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Notes on Invention and Innovation in Less Developed Countries

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I. Introduction

Invention and innovation in the less developed countries present particular problems for analysis because of the special characteristics of the organization of their economies, their resource proportions and their relations with more advanced economies and partly because of the intensity with which their economic growth is being pursued. In this paper I hope only to illustrate rather than resolve the difficulties in understanding the role of technical change and in making policy for it.

The distinction which I shall adopt between invention and innovation is between the processes by which new products or processes are created and the actual implementation of the new processes and production of the new products. I shall not try to maintain the distinction which has been made much of in the past, especially by Schumpeter, between the first use of a new technology and its subsequent imitation. In some instances that distinction may be profound but I think those cases are exceptional. The limited literature with which I am familiar on the sociology of innovation suggests to me that the distinction is usually a matter of degree and that the psychological and cultural barriers to imitation of a technological

change are often no less significant than those to the first use.[1] The innovation-imitation distinction may also be given an economic interpretation in terms of the relative risks involved. It might be argued that except where monopolization is complete the first innovator creates a true externality which reduces risk: the knowledge of his success or failure. But success or failure is not always quickly identified, except in extreme cases and even in the case of success in less developed countries neither the original innovator nor his potential imitators may be fully aware of how much is due to the new seed or new product, for example, or the special attention and favors of government officials.

The role of process innovation in directly increasing factor productivity is only one of its important functions in the less developed areas. It is, however, that function in which economists have been most interested and which will be the main subject of this paper. Product innovations, by which new goods are created, offer a different set of analytical challenges including the one of rigorously maintaining the process-product innovation distinction itself. "New" goods in less developed countries may be "old" goods in the more advanced countries. Their production raises questions of the relative effectiveness of investment in import substituting versus export gaining industries which I do not wish to take up here.

Process innovations in the less developed countries, as in the more advanced, are generally taken to mean a change in "technology" with

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[1] Professor E. Hagen's On the Theory of Social Change, 1962 has influenced my views though I cannot find a particular supporting quotation. The frequent references to the difficulties of dispersing the technical changes demonstrated in pilot projects may also be adduced in partial support of this view.

a corresponding change in factor productivity. Engineers know what a "technology" is and identify processes by the character of the physical and chemical transformations involved or the equipment which produces them. Economists on the other hand do not need to know about physical and chemical processes and identify technologies by the amounts of productive factors used and the associated outputs. The production function is simply a summary of all the alternative physically efficient combinations of productive factors which are necessary for different output levels. Because of the theoretical convenience, economists are fond of representing production functions by smooth and continuous analytical functions. Technical change substitutes for one set of factor inputs, which are required for a particular output, another set, which is superior in the sense that it uses less of at least one factor. It is often represented as a change in all the possible factor combinations associated with each possible level of output but need be only a change in a particular factor combination.

Economists have customarily distinguished the actions of firms in changing their input combinations because of changes in the relative prices of the inputs, i.e., factor substitution, from those changes due to innovation of new technologies. This distinction has its origins in the different sources of the causal factors. Changes in input prices are given a straightforward economic explanation in terms of changes in demand and supply conditions of the inputs. The deeper reasons for such changes are in turn the subject of some of the more fundamental analyses in economics. Even with constant factor prices, optimal input proportions can change with the scale of output unless the production function has the particular property of being homogeneous of the first degree. The ascription of this property to production relations is usually a matter

of theoretical convenience rather than one for which there is a strong empirical basis.

Though the innovation--factor substitution distinction is certainly significant, from an over-all point of view it need not be important to an individual firm engaged in the choice of a new set of input and output proportions. The firm is concerned only with its profits and costs. Perhaps it might be argued that there is greater uncertainty associated with innovation as compared to factor substitution which justifies the distinction at the level of the firm. But this need not be true at all for the imitators of the first innovator, and, depending on the circumstances, need not be true even for the first innovator. Factor substitution may also be exploration of relatively unknown territory for the individual firm, especially when it is associated with substantial changes in the over-all level of its output.

