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APPROPRIATE TECHNOLOGY AND ECONOMIC DEVELOPMENT

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The decades since the end of World War II have witnessed a continuous concern for the process of economic development. Many different theories concerned with both economic growth and development have provided useful, but somewhat incomplete, insights about the process of economic change.[1] These theories have been reflected in the formulation and reformulation of public policies aimed at promoting economic development. Development strategies which reflect such policies range from early emphasis on capital intensive industries to the current concern with appropriate technology. The latter has resulted from a realization that economic growth is a necessary but not a sufficient condition for economic development.

In this paper, we (1) review the assumptions underlying the idea of appropriate technology,[2] with regard to factor proportions and factor homogeneity, in order to represent the idea for analytical evaluation; (2) compare the economic efficiency of appropriate technology with that of capital intensive and indigeneous factor endowment approaches to economic development, and (3) examine the short-run and long-run aspects of appropriate technology approaches to economic development. This study makes use of the, now common, definition that the objective of economic development is to raise the standard of living of a majority of the people in an area, region, or country. This can be accomplished by increasing employment and productivity of the people. The idea of appropriate technology thus yields definitive implications for investment in human and nonhuman resources.

In this discussion of appropriate technology we recognize that there are constraints associated with such things as availability of investment funds, market size, raw materials and so on, which affect application, but would have no effect on the basic theory. Therefore, these constraints are not discussed in the paper.

I. Appropriate Technology, Factor Proportions and Homogeneity

The idea of appropriate technology has developed largely from the concepts of Schumaker (1973) one of whose major points was that, as an aggregate,

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we haven't yet learned how to earn a livelihood because we have devoted all our time to exploiting finite resources with high powered technology. In many parts of the world the poor are getting poorer and established processes of foreign aid and development often seem to promote their impoverization.[3] A principal cause, according to Schumaker, is the "negative demonstration effect" of a sophisticated technology introduced into an unsophisticated environment.[4]

The term "appropriate technology" has been coined, by some of Schumaker's followers, to describe his ideal. It implies the use of indigenous materials and economy in the use of scarce factors. This approach places emphasis on production at the lowest levels.[5] The "appropriate technology" concept can also be broadened to make it more useful in economic development work. For example, a combination of a person with a specific skill and a technology which will allow him to increase his productivity could essentially be said to be an application of appropriate technology. This is the concept that has been widely accepted and is the one used in this paper.

Underlying the appropriate technology concept, as in other policy emphasis, is the implicit proposition that the objective of economic development is to raise the income of individuals in an area. Further, it is proposed that this can only be accomplished by expanding employment and increasing productivity of such individuals through the choice of appropriate products and production processes. The idea of appropriate technology also requires two basic assumptions. These are : (1) that there exists strict factor proportionality in production processes and (2) that factors are not homogeneous. With these two assumptions, it is possible to use the conventional framework to represent the idea of appropriate technology for analytical evaluation.

