the coefficient of P'_N
Earlyphasia :	$P_A/P_A = .8$	$\frac{1.0}{.8} = 1.25$	$\frac{.2}{.8} = .25$	5
Middlephasia :	$P_A/P_T = .5$	$\frac{1.0}{.5} = .20$	$\frac{.5}{.5} = 1$	2
Latephasia :	$P_A/P = .25$	$\frac{1.0}{.25} = 4.0$	$\frac{.75}{.25} = 3$	1.25

Finally, if we relate these hypothetical situations to the identity that shows the dependence of the rate of change of the farm labour force on these weighting factors and on the rates of change in the total and nonfarm labour force, it is apparent that in Earlyphasia the rate of increase in nonfarm employment would have to be five times as rapid as the rate of growth of the total labour force to maintain a constant farm labour force. But in Middlephasia, if nonfarm employment increases twice as rapidly as the total labour force, the farm labour force will not increase, and for a Latephasia country, if the rate of increase in the nonfarm

labour force exceeds the rate of increase in the total labour force by a mere 25 per cent the absolute size of farm labour force will be declining.

The significance of this simple exercise in the "arithmetic of structural transformation" is magnified by two highly important characteristics of the contemporary underdeveloped countries. First is the unprecedentedly rapid growth of population which, with a lag, implies similar rapid rates of increase in their total labour force. Second is the combination of circumstances that lead to a rather abundance of labour. The reasons for this are complex, but it is sufficient to note here that this is a tendency that is not easily changed, in part because for a good many industrial processes the technical superiority of the latest capital - intensive technologies, developed in the economically advanced countries, is so decisive that it more than offsets the difference in relative factor prices in an underdeveloped country.[4]

Rates of growth of total population and labour force of 2 or 3 per cent have become commonplace in the contemporary less developed countries, and it appears to be extremely difficult to achieve expansion of nonfarm employment at a substantially higher rate than the total labour force is growing. Recent experience suggests that rates of growth of nonfarm employment of 3 per cent must be regarded as rapid and 4.5 per cent appears to be something of an upper limit. If total labour force is growing at only one per cent, the rate that was typical of the contemporary industrialized countries as they experienced their "population explosion," growth of nonfarm employment at 3 per cent per annum will lead to rapid structural transformation. Even a country of the Earlyphasia variety would begin to register a decline in the absolute size of its farm labour force after only 29 years if those conditions were fulfilled. But if the total labour force is growing at 2 per cent while nonfarm employment is increasing at 3 per cent, this turning point would not be reached for approximately 125 years. If the total labour force and nonfarm employment are both increasing at 3 per cent, even the relative size of the farm labour force will not decline. And with a 3 per cent rate of growth of the total labour force the rate of structural transformation would be slow even if it were combined with extremely rapid growth of nonfarm employment ; a rate of 4.5 per cent annually would only lead to a decline from 80 to about 60 per cent in agriculture's share of the total labour force in the course of 50 years. The comparisons in the tabulation below point up the sharp contrast in the prospects for changes in the occupational composition of the labour force in countries of the Earlyphasia and Middlephasia varieties over a 50-year period for which hypothetical growth paths have been computed.[5]

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4 For an excellent discussion of these issues, see W. A. Lewis, **Development Planning**, New York, 1966.

5 For fuller detail including a series of charts showing hypothetical growth paths of total farm, and nonfarm labour force, see B.F. Johnston, **Agriculture and Economic Development: The Relevance of the Japanese Experience, Food Research Institute Studies**, Vol. V1, No. 3, 1966 pp. 267–73 and Appendix III.