At any moment a number of different factor combinations might simultaneously be actively in use in producing a given commodity even if all firms are behaving optimally with respect to their choice of techniques. This is because fixed capital, labor and material inputs are often limited in their capacity to be adjusted to new factor combinations and "old" combinations may rationally continue to be used as long as the variable or current costs of the old are less than the total costs of the "new," all properly discounted. Thus it will ordinarily take some period of time for a new process innovation to become predominant and for a change in input prices to work itself through an economy. The speed of dispersion depends in part on the potential flexibility of the existing productive factors in entering into new input combinations. Disembodied technical change which is ordinarily taken to mean that it is not uniquely associated

with a particular type of capital may or may not proceed more quickly than embodied innovations. Technologies are also embodied in labor skills and materials and these too have fixed cost elements which should be ignored in calculating the current costs of the "old" technology but not in such calculations for the new one.

The above discussion restates the various types of changes which may lead to use of different input-output combinations in the production of already known goods and services: input substitution resulting from changes in their relative prices, a more efficient adjustment to given relative factor prices at pre-existing output levels, the effects of changes in the scale of output with given factor prices or the innovation of a new technology. In turning to a discussion of technical change in less developed countries I shall try to observe these distinctions and ask whether there are special features of less developed countries which act to impede the achievement of the most effective input combinations.

There are economic as well as non-economic theories of invention to account for the appearance of new technologies and new products. The theories are partial and incomplete but nevertheless I believe they will provide some insights at a later point in this paper.

II. Innovation in Less Developed Countries

There are theories of the condition of the less developed countries in which technical change is not mentioned, but these should not be taken as implying a subsidiary role for such changes. Economic development is seldom envisaged as a scalar expansion of all productive factors and outputs in some original set of proportions. Thus, when the "vicious circle

of poverty" or the need for "infrastructure" or the arguments about "balanced growth" are adduced, the omission of discussion of technical change is usually only a convenient device for the purpose of obtaining greater insight into the role of other factors. The omission is to some extent, however, a reflection of the paucity of our understanding and practical knowledge. For example, it is easy to criticize most of the various quantitative development planning models on the grounds of their omission of technical change. Yet, in many of the models there is in principle no barrier to the embodiment of changes in technical coefficients. The difficulty is in the lack of a theoretical and empirical basis to predict such changes.

We may make headway in appreciating the barriers to achievement of the most effective factor combinations in less developed countries by examining some of the customary assumptions, starting with that of rational profit maximization. There is an abundant literature with the theme that lack of development is characterized by the absence of purposive, profit-maximizing rationality. This is often accompanied by the argument, as in some theories of the "rise of capitalism" that the appearance of such rationality will as a natural consequence lead to economic growth. Though the examination of situations characterized by the absence of profit maximizing rationality would be of general interest, the only object here is to indicate the possible effects on the technology used.

Irrationality may take the form of acceptance of new technologies simply because of a faith in modernity as well as an uncritical perseverance with traditional methods. This point has been made before and there is not much more which can be said. Though there is an underground of

stories which are told of technological "mistakes" a judgment as to their quantitative significance is difficult. For example, on the one hand we have Professor Theodore Schultz, who argues that peasants in less developed countries have made a more or less optimal adjustment to their circumstances.[1] At the same time there is an abundant literature which argues that there are often technical changes easily within the reach of such peasants which would increase their output if only their psychological and cultural blockages could be removed.[2]

It is difficult in any case to distinguish the effects of irrationality and the absence of the customarily assumed profit-maximizing motivations. In many of the less developed countries it would be unusual and socially not acceptable for a productive enterprise to be organized as a firm employing labor and other resources by impersonal contracts in order to maximize profits. The predominant form of social organization for work is often the extended family or the tribe or the government firm with no inclination to maximize its profits. A brief analysis of one such case will help to indicate some of the difficulties in identifying the sources of technical change and the reasons for the use of factors in different relative intensities. Suppose in Figure 1 the line OABCD represents the conventional total product curve for a family farm. In many countries the farm will simply accommodate as many producers and consumers as there are in the extended family.[3] It is rational to treat the subsistence

