THE CHOICE OF AGRICULTURAL TECHNIQUES IN UNDERDEVELOPED COUNTRIES*

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I

Most writings on the problem of choice of production technology are based (explicitly or by implication) on assumptions which apply more easily to industry than to agriculture.[1] A model of a different character seems to be necessary to discuss the issues involved in the choice of techniques of agricultural production in underdeveloped economies. In particular, one has to examine the implications of having a non-wage economy and also of having land as one of the dominant factors of production.

In most underdeveloped economies, agriculture is almost entirely a household operation. This is particularly true of countries like India. The cultivator's earnings consist of sales receipts minus production expenditures, rent, and interest payments. In contrast to a wage economy, in a situation of this sort the problem of choice of technology need not give rise to any conflict between maximizing immediate output and maximizing the rate of accumulation.[2] This holds

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1. See A. E. Kahn, "Investment Criteria in Development Programs", Quarterly Journal of Economics, February 1951; H. B. Chenery, "The Application of Investment Criteria", Quarterly Journal of Economics, February 1953; M. H. Dobb, "A Note on the So-Called Degree of Capital-Intensity of Investment", Economie Appliquee, 1954, reprinted in his On Economic Theory and Socialism, London, 1955; idem., "Second Thoughts on Capital-Intensity of Investment", Review of Economic Studies, 1956; Galenson and Leibenstein, "Investment Criteria, Productivity and Economic Development", Quarterly Journal of Economics, August 1955; Otto Eckstein, "Investment Criteria for Economic Development and the Theory of Intertemporal Welfare Economics", Quarterly Journal of Economics, February 1957; F. M. Bator, "On Capital Productivity, Input, Allocation and Growth", Quarterly Journal of Economics, February 1957; A. K. Sen, "Some Notes on the Choice of Capital Intensity in Development Planning", Quarterly Journal of Economics, November 1957.

2. See M. H. Dobb, "Second Thoughts on Capital Intensity of Investment", op. cit.; also "Some Notes on the Choice of Capital Intensity in Development Planning", op. cit., pp. 571-577, where the conflict in a wage economy is discussed. The conflict arises in a wage economy when the marginal increase in consumption resulting from a higher wages bill (due to an expansion of employment) exceeds the marginal increase in output (due to that expansion of employment). It is thus a distributional problem, which does not arise in a household economy.

true so long as the marginal propensity to save is positive, which seems a fair assumption to make. Even if the system is one of share-cropping (with the cultivator getting, say, a half of the net output and the land-owner the other half), the conflict need not be there. In these economies therefore the choice of an optimum technique is less complicated. In the rest of the paper it will be assumed that maximization of output is achieved without sacrificing future growth. This condition is likely to hold also for cooperative or collective farms run on a non-wage basis.

A second departure of this paper will be in introducing land as an important factor of production. Thus, even if labor and capital are both doubled, output (given the technique) may be less than doubled. This possibility of diminishing returns to scale (capital and labor) makes our choice of technique dependent on the absolute volume of production. Depending on the relative rates of diminishing returns, we may choose technique A for one scale of production and technique B for another. We may even choose a combination of techniques rather than employ one technique to produce the whole output.

Once land is introduced in our analysis, we have to distinguish between two types of capital goods--those which replace labor (e.g., tractors) and those which replace land (e.g., fertilizers). We may call them, for the sake of brevity, "laboresque" capital and "landesque" capital, respectively. This division is not watertight, and in some cases a capital good which is mainly laboresque may also raise productivity per unit of land. Deep plowing is perhaps a good example. Broadly speaking, however, our experience seems to suggest that while investment in fertilizers, or in irrigation, or in pest control, increases yield per acre considerably (without replacing labor), investment in machines like tractors, threshing machines, etc., is useful mainly in replacing labor (without raising yield per acre).[3] This dichotomy leads to some interesting policy problems which are discussed below in terms of a simple model.

II

In figure 1 we have four axes--west measuring capital investment; south, investment in "laboresque" capital; east, the quantity of labor necessary for cultivation; and north, the volume of agricultural output. We assume a watertight dichotomy between "laboresque" and "landesque" capital. We assume further that both laboresque and landesque capital goods wear away in one year. OC is the total amount of investment that can be made in a year, and the curve FED gives the volumes of agricultural product (to be called "corn" henceforth) at alternative levels of investment in landesque capital. The shape of the curve exhibits diminishing returns though the marginal product need not necessarily become zero (or negative). Some positive output (CF) is assumed for zero investment in landesque capital, for there is, after all, land. If BC is the amount of investment that is made in landesque capital, BE is the output. OB is the amount

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3. "While mechanization of farming operations improve considerably the yield per unit of labour, it does not necessarily increase the yield per unit of land." S. R. Sen's paper in the Proceedings on the Ninth International Conference on Agricultural Economics, London, 1956, p. 56. See also Joan Robinson, Accumulation of Capital, London, 1957, Book VI, p. 323.