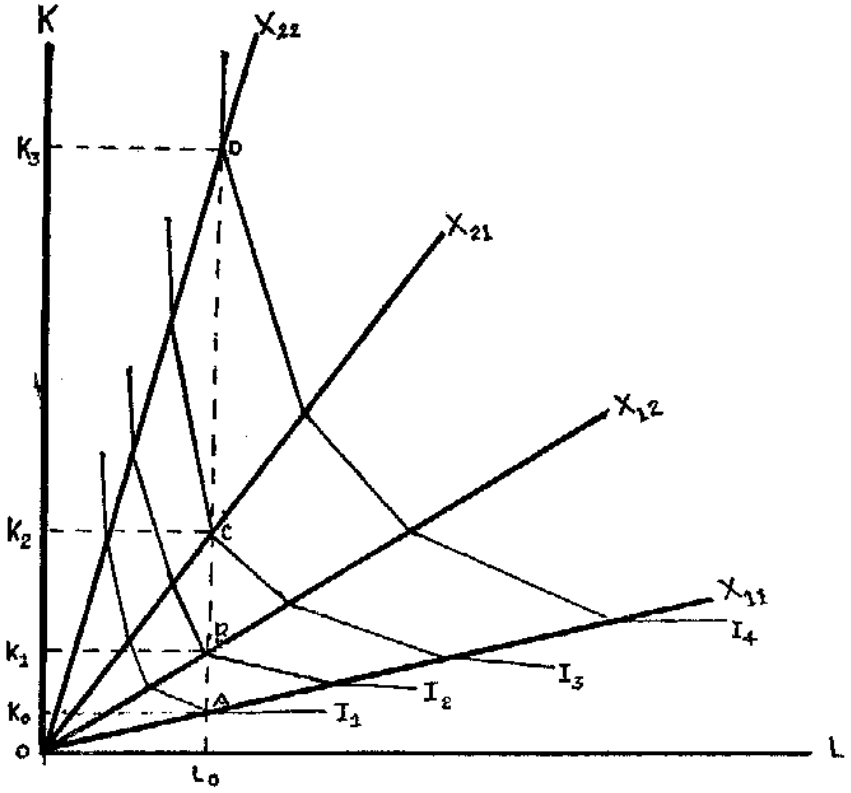
The reason for the assumption of strict factor proportionality is obvious. By choosing appropriate products and production processes appropriate technology can be interpreted as an appropriate input combination. If as is assumed by most economists and as it appears in most textbooks, factors are continuously substitutable, then the appropriate input combination determined by relative prices of inputs; but, if there exists strict factor proportionality, then the manner in which inputs are combined is determined by the technology, not relative prices. The idea of an appropriate technology must, therefore, be based on the assumption that there are strict factor proportions in production processes. This means that there may be a discrepancy between price relationships and factor proportions, a situation noted repeatedly by writers on economic development for developing countries.[6]

Homogeneity of factors is basic to the idea of substitution. However, no meaningful case can be made for the idea of appropriate technology if homogeneous factors are assumed. Thus, the appropriate technology approach to economic development requires an additional assumption of factor heterogeneity in addition to strict factor proportions. This point can be demonstrated graphically. Assuming that there are technological restraints such that factors must be combined in strict proportions

as suggested by Eckaus (1955) and in linear programming studies, each approach to economic development can be represented by a "development set," given the development objective.[7] To illustrate, technology determines both 1) the nature and types of products that can be produced and 2) methods of production. Thus, there exists a "development space" representing the products and production processes made possible by the technology. The space, being determined by technology, will change with it.

Each approach to economic development is identifiable with a subset in the development space. This may be illustrated as follows. Assume that the state of technology makes it possible to produce two products, each having two production processes, the development space may be represented by the rays x_{11}' x_{12}' x_{21}' x_{22} in Figure 1. Let us first assume that capital and labor are homogeneous.

Figure 1



Decision makers may identify a subset in the development space in light of their policy objective. For example, if a country has the actual factor endowment repre-

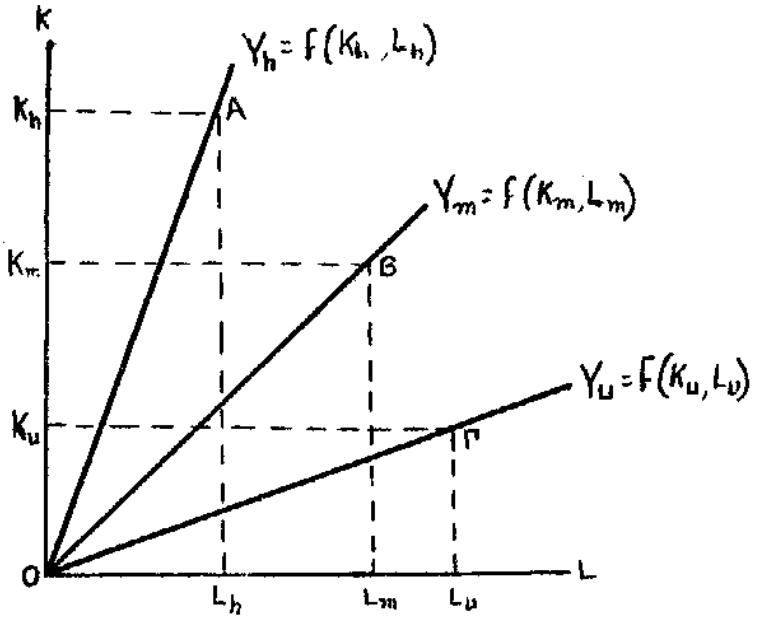
sented by the point C, in Figure 1, and it is its objective to maximize the employment of its own factors (both capital and labor), then the production ray to be chosen is x_{21}. The indigeneous factor endowment (IFE) development set, then, is C. However, if the country wishes to emphasize capital-intensive industry, then the production process to be chosen is x_{22}. The ray x_{22} thus becomes the capital-intensive (CI) development set.

