Some Notes on the Choice of Capital-Intensity in Development Planning
Author(s): Amartya Kumar Sen
Source: *The Quarterly Journal of Economics*, Vol. 71, No. 4 (Nov., 1957), pp. 561-584
Published by: Oxford University Press
Stable URL: http://www.jstor.org/stable/1885711
Accessed: 03/02/2011 08:31

SOME NOTES ON THE CHOICE OF CAPITAL-INTENSITY IN DEVELOPMENT PLANNING*

By AMARTYA KUMAR SEN

I

Considerable attention has been paid in recent years to the problem of choosing between alternative techniques of production that are open to an underdeveloped economy. The object of this paper is to discuss the basic issues involved in the choice. We shall start by examining the various criteria that have so far been suggested. In the light of the criticisms of these, an alternative suggestion will be put forward. In the second section the problem will be discussed in terms of some simple models, partly to clarify the differences between these criteria, and also to study how factors like the cost of labor or the foreign trade situation influence the choice. In this paper we shall concentrate on the problem of choice of techniques for the consumer goods sector only.

The criteria for choosing between techniques of production for an underdeveloped economy that have so far been explicitly put forward can, I think, be classified into three groups. We shall examine them one by one, at the end of which an alternative suggestion will be put forward as a fourth criterion.

A. THE RATE-OF-TURNOVER CRITERION

Professor J. J. Polak, while discussing the investment criteria of countries reconstructing after the war, suggested that investment for development should be chosen according to the rate of turnover, i.e., the ratio of output to capital.[1] Along with a few other considerations,

* I am indebted to Mrs. Joan Robinson and Mr. Maurice Dobb for comments and suggestions on an earlier draft of this paper. This is a slightly altered version of a paper for which the writer was awarded the Stevenson Prize of Cambridge University for 1956.

1. "Balance of Payments Problems of Countries Reconstructing with the Help of Foreign Loans," this *Journal*, LVII (Feb. 1943), 208. Reprinted in *Readings in the Theory of International Trade*, American Economic Association, 1949.

like the exporting possibility of the goods produced, a high output to capital ratio was made the basis for selection. The same suggestion was put forward also by Professor Norman S. Buchanan. "If investment funds are limited, the wise policy, in the absence of special considerations, would be to undertake first those investments having a high value of annual product relative to the investment necessary to bring them into existence."[2]

That this criterion is very imperfect as a general guide to policy is not difficult to realize. For one thing, a high rate of turnover may be associated with a high rate of depreciation and the rate of *net* output may not necessarily be high. But this difficulty can be avoided to some extent by stating the criterion in terms of the *net* rate of turnover, which is how it is actually put in most cases. The main defect of the theory is that it ignores the cost of employing labor in operating the capital. When the cost of employing labor in an economy is zero, a very good case can be made for the criterion of maximum addition to net output from a given amount of capital investment. If, on the other hand, employment of labor involves some cost to society, we have to take that into account.[3]

B. The "Social Marginal Productivity" Criterion

From what we have said in the last paragraph it is just one step to arrive at the social marginal productivity criterion as put forward by Professor A. E. Kahn.[4] It is suggested that from the addition to output due to the investment, the alternative output sacrificed as a result of drawing factors of production from other fields into this one has to be subtracted. Thus the factors are valued at their social opportunity cost, i.e., at what they could have produced in other fields had they not been drawn into the investment under examination. This criterion would lead to a different result from that of the rate-of-turnover approach, so long as the social opportunity cost of labor is positive. When, however, there is large scale unemployment, the opportunity cost of labor is nil, and thus labor becomes according to this approach costless. Ignoring factors other than labor, now there is no need for any subtraction and we find Kahn arguing that in this case the Polak-Buchanan criterion is "particularly desirable."[5]

2. "International Investment and Domestic Welfare" (New York, 1945), p. 24.

3. See A. E. Kahn, "Investment Criteria in Development Programs," this *Journal*, LXV (Feb. 1951), 38.

4. *Op. cit.* See also H. B. Chenery, "The Application of Investment Criteria," this *Journal*, LXVII (Feb. 1953), 76.

5. *Op. cit.*, p. 51. See also p. 40.

Thus in an economy of this sort Kahn recommends the technique with the least capital coefficient, i.e., with the maximum rate of turnover.

Professor W. A. Lewis also puts forward a similar view when discussing the question. "Special care," he argues, "has to be taken in those countries which have a large surplus of unskilled labour, for in such circumstances money wages will not reflect the real social cost of using labour. In these circumstances capital is not productive if it is used to do what labour could do equally well; given the level of wages such investments may be highly profitable to capitalists, but they are unprofitable to the community as a whole since they add to unemployment but not to output."[6] "It is then [when there is surplus labour] arguable that the real cost of using labour in cottage industry is zero, whereas factory production uses scarce capital and supervisory skills."[7]

In assessing this criterion, I think, we have to start by asking what it is that we are trying to achieve. If we are trying to maximize immediate output, labor should be valued according to its social opportunity cost and the above criterion seems quite appropriate. If, however, we are interested in the future as well, we have to look at the *rate of growth* of income governed by the accumulation of capital. And there is no reason to believe that the maximum rate of output would also give us the maximum rate of excess of production over current consumption, when employment is a variable. Here even if the alternative social product is nil, the cost of labor will be positive, given by the increase in consumption due to extra employment.[8] Thus the social marginal productivity criterion is all right if we are

6. "The Theory of Economic Growth" (London and Homewood, Ill., 1955), p. 386.

7. *Op. cit.*, p. 140.