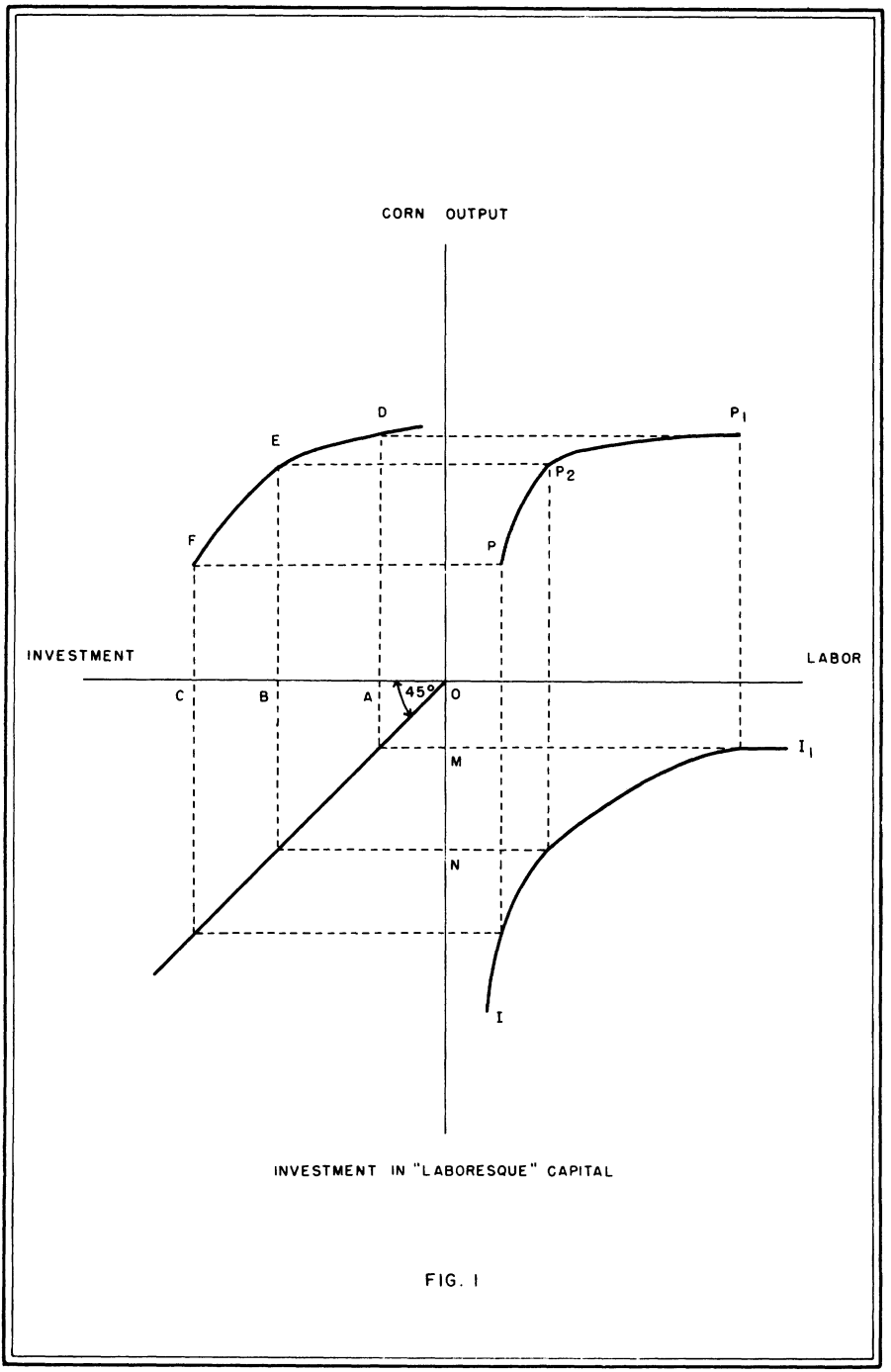
CORN OUTPUT
D
E
F
P
P2
P1
INVESTMENT
LABOR
C
B
A
45°
O
M
N
I1
I
INVESTMENT IN "LABORESQUE" CAPITAL

FIG. 1

of investment in laboresque capital. With a 45 degree line, we get ON equal to OB. The curve II^1 gives the alternative combinations of labor and laboresque capital necessary to look after the given piece of land. We assume that these requirements are fixed given the quantity of land and do not vary with the output. This is a somewhat unrealistic assumption, for if labor or laboresque capital is reduced just below the curve II^1, output will not become zero, so that labor and laboresque capital requirements are in fact fixed per unit of land. For our model however, it is sufficient to assume that the marginal reduction of output when a unit of laboresque capital is taken away to bring us below (to the north of) the curve II^1, is greater than the marginal addition to output resulting from that unit being put in landesque capital (for all relevant combinations of investment). In this case, there is no argument for going below the curve II^1, excepting when capital is so scarce that investment in landesque capital is nil.