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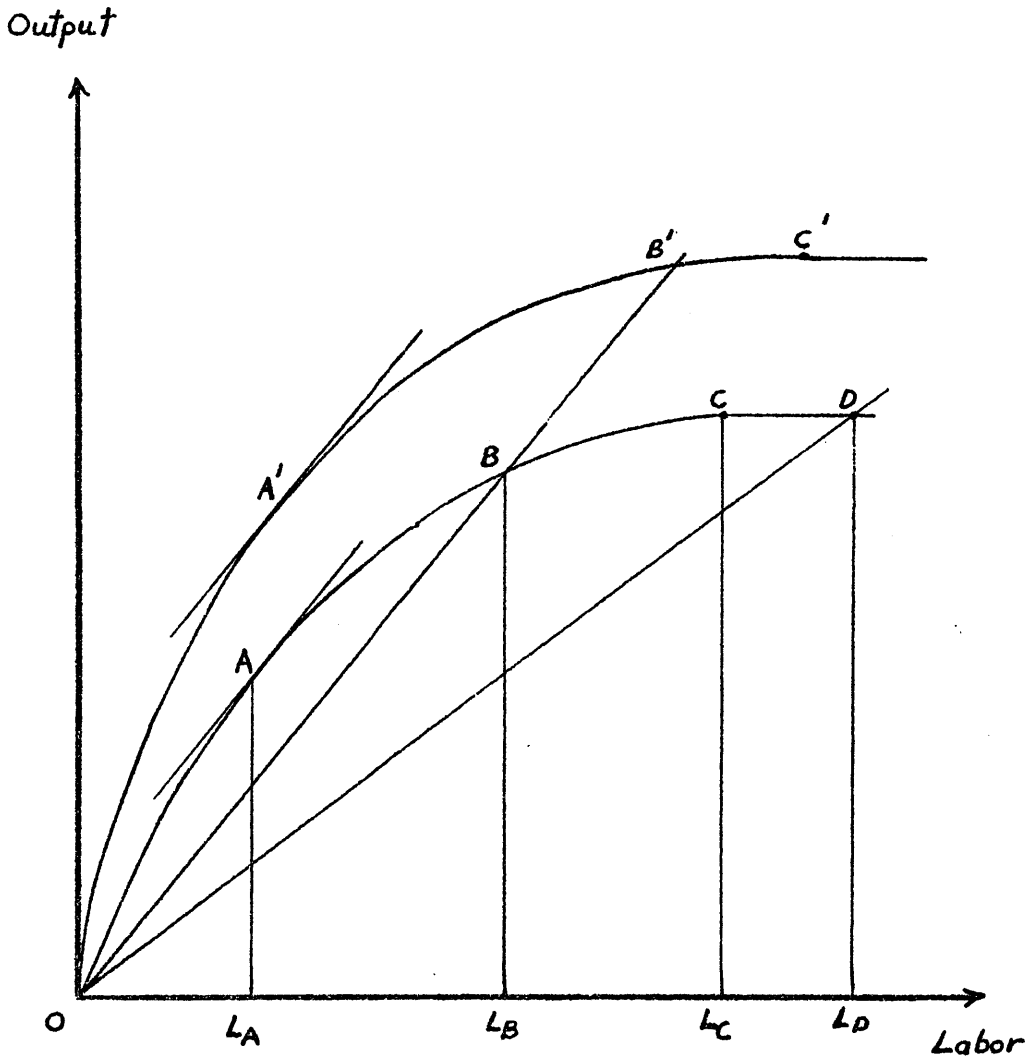
[1] Transforming Traditional Agriculture, New Haven, 1964, Chap. 3.

[2] As a fairly typical example see Kusum Nair's, Blossoms in the Dust, London, 1961.

[3] Though the particular implications to be drawn from the analysis have not been stressed before, I believe, it is related to that of Professor A. K. Sen, Choice of Techniques, Oxford, 1960 and, recently, Professors J. Fei and G. Ranis, Development of the Labor Surplus Economy, Yale, 1964, as well as some of my own previous work.

Figure 1



requirements of the available laborers as a fixed cost and to maximize the output which can be achieved with that labor.[1] If the family grows in a Malthusian way and subsistence requirements are indicated by the slope of the line OB, the size of the family will grow until L_B laborers are available and the family will produce at B.

Families of size less than L_B will be able to save and invest and in this way be able to shift the total product curve upward to, say, OA'B'C'. With perfect capital markets even the Malthusian family at B could always borrow, invest and obtain more output but there is no reason to suppose such perfection in rural, subsistence farming. On the other hand, such behavior should not be surprising and, in fact, there appears to be evidence that it does occur. It may be noted that families with a lower level of subsistence, as indicated by the slope OD might expand until L_D amount of labor was available, even though the marginal productivity of labor beyond L_C is zero. In a family organized, subsistence agriculture, it would not in fact be surprising to find farms at various points along such OABCD or OA'B'C'D' curves, since the ordinary competitive pressures would not exist.