8. Chenery, *op. cit.*, seems to confuse this point. His theory is basically a variant of the SMP criterion with a "welfare function" involving "effect on national income" (along with effects on balance of payments and income distribution). Now, when one is interested in the total national income for the period, one should value labor at its opportunity cost. Instead he values labor (equations 4 and 5) at the "increase in consumption" (pp. 82–83). "The effect on national income, ΔY, can be approximated by applying a set of corrections to the businessman's calculation of the annual *rate of profit*" (p. 82, italics mine). This appears to me to be a confusion between the rate of surplus and the rate of income flow. There is no reason why in national income measurement the increase in the consumption of the wage earners should not be included. The concept of the social opportunity cost is legitimate for the calculation of total output but not for the calculation of the rate of growth of output; the concept of the gap between marginal production and marginal consumption is legitimate for the latter, but not for the former. To avoid confusion, the distinction has to be appreciated.

not interested in the future at all. But if we take a long term point of view, the criterion need no longer be valid.[9]

C. The Reinvestment Criterion

W. Galenson and H. Leibenstein christened their criterion as that of "marginal per capita reinvestment quotient."[1] For clarification of what it means, we may quote the authors:

"To secure a clear notion of what is meant by the marginal *per capita* reinvestment quotient we must consider the basic factors involved in its determination. Briefly stated, the seven basic factors are as follows: (1) gross productivity per worker; (2) 'wage' goods consumed per worker; (3) replacement and repair of capital; (4) increments in output as a result of noncapital using innovations such as improvements in skill, health, energy, discipline and malleability of the labor force; (5) declines in mortality; (6) declines in fertility; and (7) direction of reinvestment."[2]

Galenson and Leibenstein provide the criterion with somewhat more manageable dimensions when they discuss the growth of employment. It is clear that what the authors are interested in, briefly stated, is the flow of net investment that is created by a unit of investment today. From the formula on page 357, the rate of reinvestment is found to be equated to

$$r = \frac{p - ew}{c},$$

where p = output (presumably *net* output) per machine;
e = the number of workers per machine;
w = real wage rate;
c = cost per machine.

This actually turns out to be not much different from the capitalist's rate-of-profit criterion. This coincidence is easy to explain. If the whole of the profit is reinvested[3] and the whole of the wages con-

9. The criticism of Walter Galenson and Harvey Leibenstein ("Investment Criteria, Productivity and Economic Development," this *Journal*, LXIX (Aug. 1955), 343) also boils down to this point about the valuation of labor though this may not be quite obvious.

1. *Op. cit.*, p. 351. For a neat presentation of a basically similar criterion and also for an interesting study of various other aspects of the problem of choice of capital-intensity, see M. H. Dobb, "Second Thoughts on Capital Intensity," *Review of Economic Studies*, XXIV (1956).

2. *Op. cit.*, p. 352.

3. Galenson and Leibenstein do make this assumption. "We abstract here from the very difficult problem of ensuring that this Ricardian 'surplus' is indeed reinvested . . ." (*Op. cit.*, p. 352, n. 6).

sumed, the rate of profit and the rate of reinvestment must come to the same thing.

Professor K. N. Raj of the Delhi School of Economics puts forward a similar criterion.[4] But since he considers specifically the case of a change from cottage industrial to factory production, he draws our attention to the necessity of subsidizing those who become jobless due to technological change. Thus he regards the cost of maintaining the new unemployed as part of the total costs. This makes his criterion less favorable to more mechanized production than the Galenson-Leibenstein criterion.[5] This criterion is applicable, given its value judgment, to the case where less mechanized production is being *replaced* by more mechanized production. It would, however, be very difficult to apply when we are contemplating *initiation* of production and wondering whether to make it more or less capital-intensive. In those cases, I think, it would be nearly impossible to separate out, from the pool of the jobless people, those who would have been employed had a less mechanized production technique been chosen.

The essence of the reinvestment criterion (whether the unemployed people are paid doles or not) lies in its use of the rate of growth formula associated with the names of Harrod and Domar. The reinvestment formula can be transformed into the growth economics terminology without much difficulty.

$$r = \frac{p - ew}{c} = \left(\frac{p}{c}\right)\left(1 - \frac{ew}{p}\right) = \frac{s}{a},$$

where a = capital coefficient $= \dfrac{c}{p}$

and s = savings ratio $= \dfrac{p - ew}{p}$,

4. "Small Scale Industries — Problem of Technological Change," Special Article, *The Economic Weekly* (India), April 7 and 14, 1956. This point is discussed also by Hans Neisser, "Investment Criteria, Productivity, and Economic Development: Comment," this *Journal*, LXX (Nov. 1956), 644, and by Galenson and Leibenstein in their "Reply," *ibid.*

5. As the dole paid to the unemployed is increased relative to the wage rate, Raj's criterion approaches that of the rate of turnover. In the limiting case where the dole is equal to the wage rate, the two criteria coincide. The laborer gets the same income whether he is employed or not, and the technique that maximizes production also maximizes surplus. Raj also assumes that the rural cottage-industrial wage rate is lower than the urban wage rate. This also makes his criterion more favorable to less mechanized production.

assuming that the whole of wages is consumed and the whole of the rest reinvested. Thus the maximization of r results in the maximization of the rate of growth.

The Galenson-Leibenstein criterion is based on a number of simplifying assumptions, e.g., the techniques have the same gestation lag, the whole of the surplus is reinvested, and so on. These, however, do not constitute any basic limitation of the theory as in actual calculations they could be taken care of. Some questions can, however, be raised about the fundamental validity of the Galenson-Leibenstein criterion.

First, it is assumed in the criterion that the total amount of investment that one can make in the initial period, is fixed irrespective of the technique chosen. Only with this assumption can one say that the technique which gives us the maximum rate of investible surplus per unit of capital investment will give us the maximum rate of growth. That the assumption need not be valid can be realized very easily if we take cases with different propensities to consume of the factors contributing to the respective investments. If, in the case of investment A, the owners of factors of production consume half of what they get, an investment of \$100 will mean an addition to the effective demand for consumer goods of \$50 in the next round. If in the case of investment B, the factor owners consume whatever they get, the same amount of investment will lead to an additional effective demand for consumer goods of \$100 in the next round. Thus given the real resources available in the economy, we may be in a position to have a larger initial capital investment if we chose technique A rather than B. It is therefore possible that even if technique B gives a higher rate of investible surplus *per unit of capital investment*, it may not give us a higher rate of growth.

The practical importance of this criticism depends, of course, upon the actual size of the difference in the propensities to consume. This difference will vary from case to case, but in some cases it may be quite important, as technological change often implies the replacement of a number of unskilled laborers by some skilled workers with lower propensities to consume. Also the producers of different co-operating factors of production may have different spending habits.

Secondly, the same problem may arise in a different garb in connection with international trade. Galenson and Leibenstein do not distinguish between the costs of buying foreign goods and those incurred in the home economy. When one technique has a higher import-content than another and when extra foreign aid is not specially available when the first is chosen, the balance-of-payments

problem introduced by the adoption of the first technique has to be taken into account. I think the best way of measuring the additional cost of higher import-content is to value the import at its export-equivalent. That is, we have to see how much more exports we have to ship abroad to meet the additional imports. Thus if technique A has no import-content and technique B involves imports worth \$100 in addition to expenditures made at home, and if to meet the foreign currency requirement of \$100 we have to export \$150 (at home prices), by subsidization or other methods, we should add \$150 and not merely \$100 to home costs in the latter case.[6]

This is a consideration of great practical relevance for very many choices of techniques. Thanks to the lack of a sector producing modern capital goods in an underdeveloped economy, the difference between the import-content of factory production and that of cottage industrial production is simply enormous, and choice between the two is very often the basic question in investment allocation in an underdeveloped economy. The Galenson-Leibenstein approach neglects this aspect of the problem altogether.