	Earlyphasia		Middlephasia	
	Farm labour force as % of total at end of 50 years	Years before farm labour force begins to decline	Farm labour force as % of total at end of 50 years	Years before farm labour force begins to decline
A. If total labour force is increasing at 1% and nonfarm labour force is increasing at 3%	48	29	2 *	0
B. If total labour force is increasing at 2% and nonfarm labour force is increasing at 3%	68	50	19	32
C. If total labour force is increasing at 3% and nonfarm labour force is increasing at 4.5%	59	50	2 *	21

The combined influence of high rates of growth of population and labour force and a situation in which agriculture's initial share in the total labour force is large have a number of important implications. Perhaps the most fundamental is that positive measures to encourage family planning to bring birthrates into balance with sharply reduced death rates is crucial for the realization of a country's goals for general economic growth. There are some grounds for optimism that just as the decline in death rates for the contemporary underdeveloped countries has been unprecedentedly rapid, so also will be the decline in birthrates. The well-informed director of the Population Council's demographic division concludes, however, that the rate of population growth in developing countries is not likely to be reduced substantially in less than about two decades ; and a further 15 to 20 years will be required before a reduction in birthrates will show up as a reduced rate of growth of the labour force.[6]

Of principal concern in the present context, however, are the ways in which the prospective changes in the total and farm labour force influence the priority to be given to investment in mechanization as opposed to alternative measures for promoting expanded agricultural production. The following points appear to be particularly relevant to the choice of measures for promoting agricultural development.

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* As the nonfarm labour force becomes a large fraction of the total, it obviously becomes impossible for its rate of growth to substantially exceed the growth rate of the total labour force. The computations summarized here made the simplifying assumption of constant rates of growth of the total and nonfarm labour force. If the differential between the assumed growth rates is large and the initial conditions are those of Middlephasia, a "year of absurdity" will be reached within the 50-year period in which the nonfarm labour force exceeds the total.

6 D. Kirk and G. Jones, **World Population: Causes and Consequences of Growth Differentials**, Iowa State University, Ames, November 1966.

(1) The familiar arguments concerning the need for agricultural mechanization in order to "release" labour for nonfarm jobs have little validity under the conditions that prevail in underdeveloped countries today. The problem instead is to achieve sufficiently rapid expansion of job opportunities to absorb the new entrants to the industrial labour market. The growth of sizable "floating populations" in the environs of Buenos Aires, Dakar, Calcutta, Lagos, and other cities in developing countries is visible evidence of the magnitude of the problem.

(2) Owing to its special character as the "self-employment sector" par excellence in an underdeveloped country, agriculture must for many years continue to provide productive employment for the bulk of the labour force — and a large fraction of the annual additions to the labour force. Thus the size of the farm labour force in most of the developing countries must be regarded as a datum determined by exogenous factors. Hence, the social returns to investment in mechanization that mainly substitutes for labour are likely to be low. On the other hand, investments in inexpensive farm implements that serve to ease seasonal labour bottlenecks may yield high returns, in part because they contribute to fuller year-around utilization of the farm labour force.

(3) Policies that will lead to more rapid growth of nonfarm employment are important. There is certainly some scope for reducing the queuing up for available jobs in urban areas by narrowing the excessive wage differentials that often characterize the "modern" industrial sector and for encouraging a less capital-intensive pattern of investment in other ways as well. But for most developing countries such efforts can only lessen, not eliminate, the need for agriculture to continue to absorb a large part of the annual additions to the labour force. No other conclusion seems possible given the prospective rate of growth of population and the magnitude of the capital requirements for transportation, educational facilities, and other types of infrastrucure — as well as for agricultural and industrial development.

(4) Developing nations thus face a formidable challenge if they are simultaneously to satisfy the resource requirements for agricultural expansion and for industrial development. The fact of rapid population growth underscores the need for a substantial rate of expansion in farm output ; it also increases the capital requirements for structural transformation. But the extent to which agriculture competes with the industrial sector for the scarce resources of capital and foreign exchange will vary considerably depending upon the type of agricultural development strategy that is pursued.