In contrast with this type of family organization of the firm, a profit maximizer in this situation who could hire labor at the subsistence rate would use only L_A amount of labor, operate at A, where the marginal product of labor equaled the subsistence wage, and make profits. If the

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[1] If the ratio of work force members to non-members is fixed, the discussion can be conducted, as here, in terms of the number of laborers in the work force and their subsistence defined to include the requirements for their proportionate share of those in the family who are not members of the working force. Otherwise it becomes slightly more complicated to make the simple point of the argument presented.

subsistence rate were indicated by the slope of the line OD, the profit maximizer would operate at E. Consider, further, the effect of vigorous competitive, non-Malthusian entrepreneurship in such a sector. Since the use of inputs by rational, profit-maximizing employers is more efficient, their output would have lower costs and they could systematically displace the Malthusian family firms which have no cushion of surplus above subsistence. In the process, resources would be drawn out of family firms into the firms of the profit-maximizing employers and a group of "landless laborers" would be created. Even families not at the extreme Malthusian limit may not be able to resist the superior competitive position of firms operating at A if the latter firms reduce prices to such an extent that the inefficient firms cannot maintain their capital. The profit maximizer might even be able to hire "part-time" labor from family farms at less than subsistence rates if their marginal productivity on these family farms is lower than subsistence. This, of course, depends on the ability of a "part-time" laborer to maintain his associations with the family so as to obtain the remainder of his subsistence requirements.[1]

The point of this analysis is that an outside observer looking at an industry composed of family firms and profit-maximizing employers would find a number of different factor intensities and factor productivities in existence. It would not be hard to think of institutional behavior in which such a varied pattern would be maintained for a considerable period. In other situations more efficient factor combinations might slowly replace less efficient ones. The replacement may come relatively swiftly, however,

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[1]This analysis can apply just as well to family firms in advanced countries as to those in less developed areas.

with other social changes.[1] Such changes might well appear to be technological innovation if one could not see below the surface of events when in fact they would represent employment of known and conventional technologies and considerable social innovations. On the other hand, technological innovations and social innovations might be closely associated. Process innovations might generate profit opportunities so much more attractive than those previously available as to change traditional patterns of behavior. Or product innovations which create new social positions can facilitate new factor combinations which would have been barred by custom in traditional products.

The above analysis provides an example of the influence on choice of technology of behavior which does not correspond to the customary assumptions of rational profit maximization. Other cases could be developed at the other end of the spectrum of organization -- e.g., the modern, government-subsidized firm, staffed from the civil service, whose mode of operation is influenced as much by civil service criteria or income redistribution goals as by the usual criteria of economic efficiency.

When firms are rational profit maximizers, the analysis of the dispersion of technological innovations falls within the body of existing economic theory.[2] Though the qualitative analysis in this case will be the same for less developed countries as for advanced countries, the particular quantitative results in technical dispersion may vary substantially due to the different weights of the controlling factors.

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[1]This would, I believe, apply for example to the Enclosure Movements in England in the eighteenth and nineteenth centuries.

[2]See, for example, W. E. G. Salter, Productivity and Technical Change, Cambridge, 1960, Part I.

A priori judgments about these are difficult. For example, risk elements in costs associated with new technologies are often considered to be more significant in less developed than in advanced countries. Even if this is so, such cost differentials may be offset in the less developed countries by a greater assurance as to revenues which derives from government protection or the monopoly position which is often associated with new products or processes in less developed countries.

The extensive debate in the literature on the choice of technology in less developed countries is relevant to the dispersion of technological innovations. The debate has, for the most part, been addressed to the normative question: "What is the optimal choice of technique in the less developed countries?" Though the issues have not been fully resolved, it is now clear that the answer takes the form: "It depends on the content of the development goals and whether there are any relations between their attainment and the technology other than the direct contribution of output to the national product." When the goals include achievement of a certain growth or employment rate and these in turn are related to the savings rates from the different factor shares which in turn depend on the relative input intensities, the optimal choice of technology may well be different than it otherwise would be. The normative discussion has not, however, culminated in practical measures to control technological choice other than the suggestion of subsidies or government exhortation. This is in part because the analytical development in this field, as in the area of planning models, has far outstripped the empirical basis which exists for implementing the normative proposals.