Thirdly, the Galenson-Leibenstein criterion neglects the fact that present income may be more valuable to society than future income. While the social marginal productivity criterion pins its attention on the present, the rate-of-reinvestment criterion goes to tne other extreme. A higher rate of reinvestment may mean a higher rate of growth of income and thus may promise higher income sometime in the future, but that in itself is no reason for choosing that technique. If we value present income more than future income, we may prefer to have a lower rate of growth and a higher rate of immediate income. This preference for the present need not arise from "irrational telescopic psychology," but, for example, may be due to the very rational consideration that our present income being less than our future income, the value of additional income to us is much more at the present moment. This problem of time preference leads to a number of complexities which we shall encounter when we try to put forward an alternative criterion; but that a complete neglect of the problem is illegitimate seems clear. The SMP and the reinvestment criteria represent the two extreme positions on this time question.[7]

6. If there is scope for cutting down other imports to finance this and if that rather than expansion of exports is the method chosen, we have to examine its social cost.

7. Since this paper was written, two articles on capital-intensity have come out in this *Journal*, LXXI (Feb. 1957), namely by Otto Eckstein, "Investment Criteria for Economic Development and the Theory of Intertemporal Welfare Economics," p. 56, and by Francis M. Bator, "On Capital Productivity, Input

D. The Time Series Criterion

In the light of our criticism of the reinvestment criterion we can put forward an alternative suggestion. When confronted with the choice between various techniques, we start by finding out our "best guess" of the time series of real income flows corresponding to each technique. This is done by applying the rate of reinvestment with corrections due to the variability of the volume of investment as we choose one technique rather than another. The variability, as we have shown earlier, may arise from things like different spending habits of the factors of production and the varying import-content of investments employing different techniques. If $\left(\frac{r_1}{r_2}\right)$ is the ratio of reinvestment with technique 1 and technique 2 respectively and if $\left(\frac{m_1}{m_2}\right)$ is the ratio of the volumes of investment that can be undertaken when we choose the respective techniques, technique 1 will lead to a higher or a lower rate of growth depending on whether $m_1r_1 >$ or $< m_2r_2$. This way the two time series of real income flows are obtained.[8] In deriving the two time series one has to remember that there need not be constant returns to scale, as normally assumed, and the relative factor prices may also change with the scale of production, as factors need not be in equally elastic supply.

After getting the two time series of income flows we have to apply the relevant rates of time discount, and even if $m_1r_1 > m_2r_2$, we need not necessarily choose technique 1. The time discount is necessary, it appears to me, because of at least two reasons[9]: (a) the diminishing marginal social utility of income with the rising income

Allocation and Growth," p. 86. It is particularly necessary to refer to Professor Bator's article, as he denies the importance of the problem of choice over time involved in the question, on which we have put so much emphasis. In fact Bator's model leads him to conclude (p. 99) that there is "no conflict" between maximizing the present output and maximizing the growth rate. This conclusion is the result of his assumption that "the rate of saving is independent of the (as if) market imputed distribution of income" (p. 98). This, of course, amounts to assuming away the problem itself.

8. Actually due to the interdependence of economic activities a better way of looking at the problem may be in terms of alternative combinations of fixed-capital-stock and current-input-flow matrices. A more capital-intensive technique involves raising some items of the former matrix to reduce some items of the latter.

9. The much-discussed "telescopic psychology" does not appear to me to be strong ground for time-discount in planning problems. We are interested not in the value to today's men of the satisfaction of the men of tomorrow, but in the value of the satisfaction of tomorrow's men themselves. So the "optical illusion" need not be taken very seriously.

level,[1] and (b) the uncertainty of the future. If marginal social utility of income falls quickly and becomes negligible as income rises beyond a certain level, it is possible that a higher rate of growth of income may not give us a higher sum of total social satisfaction. Again beyond a point it becomes very difficult to apply all these rational calculations, as it is too difficult to foresee what is going to happen. Thanks to the imperfection of our knowledge, it is not possible to work out all the results of today's actions, for all time to come. We may choose a high degree of capital intensity and sacrifice some amount of present income for expected future benefit; but a technically advanced war, for example, may settle all problems before that future arrives. Thus in addition to the utility function with the assumption of perfect certainty, we need a valuation of uncertainty discount for a rigorous solution of the problem.

In applying our criterion to actual choices of capital intensity such a rigorous solution is not possible as we cannot get the required utility and uncertainty functions. A less satisfactory but more workable method is to fix the period of time we are going to take into account and see whether the loss of immediate output incurred by choosing the more capital-intensive technique is more than compensated by the extra output from it later, before the period of consideration is over. We may actually conceive of a "period of recovery" (T) defined[2] as the period of time in which the total output (the sum of yearly flows) with the more capital-intensive technique, is just equal to that with the less intensive technique.[3] Figure I illustrates the period of recovery. The H and L curves give the two time series of consumption flows with the respective techniques. OT represents the period of recovery, as the surplus-area for the more capital-intensive technique (BCC') is exactly equal to its deficit-area (BAA').

1. We are assuming cardinality and interpersonal comparability of utility. This is, as three decades of criticism has made abundantly clear, not quite correct. However, even if we use more sophisticated social welfare functions, the fact that we value income less when we have more of it must, it appears to me, be taken into account.

2. It is actually more meaningful to define the period in terms of the recovery of the *consumer* goods output rather than in terms of that of *income* as such. In the following models, in fact, we do define it in terms of the consumer goods output.

3. This is similar to the Soviet "period of recoupment" but not the same. We are looking at the problem from the point of view of alternative output flows with given investment possibilities; the period of recoupment refers to the alternative costs to produce a given flow of output. In growth problems the first is more logical.

The importance of the period to be taken into account in technological choices is emphasized also by K. N. Raj. "Application of Investment Criteria in the Choice between Projects," *Indian Economic Review*, Aug. 1956.