The above indicates that it is possible to identify a development set based on CI and IFE approaches even if capital and labor are homogeneous. However, when factors are homogeneous, no appropriate technology (AT) development set can be identified. For example, in Figure 1, each of the four production processes, x_{ij}'s, is compatible with the full employment of labor, OL_0. One cannot, therefore, say which of the production processes or input combinations (A, B, C, or D) is appropriate. In other words, it is not possible to determine a unigue product and production process consistent with maximization of employment from the data on technology, if factors are homogenous.

For data on the state of technology to provide information about appropriate product and production processes, factors must be heterogeneous and there must be strict factor proportionality in the production process. In this case, for any specific production process, capital, labor and raw materials are complementary. More importantly, capital of particular functional characteristics and degrees of technical sophistication must be combined with labor of specific types and degrees of skill.

To illustrate, suppose that, for a given country, the state of technology, human skills, and raw materials makes it possible to produce three products with highly sophisticated, moderately sophisticated and unsophisticated technologies combined with highly skilled, moderately skilled and unskilled labor respectively. Further assume that each product can be produced with only one process. These assumptions yield a development space presented in Figure 2.

Figure 2



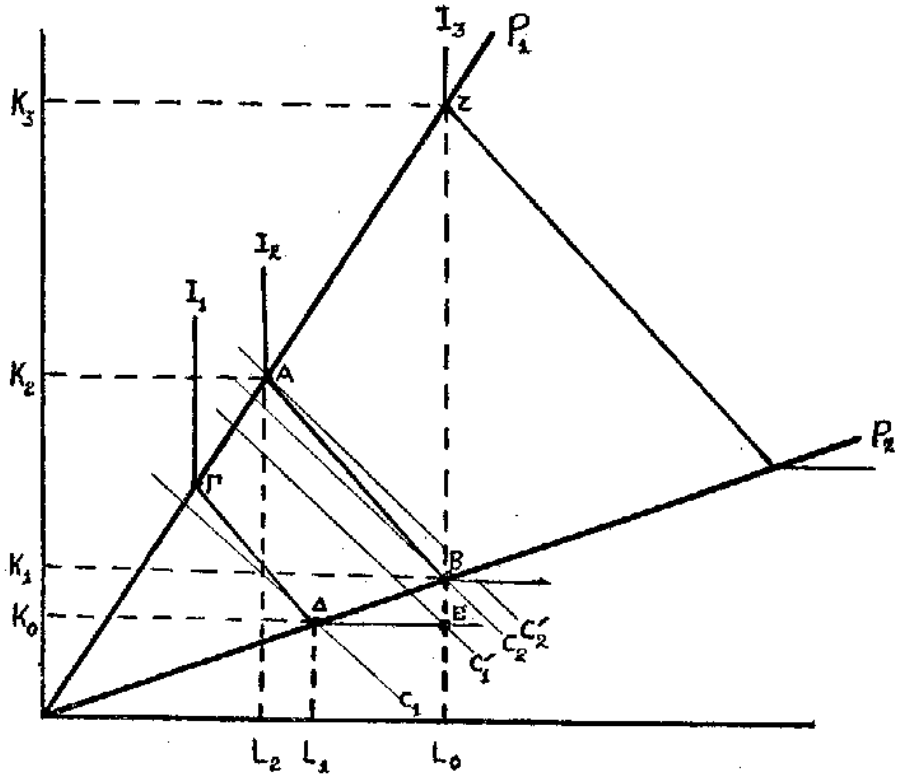
In the development space, an AT development set (representing appropriate products and production processes) can be identified given the objective of maximizing employment. For example, if a country possesses moderately skilled and unskilled labor, then the appropriate production processes are given by the rays Y_m and Y_u. If the stocks of moderately skilled and unskilled labor are respectively OLm and OL_u as represented on the horizontal axis, and if the country wishes to maximize its employment using the AT approach, then the appropriate input combinations are represented by the points B and T on the Y_m and Y_u rays.[8] These two points constitute the country's AT development set. This set does not include any point on the ray Y_h because the country does not possess highly trained labor. The appropriate input combinations represented by the points B and T in Figure 2 require OK_m and OKu respectively of moderately sophisticated and unsophisticated capital which must be provided. Such capital types, however, are relatively inexpensive as compared with capital of highly sophisticated types.