It is often assumed that the range of technical choice available to the less developed countries is biased toward labor saving and capital-using technologies, since that has been the history of innovation in the more advanced countries. Some recent developments in the theory of induced invention can be adduced to help clarify this point. Professor William Fellner has been among the most active persons in drawing attention to the possible significance of induced invention for the explanation of some of the characteristics of economic growth.[1] Professor Charles Kennedy[2] and Dr. Christian Weizacker have led in extending the argument which has long historical antecedents[3] but which was made most explicitly by Professor John Hicks[4] that there is a tendency for innovations to have a labor-saving bias. The argument briefly, as Kennedy puts it, is that the search by entrepreneurs for cost-reducing inventions is given a capital or labor saving bias depending on the relative share of the factors. Since labor's share is the larger, there will be a tendency for innovations to be labor-saving. To demonstrate this, Kennedy makes use of a transformation relationship between reductions in capital cost and reductions in labor cost which is implicitly assumed to be symmetric. Professor P. A. Samuelson has shown that if relative shares are not technically determined, as in the Cobb-Douglas production functions, the argument leads to the paradoxical

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[1] W. Fellner, "Two Propositions in the Theory of Induced Innovation," Economic Journal, June, 1961; and Trends and Cycles in Economic Activity, New York, Chap. 9.

[2] C. Kennedy, "Induced Bias in Innovation and the Theory of Distribution," Economic Journal, LXXIV, Sept., 1964, pp. 541-548.

[3] M. Blaug provides a useful brief evaluation of the arguments in his article, "A Survey of the Theory of Process-Innovations," Economica, Feb., 1963, pp. 26-30.

[4] J. Hicks, Theory of Wages, London, 1932, Chap. 5.

result that in equilibrium labor and capital shares will be equalized.[1] With other strong assumptions about the nature of the production functions and the relative growth rate of capital and labor, Samuelson is able to deduce a labor-saving bias for inventions. However, against such arguments for an inherent labor-saving bias, Samuelson and Salter have argued that entrepreneurs in seeking out inventions are interested only in reducing total costs. In pursuing this goal, and without knowledge as to the relative ease with which labor or capital saving cost reductions can be achieved, there is no reason to believe they will have a tendency toward either labor- or capital-saving innovations. Finally, the once widely held belief that for whatever reason inventions were as a matter of factual record for the most part labor-saving is more generally challenged.[2]

These recent arguments do not mean that the menu of technologies in advanced countries from which less developed countries may choose has no particular bias as compared to those already in use. Rather they indicate that the existence of such a bias cannot be inferred from an economic rationale alone. It is also true that if advanced countries are in fact characterized by relative capital abundance, they will take advantage of the substitution possibilities which may exist in order to use relatively less labor. It might then be argued that whatever the factor bias in the invention which created the technology, the relatively capital intensive factor combinations resulting from input substitution are 'frozen' into the design of standard equipment. In turn, the less developed countries

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[1] P. A. Samuelson, "Notes on the Weizacker-Kennedy Theories of Induced Invention," to appear in Review of Economics and Statistics.

[2] See M. Blaug, op. cit., pp. 22-24.

may face the alternative of either buying the standard equipment or paying higher prices for equipment especially designed for their own factor intensities. In either case the input substitution which potentially exists in a technology does not become as fully available to the less developed countries as to the advanced countries, due to economies of scale in manufacturing equipment for the latter.

III. Invention in Less Developed Countries

Issues in the theory of induced invention were raised above with reference to the question of the character of the technologies available from the advanced countries for use in the less developed. In approaching directly issues related to invention in the less developed countries, it might be useful to begin at a somewhat more general level. Richard Nelson has contrasted a "demand" theory of inventions and what I shall call a "supply" theory to indicate the predominant influences in each type of explanation.[1]

The demand theory, which may be described as a "necessity is the mother of invention" theory, as Nelson summarizes it, argues that: "Social need, usually manifesting itself through perceived opportunities for private profit, not chance, is the cause of inventions."[2] In this theory, to oversimplify somewhat, inventions are for the most part produced to order by step-by-step refinement of the known "state of the art." The rate of "production of invention" depends on the profitability of the inventive

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[1] R. Nelson, "The Economics of Invention: A Survey of the Literature," The Journal of Business, XXXII, April, 1959, No. 2, pp. 101-127.