The period we are ready to take into account is U (given by our judgments). When $U < T$, technique L is preferable; when $U > T$, technique H should be chosen; the point of indifference is given by $U = T$. If we assume $U = 1$, we get the rate-of-turnover criterion;

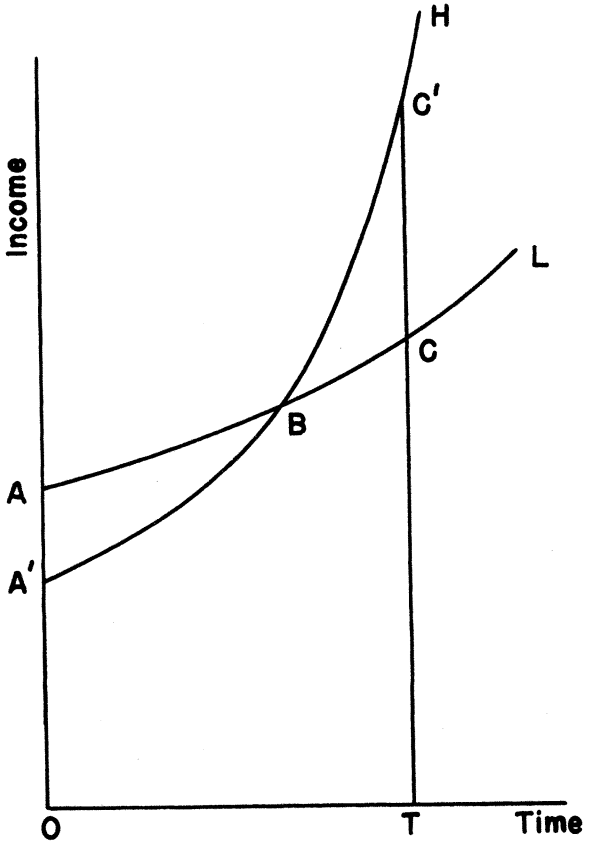

FIGURE I

being interested in the first period only, the technique with the higher rate of immediate output is preferred. If we assume $U = \infty$, we get the rate-of-reinvestment criterion; being equally interested in all time to come, a higher *rate* of growth is all we want.

The defect of this approach lies in its arbitrariness. We have to assume that up to the end of the period U, each unit of income is equally valuable and there is no preference over time. But beyond that point no income is of any value at all. This brings in the time

factor rather suddenly and with extreme severity.[4] But such arbitrariness is difficult to avoid due to the very nature of the problem, and the approach of the period of recovery may have considerable operational value. In any case by choosing nonextreme values of U it can be made less arbitrary than the approach of the SMP criterion or that of the criterion of reinvestment. It is impossible to arrive at a realistic criterion for tackling this question which will be considered to be fully satisfactory intellectually. The object of the exercise, one has to remember, is not perfection, but minimization of imperfection. The period-of-recovery approach can be properly understood only when this is recognized.

II

We may now apply the criteria to some very simple models and thereby bring out their essential differences. The first model will be chosen in a way that will make the time series criterion coincide with the Galenson-Leibenstein criterion — the assumptions of the model will make the total investment possibility constant in terms of direct outlay and it will be assumed that $U = \infty$. This criterion will be contrasted with the social marginal productivity and the rate-of-reinvestment criteria. As a part of the contrast some observations will also be made on the relationship between the cost of labor and the choice of capital intensity. In the second model international trade will be introduced and the time series criterion will diverge from the reinvestment criterion. In this connection some observations will be made on the relationship between the foreign trade situation and the choice. In the third and the last model the problem of time preference will be introduced and the concept of the period of recovery will be applied.

(I) The First Model. We are looking at a stationary underdeveloped economy which is experiencing no economic growth. The social organization is precapitalistic and production is family-based. There is a big pool of unemployed labor in the economy, though due to the social organization, the unemployment may be "disguised." The government is contemplating the initiation of economic development with some public investment. It has decided against using the method of "forced savings" through inflation and it will invest only to the extent that a technical surplus of production over current consumption is already available. Thus if the subsistence economy provides no surplus at all and if there is no foreign help, the economy is

4. This is more illegitimate for the "diminishing marginal utility" part of time preference as it is a function of income and not of time as such. The uncertainty factor, however, is more definitely a function of time.

obviously in the grip of complete stagnation.[5] Let us assume that the government has managed to realize some surplus through taxation or other means, and that the problem is in what form to invest it.

The economy consists of two sectors — the "backward" subsistence sector and the "advanced" sector under construction. We refer to them as sectors B and A respectively. Labor supply to sector A, we assume, is perfectly elastic in the relevant range due to immigration from sector B.[6]

Sector A can be subdivided into two departments — I and II, the former producing capital goods and the latter corn, which we take as a "composite commodity" to avoid the index number problem.[7] For analytical convenience all factors other than labor and capital will be ignored. We assume further that all the techniques have the same gestation lag, that a capital good once created lasts forever (i.e., there is no depreciation), that the real wage rate per labor-hour is the same for all the techniques and is constant over time, and that the whole of the wages bill is consumed and that the whole of the surplus over wages is reinvested. In this particular model we also assume that capital goods are produced by labor alone and that the economy is closed. We shall deal with a choice between two techniques — H and L; the former has a higher capital intensity, defined as the number of laborers employed in department I to produce enough capital goods to employ one laborer in department II. We use the following notations for technique L.

w = real wage rate per period in the production of corn;
$\bar{w}$ = real wage rate per period in the capital goods sector;
a = "capital intensity" as defined above;
P_c = labor productivity in corn production in department II of sector A;
L_i = labor employed in department I;
L_c = labor employed in department II;
C = total corn produced in sector A;
W_c = total wages bill in department II of sector A;
and N = the surplus of corn production over the wages bill $(C - W_c)$, in department II.

5. Compare this problem with that of Marx's "Primitive Accumulation."

6. For a discussion of the reasons for using this type of "classical" supply curve of labor, see W. A. Lewis, "Economic Development with Unlimited Supply of Labour," *Manchester School*, XXII (May 1954), p. 139.

7. See Joan Robinson, "The Production Function and the Theory of Capital," *Review of Economic Studies*, XXI (1953–54), p. 85. See also *idem*, *The Accumulation of Capital* (London: Macmillan and Co., 1956), pp. 64–65.

In the case of technique H we use primed notations. Numerical suffixes refer to the relevant time periods.

As temporary assumptions we have, $w = w'$ and $\bar{w} = \bar{w}'$. We know that $a < a'$. Obviously P_c must be less than P_c'; otherwise there would be little reason to take the more capital-intensive technique seriously.