II. Comparative Efficiency of Appropriate Technology

Appropriate technology is now regarded as an alternative to the capital intensive approach to economic development. It may also be an alternative to an indigeneous factor endowment approach.[9] In this section we compare the implications of the AT approach to that of the other two with special reference to efficiency, capital investment, employment, and flow of savings.

For this comparison, we make a number of simplyifing assumptions. Specifically, we assume strict factor proportionality in production process, a relatively abundant supply of labor and a relative scarcity of investment funds. We also assume that labor is relatively less expensive than capital as compared with their respective marginal productivities. In Figure 3, there is depicted a situation in which a product can be produced with one of two processes, a capital-intensive[10] one (P_1) and a labor intensive one (P_2).

Figure 3



Production off these rays is less efficient than production on the ray. The cost lines C_1 and C_2 are shown with the sole objective of reflecting relative costs at the same level of output, thus C_1 and C_1' reflect costs only for production at the I_1 level and are not to be compared with C_2 and C_2', which are related to I_2.

We assume that the capital intensive process P_1 combiness sophisticated technology with highly trained personnel while the labor intensive process combines unsophisticated technology with unskilled labor. It is also assumed that the country possesses $^{O}L_o$ of unskilled labor and $^{O}K_o$ of unsophisticated capital represented by the point E in Figure 3. This point can be regarded as representing the IFE development set. However, assuming the objective of maximizing employment and assuming strict factor proportionality, the point B constitutes the AT development set.[11]

It can be seen from figure 3 that there can be full employment by either the IFE (point E) or AT (point B) approaches. The AT approach however, requires additional capital investment of $OK_1 - OK_0$, which makes it possible to increase output by $\Delta I = I_2 - I_1$.

The IFE approach, although it does not require additional capital investment, is not economically as efficient as AT approach because it cannot attain an optimal input combination represented on the ray P_2. Because of this relative inefficiency, it will cost more to produce a given level of output if the IFE approach is used. For example, an output Level I_1 can be produced if both factors are fully employed at point E. The cost of producing this output by the IFE approach is c_1' which is higher than the cost of producing the same output level (I_1) with the input combination represented by Δ using the AT approach. That is, $c_1' > c_1$ in Figure 3.