[2] Ibid., p. 103.

activity. In the "supply theory" it is science and the "social heritage of knowledge and technique which is the real mother of invention."[1] Inventions occur independently of any social need and are explained by the momentum of scientific progress. It is the innovation or implementation of inventions which is dependent on social and economic conditions.

As Nelson says, neither the demand nor supply theories appear adequate in themselves to explain many of the case histories available to us which appear to " . . . illustrate the interplay of moving frontiers of knowledge and growing need . . ."[2] Neither of the theories provides any a priori basis for believing that inventions will have a particular bias in saving one or another of the productive inputs. The theory of induced invention as developed by Samuelson leads to the conclusion that "Induced invention has no systematic bias and the drift of relative shares depends on the drift of exogenous technical changes and upon the change of factor proportions (as affected by the relevant elasticity of substitution)."[3]

This discussion is relevant to the rationale of research and development activities in less developed countries. There is a widely held view that research and development activities in less developed countries considered as an investment have a rate of return so high as to warrant a much larger effort than anything now underway. This opinion is usually supported by the customary references to the studies which have indicated that technical

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[1] Ibid., p. 106.

[2] Ibid., p. 107.

[3] P. A. Samuelson, op. cit.

change has been a major contributor to economic growth in advanced countries and to the case studies in which the rate of return to research appears to have been enormous. However, even if these studies are accepted at face value, since technical change can come about by transfer as well as indigenous development, a separate argument is required to justify research and development programs in the less developed areas. One such argument would be that the uniqueness of their resources limits the value of technological transfers though previous results indicate the potential of research directed specifically at those unique features. This appears to be the view of Professor T. Schultz with respect to agriculture in less developed countries but it may have a wider application. A supporting argument would be that monopoly positions in advanced countries permit them to extract most of the benefits of technological transfers. Research has also been justified as an activity which is necessary to achieve higher education of the quality desired in less developed countries.

It cannot be assumed that both the costs and benefits of research and development in the less developed countries are the same as in advanced countries. Research and development and education are to some degree competitive in their demands for scarce personnel and other resources. If the shortages of educated personnel and, therefore, of teachers, is relatively greater in the less developed countries than in advanced countries, that would suggest the desirability of research and education proportions weighted more toward the latter.

There is relatively little systematic information about the relationships between "inputs" and "outputs" in the research process but there have been suggestions that there are important economies of scale. These

might place a diversified research program beyond the reach of most of the less developed countries though it would still be feasible to carry out specialized research programs at an appropriate scale. Yet the size or endowments of many of the less developed countries might not permit them to obtain benefits from the research to the same degree as in the case of larger and more diversified economies.

Recognition of the tremendous benefits which have accrued from research should, moreover, not be transformed into the assumption of a short and predictable connection between research and growth. There is ample testimony to the uncertainty and high failure rates involved.[1] There is little organized information on the gestation periods between research expenditures and their achievement of substantial economic benefits. But in numerous case studies the delays stretch over time spans several times longer than ordinary investment gestation periods. The evidence on the relation between research and growth in, Some Factors in Economic Growth in Europe During the 1950's[2] may or may not bear directly on this point but it should lead to some caution. It is pointed out there that, "there is no correlation between the rates of growth of output and research outlays during the period studied,"[3] for twelve countries from 1950 to 1960. This conclusion may be the result of using a period which is too short to permit the benefits to be achieved, the existence of a relationship which is too complex to be found by simple statistical correlation, or, in fact, the lack of any relationship.

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[1] R. Nelson, op. cit., pp. 112-115, esp.

[2] Economic Commission for Europe, United Nations, 1964.

[3] Ibid., Chap. 5, p. 7.

The policy issues of what type and how much activity to support in research and development are particularly difficult for the less developed countries. The divorce of economic from other criteria is less warranted yet the relationships are less clear among the economic and other influences which have determined the fields of relative scientific advancement. A tentative answer to the policy question on economic grounds, taking into account the risk and scale elements mentioned above and the possibility of technological transfers, would advise concentration on problems directly related to each country's natural endowments and growth requirements. Another type of answer would be to emphasize whatever fields in which some success has already been achieved. This would recognize effects of economies of scale and be more closely related to the political and educational arguments for scientific research in less developed countries. Such qualitative answers are obviously not satisfactory to budget makers: they do not tell "how much" and as to type of research they may even point in different directions. Much more analytical and empirical effort is needed, however, before better answers can be given.