Let us start with a surplus S of corn extracted from sector B to make the initation of Sector A possible. We assume that wage earners in department II are paid out of their production.

$$L_i = \frac{S}{\bar{w}} \qquad L_c = \frac{S}{\bar{w}a}; \qquad C = \frac{SP_c}{\bar{w}a}.$$

Similarly

$$C' = \frac{SP_c'}{\bar{w}a'}.$$

If we are interested only in the total product for the first period, our choice would depend on whether

$$\frac{P_c'}{a'} > , = \quad \text{or} \quad < \frac{P_c}{a}. \tag{1}$$

This is the rate-of-turnover criterion.[8]

Production in future years will depend not merely on the flow of output from the initial investment, but also on that from additional investments undertaken with the surplus product. So if we are interested in the maximum rate of growth of output, the relevant consideration is the rate of surplus.

$$N_1 = C_1 - W_{c1} = \frac{S}{\bar{w}} \cdot \frac{P_c - w}{a}.$$

$$N_1' = C_1' - W_{c1}' = \frac{S}{\bar{w}} \cdot \frac{P_{c'} - w}{a'}.$$

We should choose H or L or be indifferent between them depending

$$\text{on whether } \frac{P_{c'} - w}{a'} > , < \text{ or } = \frac{P_c - w}{a} \text{ respectively.} \tag{2}$$

This is the rate-of-reinvestment criterion.

All this can be represented in diagrammatic form without much difficulty. In Figure II there are three axes — the south representing employment in department I, the east employment in department II and the north the corn output of the latter department. OI is the

8. The social marginal productivity criterion coincides with this, as unemployed labor is available in the economy.

amount of labor that can be employed with the available corn surplus at the prevailing wage rate. Employment in department II depends on the degree of capital intensity chosen, it being defined as the number of laborers that have to be employed in department I to produce enough capital goods for employing one man in department II. Three degrees of capital intensity are used in the figure, represented in the increasing order by the tangent of the angles OL_cI,

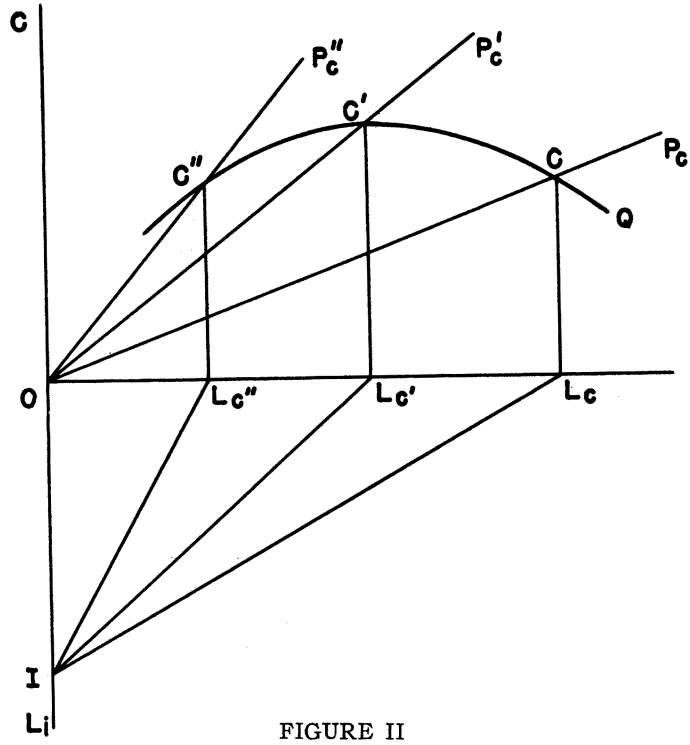

FIGURE II

$OL_{c'}I$ and $OL_{c''}I$ respectively. The employment created as a result of this investment is OL_c, $OL_{c'}$ and $OL_{c''}$ respectively. With increasing capital intensity, the product per unit of labor in department II rises, represented respectively by the tangents of the angles P_cOL_c, $P_{c'}OL_c$ and $P_{c''}OL_c$. Thus the corn output when the first technique is chosen is CL_c, when the second is chosen $C'L_{c'}$ and when the third is preferred $C''L_{c''}$. By taking infinitesimal changes in the degree of capital intensity, we derive the curve Q representing the relationship between employment in department II and the output of corn, governed by the technological possibilities. In Figure III, we have the

curve Q and a line Wc representing the total wages bill in department II. As we have assumed a given wage rate, the latter is a straight-line. E represents the point of maximum output. P is the point of maximum surplus of corn production over consumption, as the slope of curve Q at that point is equal to the wage rate. If we adopt the rate-of-turnover criterion, or the SMP criterion when unemployed labor is available without affecting production elsewhere, we should choose point E. If, however, we adopt the rate-of-reinvestment criterion, point P should be chosen.

An interesting possibility is represented by point E lying below the wage-line, as in Figure IV. This means that maximization of output would involve negative surplus.[9] Point T gives maximum

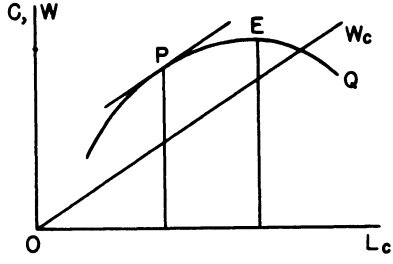

FIGURE III

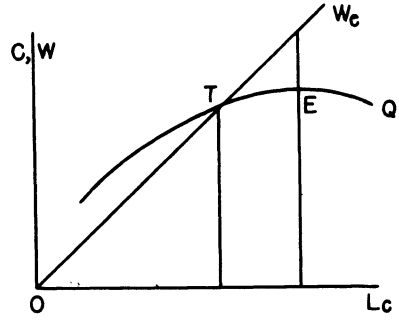

FIGURE IV

output consistent with the condition that output covers the wages bill ($P_c = w$). It is thus possible that full application of the SMP criterion or the rate-of-turnover criterion may involve capital contraction rather than accumulation.

In Figure V, it is illustrated that a rise in the wage rate makes it more profitable to choose a more capital-intensive technique. When the wage-line moves up from W_c to $W_{c'}$, the point of maximum surplus becomes A rather than B, as $B_2B_3 < A_2A_3$, although $B_1B_3 > A_1A_3$.[1] This follows also from relation (2), as a technique with a higher rate

9. I am indebted to Joan Robinson for drawing my attention to this possibility.

1. If, however, lower productivity (with the same technique) tends to go with lower wages, this effect will to that extent be countered. See M. H. Dobb, "A Note on the Degree of Capital Intensity of Investments in Underdeveloped Countries," *Economie Appliquée*, VII (1954); reprinted in his *On Economic Theory and Socialism* (London, 1955), p. 148. Also see *idem*, "Second Thoughts on Capital-intensity of Investment," *Review of Economic Studies*, XXIV, 37–38.