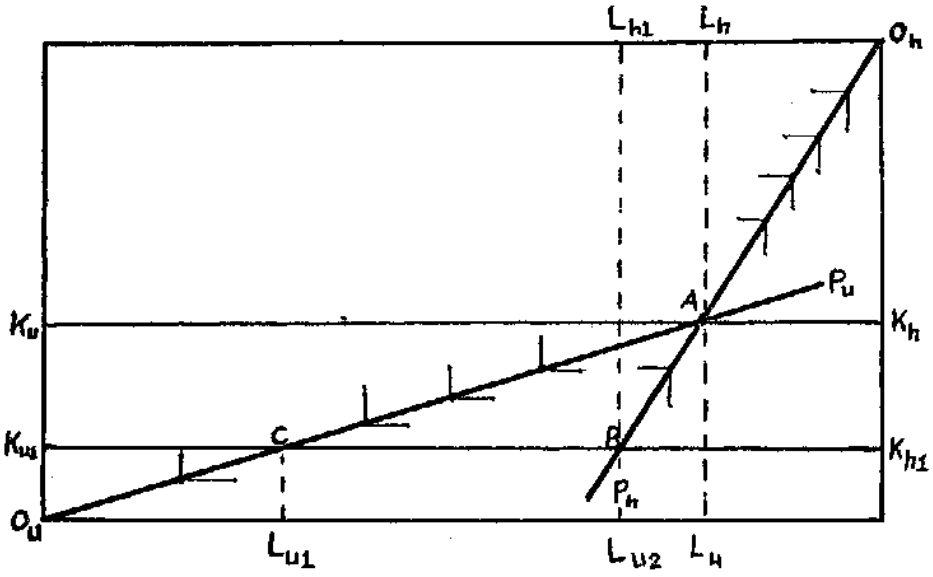
Since, by assumption, the country in question does not possess highly-trained labor, the process P_1 is not in its development set. However, in order to compare the employment impacts and relative efficiency of CI approach with those of AT approach, suppose that additional training can be given to the unskilled labor so that the CI approach can be adopted. To simplify our analysis, we compare the relative efficiency and employment impacts of the two approaches at the output level I_2 which is the full employment output under AT approach.[12]

At this output level, the CI approach (point A) utilizes more capital investment (of OK_2) but will not provide full employment. In fact there will be unemployment of $L_0 L_2$ at this output level if the CI approach is used. The CI approach is also not as efficient as the AT approach. For example, the cost of producing the output I_2 is c_2' by the CI approach as compared with a lower cost of c_2 using the AT approach. Under the CI approach, the only way to obtain full employment would be to retrain the entire labor force and increase capital investment to OK_3. But lack of capital will prevent this happening, even if training were possible.

Further contrast between the CI and AT approaches can be obtained by comparing the impacts of alternate allocation of a fixed amount of investment on the employment of labor. For such a comparison, Figure 4 depicts the assumption that a production process (P_h) using sophisticated technology is complemented by skilled personnel, and another production process (P_u) using unsophisticated technology is complemented by unskilled labor. Total labor endowment consists of O_uL_u of unskilled personnel and O_hL_h of skilled labor (represented on the horizontal sides of the box diagram in Figure 4). To complement O_uLu of unskilled labor to use the production processs P_u, O_uK_u of capital investment is required. Similarly, O_hK_h of sophisticated capital investment is required to complement O_hL_h of skilled labor to implement the production process P_h. The AT development set is thus represented by the point A. If the amount of capital investment required is also available, then the AT approach will provide full employment. Alternately, if the CI approach is

emphasized, more of capital investment will be allocated to the production process P_h. For example, if O_hK_{hl} is allocated to P_h, then only O_uK_{ul} will be available to P_u. Such an allocation will mean that employment of unskilled labor will be O_uL_{ul} and that of skilled personnel will be O_hL_{hl}. This means actual use of process P_h will be at point B and of P_u^* at point C. Since unskilled labor cannot be substituted for skilled personnel, unemployment among unskilled personnel will amount to $O_uL_u - O_uL_{ul} = L_uL_{ul}$ while the increase in the employment of skilled workers of $O_hL_{hl} - O_hL_h = L_h^{\prime}L_h$ must be imported. It would of course be possible to train domestic

Figure 4



personnel to satisfy the additional requirement for skilled workers $L_{hl}L_h$. Even so, there will still be unemployment of unskilled workers, since the increased demand for skilled workers amounts to only $L_{hl}L_h = L_uL_{u2}$. In this case the net increase in unemployment of unskilled workers resulting from the emphasized CI approach would be $L_{u2}L_{ul}$.

The fact that the CI approach to development causes unemployment also means that there will be adverse effects on the supply of investment funds. In most developing countries investment funds come from either foreign exchange or from domestic savings. The added unemployment means that any savings these people may have done before, will be terminated. In addition, they have autonomous consumption. This means that the effects on the rate of savings associated with

unemployment of unskilled workers will amount to the value of autonomous consumption plus the amount of personal savings foregone.

