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YALE UNIVERSITY

Box 1987, Yale Station
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LESS DEVELOPED COUNTRIES, TECHNOLOGY TRANSFER AND ADAPTATION, AND THE ROLE OF THE NATIONAL SCIENCE COMMUNITY

by

Richard R. Nelson

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LESS DEVELOPED COUNTRIES, TECHNOLOGY TRANSFER AND ADAPTATION, AND THE ROLE OF THE NATIONAL SCIENCE COMMUNITY*

Richard R. Nelson

Yale University

What kind of role can be played by the scientific community in a less developed country in furthering the country's development? In this paper I will try to develop a perspective on this question by describing the view of underdevelopment and the development process that tends to be held by development economists and then contrasting the economist's view with the one that tends to be held by the natural scientist. The development economist, by and large, has placed less weight on organized science as a factor in development than has the natural scientist; while the economist may underestimate the role of science in development, the natural science community may overestimate it. In any case the reasons for the differences are well worth exploring.

Section I will review the nature of the economic development problem as viewed by many development economists. I shall consider both the informal theorizing based on relatively rich appreciation of facts and numbers associated with the condition of "less developed", and the more formal theory,

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sharper but less rich, that has evolved in attempts to "explain" the anatomy of underdevelopment.

The economist's view of causation is strikingly different from that which seems to characterize the literature on science and technology in development written by natural scientists and engineers. To put it overly simply, the economist tends to view economic development as a process of "investment;" the natural scientist views the process as that of "technology transfer" and "adaptation". It seems to me that both are half right. I will discuss these differences in Section II. Section III will focus on the role of the science community in the less developed countries, in the context of the earlier discussion of causation and process. While I come up with more questions than answers, perhaps the questions are closer to the right ones than those that have been posed by either the main line development economists or the natural scientists. And posing the right questions certainly is an important step towards getting the right answers.

The Nature and Causes of Underdevelopment; The View of the Development Economist

Almost all poor countries would be considered less developed (Japan of a decade ago being a possible exception) and almost all less developed countries are poor (but not Kuwait for example). However, underdevelopment clearly is a more complex phenomenon than simply low per capita income. What are the characteristics associated with being underdeveloped? What explains the vast differences across nations in degree of development? How can development be initiated or accelerated? This trio of related questions has been the central concern of development economists, going back as far as Adam Smith, and considerable research has been directed toward them particularly over the past twenty years. I think it fair to say that we now know a good deal about the first question which involves description, significantly less about the second which requires specification of causation, and still less about the third which requires in addition knowledge about how to break into the causal system effectively and reliably. In many ways the situation is similar to that in meteorology where a vast amount is known about various complexes of weather conditions, there is some considerable knowledge of the "whys" behind what we observe and relatedly some ability to predict weather, but very limited ability to deliberately influence what the weather will be.

We understand the anatomy of underdevelopment in some considerable detail.[1] We know for example that low per capita income tends to go with: high percentage of the work force in agriculture, a large percentage of the small manufacturing sector in industries like textiles and food stuffs, high birth and death rates, small amounts of physical capital per worker, limited communications systems, low literacy rates and levels of average educational attainment, very few doctors per person. The terms "large" and "small" here of course are meant as comparisions with the situation in "developed" countries as measured by per capita income. If we look at the development of countries over time the dynamic picture is consonant with the cross section; as per capita income rises in a country so does the percent of the work force in manufacturing, capital per worker, education, etc.

The relative importance of a nation's scientific community clearly is related to the level of development where, following the definitions used by UNESCO, the scientific community is meant to include engineers and technicians of advanced training as well as scientists. Less developed countries are characterized by a small fraction of scientists and engineers in the work force compared with more developed countries, and very limited R and D. Further, the importance of the science community tends to grow as the country develops over time. I mention these totally unstartling facts because for some reason some people seem to have been impressed by them.[2] Many factors are associated with being less developed and change toward the levels associated with the more developed countries as the country develops. Whether the association between the level of development and the level of science yields any guide to development policy and strategy would appear to hinge on two question. To what extent can the low level of science in the less developed countries be considered as "causal" rather than caused? If causal, to what extent and at what cost can science and engineering in the less developed countries be effectively and reliably augmented or enriched?