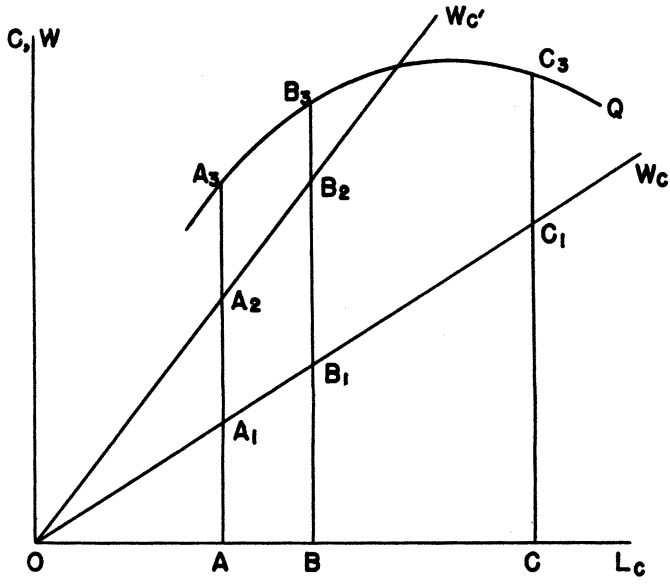

FIGURE V

of surplus per laborer ($P_c - w$) is relatively less affected by a rise in the wage rate.[2]

From this it does not follow, however, that a lower wage economy should necessarily choose a lower degree of capital intensity. In fact, the scope of variation of capital intensity may be very limited, and it may well be that, of the available techniques, the same is best for most wages. In Figure V, if A and C were the only techniques that existed, a fall in the wage rate from $W_{c'}$ to W_c would have kept the technique unchanged at A, ($C_1C_3 < A_1A_3$). This discontinuity in the production function is a possible explanation of the fact that even low wage economies very often choose techniques that are hardly different from those of the advanced economies.

Lastly, since we equate labor cost to the net increase in consumption due to additional employment, if a part of the former consumption of the laborers previously in sector B can be recovered, the effective wages will be less. If consumption per head in the subsistence sector is k and the proportion of it that can be recovered is q then

$$N_1 = \frac{S}{\overline{w}} \cdot \frac{P_c - w + kq}{a} = \frac{S}{\overline{w}} \cdot \frac{P_c - w(1-f)}{a}, \text{ putting } f = \frac{kq}{w}.$$

2. See in this connection, Joan Robinson, "The Production Function and the Theory of Capital," *op. cit.* Also see *idem*, *The Accumulation of Capital*, *op. cit.*, chap. 10.

Recovery of consumption of the formerly unemployed is similar to a reduction of wages and in a borderline case can make us choose a less capital-intensive technique. Left to the free market, however, the scope of recovery is not great, since, in all probability, the remaining rural population will consume nearly the whole of the extra income left by the villagers leaving for the town, as their marginal propensity to consume is very near unity. Taxation linked with the exodus from the rural area, or some system of "compulsory delivery," may, however, achieve this end. This shows the dependence of technological choice on the fiscal policy in operation in the economy.[3]

Before we move over to the next model, we may summarize the observations we have made on the connections between labor-cost and technological choice. (1) Even if there is a lot of unemployment in an economy and the social opportunity cost of using labor is nil, it will be a mistake, if we are interested in the rate of growth of the economy, to treat labor as costless and to substitute capital for labor whenever possible. (2) If the rate of growth is our criterion, lower wages should influence our choice in favor of lower capital intensity, though in many cases, due to the discontinuity of the production function, this point is of only academic interest. (3) The higher the amount of former consumption of the newly employed people that can be recovered through taxation, or compulsory delivery, or other means, the lower should be the capital intensity chosen, given a continuous production function.

(II) The Second Model. Let us now release the assumption that machinery can be produced by labor alone, which means we also have to give up the assumption of the economy being closed, as an economy which is just starting to develop has to import some machinery (at least to make other machinery) to be in a position to exploit modern technology rather than re-enact the whole drama of industrial revolution from beginning to end step by step. It is assumed that while machinery for technique L can be produced by labor alone, that for technique H needs capital goods imported from abroad. This contrast agrees roughly with that between cottage industrial and factory production which all underdeveloped countries face. For a large number of processes, like spinning, weaving, oil-pressing, rice-pounding,

3. This point, among others, is discussed in the Indian context in my note on "Labour Cost and Economic Growth," *Economic Weekly* (India), Sept. 29, 1956. It was followed by some controversy on this question, among others in the October and November issues of the *Weekly*, which may be interesting, especially to those who are fond of polemical writings. A controversy on an identical point seems to have taken place in this *Journal*, LXX (Nov. 1956). See Hans Neisser, *op. cit.*, and Galenson and Leibenstein, "Reply," *op. cit.*

this contrast is very sharp — cottage industrial production involves the use of very simple tools that can be easily produced and factory production involves much more sophisticated machinery that has to be imported from the industrially advanced countries. The choice between the two is very often one of the most controversial problems of development planning. For the sake of simplicity let us also assume that while the machines to make consumer goods last forever, machines to make machines wear away in a year.