The counter argument is that use of sophisticated capital and labor increases returns to owners of these two factors and, since these people live above the subsistence level, they are more likely to be significant savers. Therefore, savings should increase. First, savings of skilled labor will increase only if they are not imported. Imported workers generally send their excess out of the country. Secondly, while owners of sophisticated capital and labor have high incomes, they are usually a small minority of the population. Their increased savings would have to offset both negative impact on the flow of savings due to unemployment and any funds used to pay for imported skilled workers.

III. Appropriate Technology in the Long Run

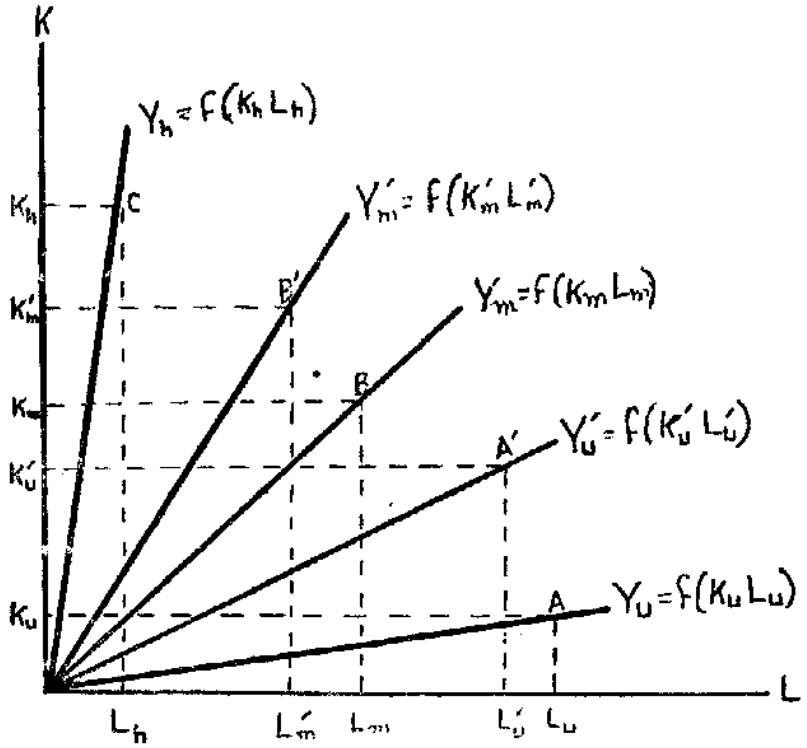
As previously noted, the objective of economic development has to be to raise the income of individual members of the society. This can only be accomplished by increasing employment and productivity of members of the society. Under the AT approach, there are assumptions of (1) strict factor proportionality and (2) complementarity between capital (of specific functional characteristics and degree of technological sophistication) and labor (with particular set of skill and training.)

These assumptions indicate that while the application of high technology capital and highly skilled labor to problems of growth in a society where most of the labor force is unskilled, may cause economic growth to occur in terms of increased gross national product, this is not a sufficient condition for economic development. Instead, by matching appropriate types of capital and technology to the specific sets of skills of the labor force, it should be possible, in the short run, to increase employment and productivity without changing the skill training of the individuals. In the long run, not only can the skills and training of the labor force be upgraded and expanded, but existing production functions may be modified and new products as well as new production methods may be introduced.

Economic development policy based on appropriate technology will mean that in any short run situation, economic activities should be carried out in the AT development set. In the long run one aspect is to seek to upgrade the skill level and expand the skill types of the labor force in order to change the appropriate development set and pursue development activities in the new set. This can be done even if there is no change in development space. For example if, in Figure 5, the development space is (Y_h, Y_m and Y_u) and the stock of human resources in $t=1$ is OLm and OL_u, then the AT development set is given by (A, B). This set does not include Y_h because there is no highly skilled labor available. But if skilled labor

becomes available in t = 2, then a point on Y_h can be added to the AT development set. A second aspect of the AT approach, in the long run, would be to change both skill levels and types of labor coupled with changes in the development space.[18] For example, if the technology for production ray Y_u changes to Yu' and that for Y_m changes to Y_m' then the development space in t = 2 changes to (Y_h, Y_m' and Y_u'). Now if the stock of human resources changes to (OL_h, OL_m', OL_u') the AT development set becomes (A', B', C) and appropriate technology requires that economic activities be carried out in that set in the second period.