If ON is the amount of laboresque capital than can be used, OQ is the quantity of labor needed. Point P_2 represents the combination of output (P_2Q = BE) and employment (OQ). If instead, AC amount of investment is made in landesque capital, AD (= P_1G) is the output, OA (= OM) is the investment in laboresque capital, and OG is the employment. The alternative combination of output (BE, AD, etc.) and employment (OO, OG, etc., respectively) are shown in the northeas quarter by the line PP_2P_1. It tends to flatten out as FED flattens out. The curve PP_2P_1 is the possibility line.

The factor substitution curve II^1 will become horizontal when no further substitution of capital by labor is possible. In figure 1, OM is thus the minimum possible investment in laboresque capital, and the line PP_2P_1 does not go beyond P_1. Strictly speaking, OM is not laboresque capital at all, as it is something which labor cannot replace. It perhaps consists of a minimum amount of primitive shovels, plows, etc., without which there can be no production.

OG is the maximum volume of profitable employment.[4] In underdeveloped countries like India or Egypt or some countries in Latin America, the agrarian labor force (it is believed) is greater than this and there is, as a result, a considerable volume of unemployment (open or "disguised").[5] In a situation like this, there is obviously every argument for putting in as much investment as possible in landesque capital, i.e., in fertilizers, pest control, irrigation, etc. We may choose point P_1 of the possibility line, i.e., OG employment and AD output. The ratio of laboresque capital to labor is OM/OG and the ratio of landesque capital

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4. An interesting theoretical possibility is where the available investment opportunity is sufficient to reach on one hand the point where FED is horizontal and on the other where II^1 is vertical. In this case, further investment can bear no fruit, either in raising product or in saving labor, and capital has done all it can do. Needless to add that the fear of reaching such a situation need not haunt the planners in underdeveloped countries.

5. See Mandelbaum, The Industrialisation of Backward Areas, Oxford, 1945; W. W. Cleland, The Population Problem of Egypt, 1936; D. Warriner, The Economics of Peasant Farming, London, 1939; idem., Land and Poverty in the Middle East, London, 1948; Government of India, Report of the Agricultural Labour Enquiry, New Delhi, 1945; and Ragnar Nurkse, Problems of Capital Formation in Underdeveloped Countries, Oxford, 1955.

to land is $AC/\overline{L}$, where $\overline{L}$ is the quantity of land. These two ratios give us the two relevant capital-intensities in this allocation problem.[6]

A more interesting case is where the economy has a labor shortage. In some countries in Africa, for example, the only way of getting labor for industry is to reduce agrarian employment.[7] If we want to leave only OQ amount of labor on land, ON/OQ should be the ratio of laboresque capital to labor and $BC/\overline{L}$ the ratio of landesque capital to land. BE is the corn output. The results are summarized in Table 1.

Table 1.

Assumption	Employment	Maximum output	Laboresque capital to labor ratio	Landesque capital to land ratio
Unlimited supply of labor	OG	P_1G	OM/OG	$AC/\overline{L}$
Limited OQ ($<$ OG) supply of labor	OQ	P_2G	ON/OQ	$BC/\overline{L}$

III

In the above model, the rural labor force was externally given, the assumption behind it being that the limits to urban expansion depend on factors other than agricultural production. It is possible, however, that in some situations the volume of agricultural surplus, and hence indirectly the volume of agricultural output, may itself determine the number of people that can be employed in the urban area. We must change our model a bit to take care of a situation of this sort.

In figure 2 we have the northeast quarter of figure 1. PP_1 curve gives us the possibility line. As more laborers move to the urban area, total demand for corn increases due to the additional purchasing power created by additional urban employment. OF being the initial rural labor force, DD_1 gives us the demand curve for corn which rises with a fall in the rural labor force, i.e., with a rise in the urban employment. In figure 2, OL is the rural labor force which equates

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6. There is, of course, the further problem of choosing between different types of laboresque and landesque capital.

7. See W. A. Lewis, Report on Industrialisation and the Gold Coast, Accra, 1953. "There is a shortage of labour in the Gold Coast which rapid industrialisation would aggravate" (p. 65).