Let us assume that in the case of technique H the value of machinery needed per person employed in department I at the initial foreign price is given by d. We assume, to start with, that such machines are in perfectly elastic supply. In the absence of foreign loans or aid, this foreign exchange has to be earned by exports. We assume that a part of the corn surplus is sent abroad and sold at a constant price g per unit. Thus to employ one man in department I (technique H) we need $\left(\bar{w} + \frac{d}{g}\right)$ amount of corn. This gives us a surplus-flow of $\left(\frac{P_{c'} - w}{a'}\right)$ amount of corn. If, on the other hand, we employed $\left(\bar{w} + \frac{d}{g}\right)$ amount of corn in department I with technique L, the surplus would have been

$$N = \left(\bar{w} + \frac{d}{g}\right) \cdot \frac{1}{\bar{w}} \cdot \frac{P_c - w}{a} = \left(1 + \frac{d}{g\bar{w}}\right) \cdot \frac{P_c - w}{a}.$$

Therefore, assuming the same gestation lag for both the techniques, technique H is more, or less, surplus-yielding than technique L or equally so, according as

$$\frac{P_{c'} - w}{a'} \gtrless \text{ or } = \frac{P_c - w}{a}\left(1 + \frac{d}{g\bar{w}}\right). \qquad (3)$$

When corn is not in perfectly elastic demand and foreign machinery is not in perfectly elastic supply, the condition naturally is more stringent. When η is the relevant arc elasticity of foreign demand for corn and e the relevant arc elasticity of supply of foreign machinery,[4] the condition to be satisfied becomes:

4. The use of the concept of elasticity here is a bit illegitimate, as in our model there is no trade prior to this transaction. In reality, however, we are likely to start with some trade and in actual cases the effect on other transactions

$$\frac{P_{c'} - w}{a'} \gtrless \text{or} = \frac{P_c - w}{a}\left[1 + \frac{d\left(1 + \frac{1}{e}\right)}{\bar{w}g\left(1 - \frac{1}{\eta}\right)}\right]. \quad (4)$$

A few conclusions follow from this. (1) The higher these elasticities, *ceteris paribus*, the higher should be the degree of capital intensity chosen, assuming that higher capital intensity in an underdeveloped economy goes with larger import-content because of the lack of a capital goods sector in the economy.

(2) Also the relevant elasticities are likely to be smaller when the volume of transactions are larger. As a result there is a sort of "diminishing returns" with increased production employing the technique. Thus even if the more mechanized production is preferable up to a certain point, beyond that it may become less economic. Thus a development plan may involve both the more mechanized and the less mechanized techniques for the production of the same commodities.

(3) This also makes it desirable, given the values, for the state to intervene in the technical decisions taken by the private sector. The private entrepreneur may take into account the rise in the price of foreign machinery but not the increase in the quantity of exports necessary to pay for one unit of imports.

(4) The dependence of the choice of technology on the trade elasticities leads to an interesting possibility of asymmetry. Even if it is profitable not to *import* foreign machinery and to apply the less mechanized technique L, it does not follow that if these advanced machines were given to the country, the right course for it would be to export them and to use the proceeds for production with less mechanized techniques.

Let η_1 be the relevant arc elasticity of foreign demand for machinery and e_1 the relevant arc elasticity of foreign supply of corn. If a machine is sold abroad, the earning of foreign exchange is $d\left(1 - \frac{1}{\eta_1}\right)$.

has to be taken into account. In order to cope with both sorts of situations without making our formulae too complicated, the definition of arc elasticity we resort to is:

$$\left(\frac{\text{change in quantity}}{\text{final quantity}} \Big/ \frac{\text{change in price}}{\text{original world market price}}\right)$$

When we start from a no-trade position, change in quantity is equal to final quantity, and the value of the elasticity reduces to the ratio of the other two terms.

With that the amount of corn that can be imported is given by $\frac{g\left(1-\frac{1}{\eta_1}\right)}{d\left(1+\frac{1}{e_1}\right)}$. Thus instead of employing the machine (technique H) in the country and getting a surplus flow $\frac{P_{c'}-w}{a'}$, if $\left[\bar{w}+\frac{d\left(1-\frac{1}{\eta_1}\right)}{g\left(1+\frac{1}{e_1}\right)}\right]$ amount of corn is employed in department I for technique L, the surplus-flow we get is:

$$\bar{N}=\left[\bar{w}+\frac{d\left(1-\frac{1}{\eta_1}\right)}{g\left(1+\frac{1}{e_1}\right)}\right]\frac{P_c-w}{a}\cdot\frac{1}{\bar{w}}\,.$$

We should prefer technique H, or technique L, or be indifferent, according as:

$$\frac{P_{c'}-w}{a'}>,\ <\ \text{or}\ =\frac{P_c-w}{a}\left[\bar{w}+\frac{d\left(1-\frac{1}{\eta_1}\right)}{g\left(1+\frac{1}{e_1}\right)}\right]\cdot\frac{1}{\bar{w}}\cdot\quad(5)$$

Thus there is a range within which it would be economic to *use* technique H-machinery if one has any, but not to *import* any if one has none. From relations (4) and (5), we get the condition as:

$$\frac{P_c-w}{a}\left[1+\frac{d\left(1+\frac{1}{e}\right)}{\bar{w}g\left(1-\frac{1}{\eta}\right)}\right]>\frac{P_{c'}-w}{a'}>\frac{P_c-w}{a}\left[1+\frac{d\left(1-\frac{1}{\eta_1}\right)}{\bar{w}g\left(1+\frac{1}{e'}\right)}\right]\quad(6)$$

The width of the range within which the value of $\frac{P_{c'}-w}{a'}$ must lie is given by

$$\begin{aligned}R&=N-\bar{N}\\&=\frac{P_c-w}{a}\cdot\frac{d}{\bar{w}g}\left[\frac{\left(1+\frac{1}{e}\right)}{\left(1-\frac{1}{\eta}\right)}-\frac{\left(1-\frac{1}{\eta_1}\right)}{\left(1+\frac{1}{e_1}\right)}\right]\\&=\frac{P_c-w}{a}\cdot\frac{d}{\bar{w}g}\cdot\alpha,\ \text{putting}\ \alpha\ \text{for the expression within brackets.}\end{aligned}$$

The lower these elasticities the higher is the value of α and the larger is the range R. If for example, $e = e_1 = \eta = \eta_1 = 2$, the value of $\alpha = 2.67$. If on the other hand, $e = e_1 = \eta = \eta_1 = 3$, the value of $\alpha = 1.5$. The limiting case is where $e = e_1 = \eta = \eta_1 = \infty$ when $\alpha = 0$ and the range does not exist, $R = 0$. On the other extreme, if $\eta = \eta_1 = 1$, the range is infinite and any value of $\frac{P_{c'} - w}{c'}$ would satisfy the asymmetry.