(5) Agricultural research and extension programs to develop technical innovations that are suitable to the existing small-scale farm units and which substantially raise the productivity of the farm-supplied inputs of labour and land that have relatively low opportunity cost are of key importance. Historical experience in Japan, Taiwan, Mexico,[7] and other countries indicates that agricultural research

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7 Mexico's experience has differed considerably from that of Japan and Taiwan in the extent to which the increase in output has been concentrated in a relatively small number of large, capital-intensive farm units. It has been argued elsewhere that the "Japanese model" has greater relevance to contemporary underdeveloped countries than the "Mexican model" (Johnston, 1966).

and extension programs aimed at the development and widespread dissemination of technical innovations which will lead to substantial increases in crop yields can be very effective in bringing about increases in farm productivity — in output per unit of total input. Varietal improvement combined with increasingly heavy application of chemical fertilizers and use of insecticides and other means for controlling pest damage stand out as the most strategic factors for increasing agricultural production because they complement the labour and land resources already committed to agriculture. Considerable progress in varietal improvement has already been realized in spite of the limited resources that have been devoted to research relating to tropical foodcrops, and progress in plant genetics, experimental design, soil science, and other technical fields will facilitate further significant progress as research efforts are intensified. Technical progress in the manufacture of chemical fertilizers, which has already led to large reductions in their real cost, increases the likelihood that farm output expansion based heavily on increased use of fertilizers will be profitable.

(6) Failure to exploit the opportunities that exist for relatively low-cost expansion of agricultural output is to be attributed largely to inadequate research and extension programs ; the associated inputs of high-yielding varieties and knowledge of fertilizer requirements under a wide variety of conditions that are essential in order to reap the potential benefits from substantially expanded use of fertilizers are lacking. Low levels of farm cash income and foreign exchange shortages also militate against expanded use of fertilizers, especially on root crops which are grown in large part to satisfy subsistence needs. To the extent that this is a limiting factor, it applies a fortiori to the requirements for purchase of farm machinery.

(7) The social as well as the private returns to investment in mechanical equipment will increase, of course, as structural transformation brings about a gradual decline in the relative and eventually the absolute size of the farm labour force. Expansion of the market for purchased agricultural products implies higher farm cash incomes and increased ability to purchase inputs ; and the need to increase output per farm worker increases at an accelerating rate as the farm labour force declines from some 70 to 80 per cent of the total to the 20 per cent and less that characterizes developed economies. These changes also mean a great increase in the employment opportunities available in the nonfarm sectors. This will obviously result in a bidding up of farm wage rates, and a rise in the opportunity cost of the labour of self-employed farm workers.

These considerations help to explain why mechanized production is generally of such limited importance in the less developed countries, particularly those that resemble the Earlyphasia situation described above. Where labour is abundant and wage rates low and where capital is scarce and interest rates high; purchase of expensive items of farm equipment is likely to be unprofitable. The tendency to equate agricultural modernization with mechanization may, however, lead to government policies to encourage mechanization through subsidies, duty free imports of farm machinery and fuel, and creation of large farm units that, superficially, overcome the scale barrier to mechanization.

In addition, a limited number of farm operators may find agricultural mechanization profitable even though the social returns to such investment are much lower than from expenditures for agricultural research and extension edu-

cation. This situation appears to characterize some of the Latin American countries where the agricultural sector is characterized by a "dual-size structure". Owing to the size of the farm population relative to the cultivated area, the average number of farm workers per cultivated acre is necessarily large. But a large fraction of the farm population is crowded on to extremely small holdings that produce only a very small marketable surplus and, accordingly, have little cash income for purchased inputs. At the opposite extreme in this bimodal distribution of farm land, a relatively small number of large farm operators control a major part of the agricultural land and account for the bulk of commercialized production.

Although the wages paid farm workers by these large land owners are meager, they are frequently above the marginal product of labour in the minifundia because of the tendency of farmers with extremely limited resources of land and capital to push their inputs of labour to a point where its marginal product has fallen appreciably below its average product.[8] And it is, of course the average product of members of farm households that determines the income that must be at least matched to attract hired labour. Furthermore, both the monetary and non-monetary costs of supervising a large farm labour force are likely to encourage large-scale operators to invest in labour-saving equipment in spite of the low wage rate ; wherever there is the threat of labour union action to push for higher wages, this tendency will be accentuated.