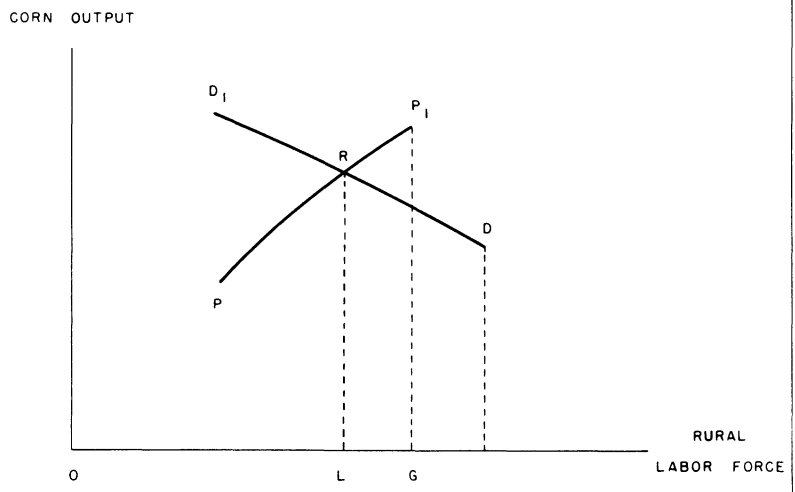
CORN OUTPUT
D1
P1
R
D
P
RURAL
LABOR FORCE
O
L
G

FIG. 2

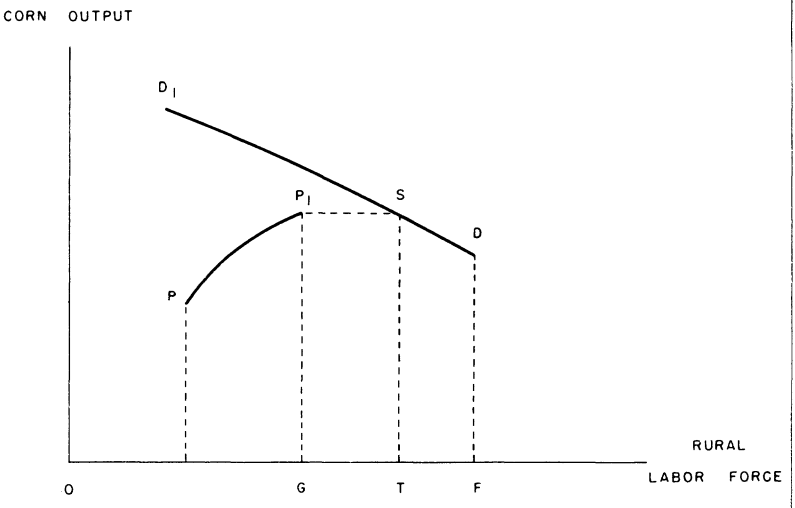
CORN OUTPUT
D1
P1
S
D
P
RURAL
LABOR FORCE
O
G
T
F

FIG. 3

demand and supply of agrarian output.[8] Thus FL is the volume of migration to the urban area, RL the output, and the capital-intensities corresponding to these can be found out from figure 1.

It is possible that DD_1 may lie wholly above PP_1, as in figure 3. In this case, we can transfer only FT number of laborers, for the corresponding demand is ST and the supply P_1G (= ST). GT number of unemployed (open or "disguised") rural people must continue to stay in the rural area. This problem is encountered in many countries like India or Egypt. In this case, the relevant capital-intensities are OM/OG for laboresque capital, and $AC/\bar{L}$ for landesque capital, as in the first row of Table 1.

We have worked out above the choice of capital-intensities both in the case where (a) agricultural output is not a bottleneck for urban expansion, and (b) agrarian output (and surplus) is the only bottleneck for urban expansion. A number of cases may be intermediate, with many bottlenecks including that of agricultural output. To tackle those cases, our model must be somewhat altered. We have also not brought in the offer of urban products which may affect the amount of agrarian output the rural population is ready to sell. This will allow variation of the curve DD_1, which can be lowered by offering more urban products.[9]

The above discussion has been conducted at a fairly elementary level, with rather simple assumptions, and our models certainly do not fit all cases of technological choice in agriculture. I think, however, they do indicate the sort of questions we have to ask in choosing techniques for agriculture, questions which are different from the ones usually asked in studies of technological choice based on assumptions that fit the industry well, but no agriculture. The nature of technological choice in a three-factor case seems to be very different from that in a two-factor economy, and it certainly demands a different technique of analysis, perhaps in the line indicated above.

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8. DD_1 may in fact give us the minimum demand for corn, i.e., the least amount of corn necessary to have a certain volume of urban employment. If the supply of corn for that urban employment is greater, as it is for any point between F and L, the extra supply of grain can be well looked after in a planned economy. In this case, OL gives us the minimum possible volume of rural employment (i.e., maximum transfer), and not the only equilibrium level. Choice of OL therefore involves a policy objective of maximum industrial employment.

9. For a study of the influence of rural-urban trade on industrial employment possibility, see my note, "Unemployment, Relative Prices and the Saving Potential", Indian Economic Review, August 1957.