Figure 5



The above indicates that technology defines the development space–and changes in technology will, therefore, cause it to change. Choice of an AT development set depends upon skill types and levels of labor. These further indicate that the explicit assumption that there are many different types of labor and capital provides opportunities for exploring additional dimensions to the processes of economic development. Such opportunities arise because labor and capital of specific nature and types are complementary.

Economic development encompasses a very large number of economic activities which are broadly classified as production, distribution and financing. Some of these activities are substitutable for one another while others are complementary. It is possible to classify substitutable activities into single activity blocks. The different blocks are, then, complementary. Activities in each block are carried out with combinations of labor with specific skills and other productive attributes and capital with particular functional characteristics and degrees of technological sophistication. Skills are based largely on scientific information which furnishes basic understanding; technological information, which enables people to improve products and processes; operational information, which enables them to operate and maintain sophisticated equipment; and coordinational information, which enables them to organize and manage. Among the other productive attributes of labor are found complementary bundles of information, which determine attitudes, such as cultural and social mores.

Thus, in each production process there is a technologically complementary set of human (labor) and non-human (capital) resources. For such a set, there is a proportionality relationship representing an optimal input combination, determined by technical requirements. In this case, it may be said that there is an equilibrium between human and non-human resources in the sense that production processes are structurally consistent and there is no bottleneck in the flow of productive activities.

The concept of such an equilibrium between human and non-human resources provides the basic argument for appropriate technology. Each person shouldc-have available those non-human resources which will enable him to optimize production based on his human resources.

The reality of the situation is that economic development is a long drawn out affair. Thus, where the human resource information base is low, sophisticated technology and capital cannot be used. But as the human resource base increases in sophistication (skill, knowledge, etc.) the sophistication of non-human resources can be raised also. This reflects the fact that achievement of optimal production from people with low information bases, will require unsophisticated technologies, but they should be the best technologies that these people can handle. Even this requires time, because so many people are capable of producing more, if they had the proper non-human resources to work with. The first step in economic development, then, should be to establish an equilibrium between existing human resources and non-human resource bases. The next step is to bring the information base of the human resource to a higher level and to furnish the non-human resources that will make increased production possible. The whole peocess bacomes a ratchet effect, with the first goal to move everyone out of abject poverty to, at least, a genteel poverty level.

The concept of appropriate technology implies also that there must be a balancing of effort. For example, a small farmer with 3 hectares of land may have potential for a considerable increase in production by increasing his operational and coordinational skills. It is well known that much of the success achieved from introduction of hybrid corn and fertilizers etc. in Kenya is due to the fact that those pushing the new technology impress farmers with the idea that certain coordinating or management principles are part of the package. Farmers who accepted the latter, but who returned to the old technology, found their yields increased significantly over those they had been used to.[14]

IV. Conclusions

Recent interest in appropriate technology reflects, in part, the realization that emphasis on capital intensive industries is not the answer to all development problems. The idea of appropriate technology, however, has not been previously defined so that it may be subjected to analytical evaluation. For this reason, this study has considered several assumptions underlying the idea of appropriate technology and has comparatively evaluated its economic efficiency and employment impacts.

Our analysis indicates that appropriate technology can be represented as appropriate input combinations based on technical considerations and policy objectives. An appropriate technology set can thus be identified on the basis of technological data and the policy objective of a country or region. However, a case can be made for such an idea only if there is strict factor proportionality in a production process and factors are not homogeneous.

It is shown that under simplifying assumptions commonly stipulated in economic analysis, appropriate technology (AT) and indigeneous factor endowment (IFE) approaches have the same employment impacts. However, the AT approach is comparatively more efficient than the IFE approach, An AT approach is also more efficient and has greater employment impacts than the capital intensive approach.