Implicit in this argument is the proposition that large landowners often have control over large holdings not because they pay a price that reflects its opportunity cost but for historical and political reasons, including the fact that land taxes have been held at low levels. Further, such landowners often have preferential access to credit at interest rates below the "true" price of capital and also have preferential access to technical knowledge because of superior education and wider contacts. Finally, in such a situation there is likely to be serious underinvestment in public education and in publicly supported programs of agricultural research and extension because landlords are not keen to tax themselves to provide such services to the mass of the rural population ; and the taxable capacity as well as the political power of the latter is limited. This type of situation is apt to result in a highly stagnant traditional subsector of the agricultural economy because its members have restricted access to technical knowledge and land as well as limited capacity to sell a marketable surplus or to buy farm inputs. And to the extent that the large-scale subsector satisfies a lion's share of the growing demand for purchased agricultural products, investment in mechanization may be highly profitable for the large, commercial operators. Nevertheless, given the underlying economic conditions, it is profitable that much higher social returns would be realized from outlays for the research, extension, and rural education required for a broad-thrust approach to agricultural development based on labour-intensive, capital-saving techniques of production.

In concluding this brief discussion of a complex set of problems, I would like to relate the analysis specifically to the question of research and development priorities for the tropical root crops.

(1) *Obstacles to mechanization of root crop production.* — The general arguments that cast doubt on the returns to investment in mechanization seem to

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8 J. W. Mellor, **The Economics of Agricultural Development**, Ithaca, New York, 1966

apply with particular force to the tropical root crops. These crops tend to be low in value and, as previously noted, they are often grown largely for subsistence consumption by farm households. Hence, the inherent limitations on use of purchased inputs apply with particular force to these crops.

(2) *Returns from varietal improvement.* — Large returns from varietal improvement are usually the result of plant breeding programs directed at the development of varieties with the capacity to respond well to high levels of soil fertility. However, there appear to be significant possibilities for raising yields of the tropical root crops by the development of varieties resistant to disease or virus damage or by simply identifying and introducing cultivars with yield characteristics superior to the local varieties. As one important example, the work carried out some years ago by the East African Agriculture and Forestry Research Organization at Anami in Tanganyika has provided the basis for very substantial increases in cassava production based on the introduction of mosaic-resistant varieties.[9] The problems to be overcome in research, in the organization of programs for multiplication of improved planting material, and in bringing about the widespread adoption of higher yielding varieties should certainly not be underestimated. The fact remains, however, that such measures are particularly well adapted to the requirements for an efficient strategy for agricultural development in the early phase of economic growth and should be assigned a high priority.

(3) *Expanded use of chemical fertilizers.* — Expansion of tropical root crop production, as agricultural production generally, will come to depend increasingly on providing and maintaining high levels of soil fertility through the use of chemical fertilizers. Larger uptake of soil nutrients as crop yields are raised will in itself increase the need for application of chemical fertilizers. Moreover, the heavy labour costs associated with frequent clearing of plots under bush fallowing can almost certainly be reduced by lengthening the period of cultivation through the application of chemical fertilizers. The gradual increase in farm cash incomes as structural transformation of these economies takes place will make it possible for root crop producers to rely increasingly on purchased inputs. Because chemical fertilizers represent a form of capital that gives a quick payoff and is highly divisible — and therefore suitable for use on small units — they are particularly well-suited to adoption by smallholders in the early phase of development. And the fact that fertilizer inputs are highly complementary to existing resources of labour and land, and also to research directed at varietal improvement, means that return to outlays for fertilizers are likely to be very high. Once again the difficulties of realizing this potential should not be underestimated. There still seems to be an acute need for better understanding of fertilizer requirements for the various root crops under different soil and climatic conditions, and the extension services and sales organizations required to promote widespread use of chemical fertilizers are lacking in most of the developing countries.

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9 B. F. Johnston, "Choice of Measures for Increasing Agricultural Productivity: A Survey of Possibilities in East Africa." **Tropical Agriculture**, April 1964.

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