This is likely to be a very important practical consideration for actual decision-making as (a) the trade elasticities are often quite low and (b) the import-content of factory investment, given by $\left[\frac{d}{g}\Big/\left(\bar{w} + \frac{d}{g}\right)\right]$, is often quite high compared with cottage industrial production of the same goods involving practically no imports.[5] This may be a case for the Indian planning policy of (i) building up a capital goods sector to produce machinery for *domestic use* in the future, and (ii) the production of consumer goods as much as possible by cottage industrial methods for the time being, which has led to a not inconsiderable amount of discussion on "inconsistency" in public policy.[6]

This aspect of the problem has unfortunately been neglected in most of the discussions on the question. For example, the otherwise excellent report on "Processes and Problems of Industrialisation in Under-developed Countries" published by the United Nations has possibly the wrong end of the stick altogether when, referring to the temporary control of factory-consumer goods industries in India to help the cottage industries, it declares:

"Such a damping down of production is *obviously* not in the interest of rapid industrialization: it is part of the price paid for easing transition from manual to mechanical production and for preventing the sudden dissolution of the ancient industrial organisation. . . ."[7] On the contrary, it is possible that such a temporary

5. When the possibility of importing consumer goods is included, even cottage industrial production may, however, have some indirect import-content arising out of its income effect.

6. Whether this was *actually* the considerations which prompted the government of India to take recourse to this asymmetrical policy, it is difficult to say, as the government has not yet bothered to tell us what criterion it adopts in choosing between techniques. Also, one must remember, that the above argument can be valid only as far as the government control of the creation of new output capacity is concerned. This provides no argument for the restriction of factory output *below capacity*.

7. United Nations, 1955, chap. 3, p. 49, italics mine.

damping down of factory consumer goods production may indeed help us to have the most rapid industrialization that the economy can achieve, by supplying consumer goods with the help of primitive techniques until the growing factory industries in the economy begin to supply the machinery needed for factory production.

(III) The Third Model. In this model we release the assumption of an absolute preference for a higher rate of growth and use the concept of "recovery" discussed earlier. We employ the notations of the previous models and, to keep the illustration simple, go back to the assumptions of a closed economy and of machinery being produced by labor alone.

Let us assume that while the less capital-intensive technique (L) offers a higher rate of turnover, it offers a lower rate of investible net surplus, i.e., while $\frac{P_{c'}}{a'} < \frac{P_c}{a}, \frac{P_{c'} - w}{a'} > \frac{P_c - w}{a}$. Let Y_0 be the output of sector B (the subsistence sector) which remains unchanged in spite of the exodus of population from it to the "advanced" sector.[8] Let S be the amount of corn surplus extracted from sector B every year from year zero. With technique L, consumers goods output in the first period is $\left(Y_0 + \frac{SP_c}{\bar{w}a}\right)$. In the second period we get in addition an output of $\frac{SP_c(P_c - w)}{(\bar{w}a)^2}$ from the capital stock created by the surplus (sector A) of the first period, and an output of $\frac{SP_c}{\bar{w}a}$ from the same year's extraction of S amount of corn from sector B. Thus the time series of real consumption flows, when technique L is chosen, is given by:

$$Y_1 = Y_0 + \frac{S}{\bar{w}} \cdot \frac{P_c}{a}$$

$$Y_2 = Y_0 + \frac{S}{\bar{w}} \cdot \frac{P_c}{a}\left[1 + \left(1 + \frac{P_c - w}{a\bar{w}}\right)\right]$$

8. Our model is based on a number of simplifying assumptions like those of unlimited supply of labor force from the unemployment pool of the subsistence sector, absence of depreciation, unchanging technical knowledge and so on, which are clearly unrealistic. But as the model is for illustrative purpose only, this does not really matter. When, however, we try to apply this approach to actual problems, these complications have to be introduced.

$$Y_3 = Y_0 + \frac{S}{\bar{w}} \cdot \frac{P_c}{a}\left[\, 1 + \left(1 + \frac{P_c - w}{a\bar{w}}\right) + \left(1 + \frac{P_c - w}{a\bar{w}}\right)^2 \right]$$

.
.
.
.
.

$$Y_n = Y_0 + \frac{S}{\bar{w}} \cdot \frac{P_c}{a}\left[\, 1 + \left(1 + \frac{P_c - w}{a\bar{w}}\right) + \left(1 + \frac{P_c - w}{a\bar{w}}\right)^2 + \right.$$

$$\left. \ldots\ldots\ldots\ldots + \left(1 + \frac{P_c - w}{a\bar{w}}\right)^{n-1} \right]$$

$$= Y_0 + \frac{S}{\bar{w}} \cdot \frac{P_c}{a} \cdot \frac{\left(1 + \dfrac{P_c - w}{a\bar{w}}\right)^n - 1}{\dfrac{P_c - w}{a\bar{w}}}$$

$$= Y_0 + S \cdot P_c \cdot \frac{\left(1 + \dfrac{P_c - w}{a\bar{w}}\right)^n - 1}{P_c - w}$$

The sum of the series up to tth year is given by

$$\sum_{n=1}^{n=t} Y_n = tY_0 + \sum_{n=1}^{n=t} SP_c \frac{\left(1 + \dfrac{P_c - w}{a\bar{w}}\right)^n - 1}{(P_c - w)}.$$

This gives us the *total* consumption of the nation over t years, when technique L is chosen. Similarly, when technique H is chosen, the same is given by $\sum_{n=1}^{n=t} Y_{n'} = tY_0 + \sum_{n=1}^{n=t} SP_{c'} \dfrac{\left(1 + \dfrac{P_{c'} - w}{a'\bar{w}}\right)^n - 1}{(P_{c'} - w)}$.

The difference between the two sums can be expressed as

$$D_t = S \cdot \frac{P_{c'}}{P_{c'} - w} \cdot \sum_{n=1}^{n=t} \left[\left(1 + \frac{P_{c'} - w}{a'\bar{w}}\right)^n - 1 \right]$$

$$- S \cdot \frac{P_c}{P_c - w} \cdot \sum_{n=1}^{n=t} \left[\left(1 + \frac{P_c - w}{a\bar{w}}\right)^n - 1 \right].$$

The least value of t which makes $D_t \geqslant 0$, is the "period of recovery," T. If T is shorter than the period we are going to take into account, U, technique H is preferable. If it is longer, technique L is to be chosen.

If we put $U = t = 1$, D_t reduces to $\frac{S}{w}\left(\frac{P_{c'}}{a'} - \frac{P_c}{a}\right)$. This is negative and we choose technique L. If, on the other hand, we put $U = t = \infty$, D_t must be positive as $\frac{P_{c'} - w}{a'} > \frac{P_c - w}{a}$; thus technique H is chosen. The first represents, in our model, the rate-of-turnover and the SMP criteria and the second the rate-of-reinvestment criterion. In the last analysis these criteria are found to be the limiting cases of a more general approach.

AMARTYA KUMAR SEN

JADAVPUR UNIVERSITY,
CALCUTTA