Appropriate technology has short run and long run aspects. In the short run, it means that development efforts are to be directed into the AT development set. In the long run, one aspect will be to seek to change an AT development set by altering the skill training of labor and matching this skill level with capital of the complementary level of sophistication. This can be accomplished even if there is no change in the development space. Another aspect will be to seek to change both the development space through technological changes and to change the development set by changing the skill level and skill-types of labor accompanied by complementary changes in sophistication of capital.

FOOTNOTES

1. Theories which have been prominent in setting policy in the past include :
   a. Those based on the concept that the growth in capital is all important to development. They include Harrod–Domar Models [Domar (1947) and Harrod (1948)]; absorptive capacity [Lee (1957) and Lewis (1954)], vicious circles [Nurske (1953) and Singer (1949)], balanced growth [Rosenstein–Rodan (1943)], and unbalanced growth [Hirschman (1958) and Scitovsky (1959)].
   b. Human resource oriented theories. These theories include the human capital idea recently reviewed by Blaug (1976), those that tie human resources to technical change via innovation and entrepreneurship [Lewis (1966), Schumpeter (1934), and Smith (1776)], those that deal with the transfer of labor resources from agriculture to industry [Fei and Ranis (1964), Lewis (1954) and Schultz (1964)] and those which emphasize attitudes and other social influences on potential workers [Adelman and Morris (1965) (1967), and Nair (1979)].
   c. Other kinds of orientation. These theories include arguments about growth poles [Myrdahl (1957) and Perroux (1955)], the size of market (common market) idea [Kindelberger (1965) and Konen and Subitz (1971)], Staple Commodity influence [Watkins (1943)], stages of growth [Rostow (1960)], and the effect of climate [Huntington (1945), Karnarck, (1972) and Lee (1957)]. Many of these theories emphasize important aspects of development, but none of them provide an adequate framework for good policy formulation.
2. Our definition of appropriate technology is not the "small is better" concept of Schumaker [1973) but, rather, a balancing of human and non–human resources.
3. For proof of this see Adelman and Morris (1971).
4. Here Schumaker is referring primarily to the fact that such an action creates unemployment, although other negative factors, such as pollution, are considered also.
5. Schumaker's "small is beautiful" concept places too much emphasis on keeping production at low levels. This part of his philosophy has not been followed by many people who have accepted appropriate technology concepts in terms of economic development. Rather, they look on technology as a way of raising productivity of unskilled people.
6. See, for example, Kindleberger and Despres [1952], Eckaus [1955]. In developing countries factor markets work very imperfectly. Government intervention, for example, may be in the form of incentives which lead to the use of capital–intensive methods even though, on a regular market, the price of capital would be too high for this type of utilization. An AT theoretical approach would suggest that such intervention should be guided by technological considerations.
7. A development set is a subset in the development space, which is stipulated by policy emphasis.

8. This illustration is highly simplified, there could, for example, be other rays and possibly production surfaces made possible by the state of technology.

9. The indogenous factor endowment approach means utilization of factors which are available in the economy regardless of efficiency of utilization.

10. While the profession officially defines capital and labor intensity in terms of numbers of units, by common usage capital intensity also implies capital of greater production potential, which is more costly, plus labor at higher skill levels and greater cost per unit. Likewise labor intensity may imply capital of lower production potential per unit combined with labor at low skill levels and low per unit cost.

11. In this example, the AT development set consists of only a single point. In the more general case of two or more technology rays, the AT development set will consist of a set of points. A decision-maker may choose an optimal point in this set in the light of his objective function. The optimal point in each set can then be compared.

12. For simplicity's sake we ignore the cost of training unskilled personnel to handle technology represented by P_1. If such costs were included, it would make the CI approach even less desireable, because it would be more expensive.

13. This means that there are questions of "what does it cost the economy to accumulate additional sophisticated capital" and "what does it cost to provide training to convert less skilled to more skilled labor." These are being studied as an extension of this project.

14. Reported in a special report of the Rockefeller Foundation by Streeter, P. 47.

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