The economist's view of economic causation traditionally has involved two chains. The first is that inputs cause or permit outputs, that output generates income, that income generates demands for the use of resources. The factors toward the end of the list above--particularly capital per worker and the education of the work force--together with such exogenous variables as the natural resource base, climate, etc., have been treated as causal with low productivity, low income, and consumption demand concentrated on subsistence consumer goods, as the economic consequences. The second causal chain relates to the environment of international trade opportunities. The allocation of economic inputs in a country is influenced not only by demand patterns, but by comparative advantage which resides in industries which employ inputs that are relatively plentiful and which require little of the scarce inputs.

From this perspective science plays an ambiguous role. It seems plausible that the availability of scientists and engineers is a constraint on production, thus their limited quantity in the less developed countries might be a factor "explaining" low average labor productivity and the pattern of economic specialization. But the exact way that scientists and engineers determine what can be produced is less clear than the way, say, machinery or simple production skills or managerial ability limit production. The lack of clarity here is not just in the eyes of the development economist. In only a few industries do business firms feel compelled to hire large quantities of scientists and engineers without some kind of government subsidy, particularly not in the less developed countries. While the evidence is clear on the importance of government support of applied R and D in such fields as defense and health, policy makers in all countries, rich and poor, have been wrestling for some time with the question of what basic research really does for the country. While public funds have usually been forthcoming they have in large part been based on faith in practical payoff rather than on hard evidence, and in part have been justified by science as a value in itself rather than a means to other values. Thus the statement that rich countries have more science because they can afford more science may be as true as the statement that the rich countries are rich because of their science. The issue of principle direction of causation is in part an empirical question, but it cannot be answered simply by seeing what goes with what. Rather a real causal theory is needed which generates a variety of implications which can be tested.

It is important to stress that, unlike understanding of the anatomy of underdevelopment where most development economists see eye to eye, and unlike broad qualitative description of causation where there is considerable agreement, there is no consensus among development economists about the formal quantitative theory linking "causes" to "effects". Much of the formal theoretical literature consists of a collection of often ingenious and provocative, but partial and usually mutually inconsistent, sub-theories. However there does exist one body of formal theory of relatively global scope that many economists, perhaps the majority, take seriously and which seems worthwhile to discuss here. I shall call this theory, for short, the neoclassical theory of production and distribution. The theory has two separable components. The first is the hypothesis of a cross country production function. The second is the hypothesis of competitive market equilibrium.[3]

The production function hypothesis is that differences in output per worker between, say, Colombia, Japan, and the United States are the result of differences in factors like machinery per worker and educational levels in the quite explicit sense that if the United States had the same quantities of these factors as Colombia (or Japan) her labor productivity would be the same, and if Colombia (or Japan) had the factor endowment of the United States her labor productivity would be equal to that of the United States. As we look across countries at the different levels of productivity and associated inputs, we really are observing different points on the same function relating productivity to inputs--to use the economist's jargon--all economies are on the same "production function". It is apparent that, depending on the restrictions one places on the nature of the production function, the hypothesis can either be empty in the sense of not really being falsifiable, or quite powerful in that there are many ways to refute it. If few restrictions are put on the "number of factors" used to explain productivity differences, or on the "shape" of the function, since the number of observations is finite, with enough ingenuity one can "explain" as closely as one chooses. On the other hand if one places some quite stringent restrictions on the number of admissable factors limiting them to, say, physical capital per worker and educational attainments, and imposes some strong restrictions on the shape of the function, say continuous and concave, then if much of the international productivity differences can be explained by the theory, one really has "explained" something.

There have been a number of empirical studies dedicated to testing this hypothesis by statistical regression techniques. Output for the economy as a whole, or for particular sectors or industries is regressed against various sets of inputs. A variety of functional forms have been assumed. Not suprisingly the goodness of fit of the looser jointed studies has been significantly better than the goodness of fit of the studies where severe restrictions were placed on the hypothesis.

Much more interesting are the empirical studies which have incorporated the second component of the neo-classical hypothesis. The market equilibrium hypothesis is that the constellation of inputs and outputs observed in a country are consistent with the equilibrium conditions generated or inforced by competition. This means that the observed payments to the different factors of production can be interpreted as measures of their marginal productivity (partial derivatives). Depending on how one looks at it, this hypothesis provides a way to estimate the slope of the production function at different points without doing statistical regression, or some rather strong constraints on the shape.

There is a considerable body of literature attempting, within the framework of this theory, to relate cross country differences in value added per worker to differences in the physical capital-labor ratio.[4] One version of the theory postulates that output per worker, Q/L, is a differentiable, increasing and concave function of the capital-labor ratio, K/L, holding other factors constant, as illustrated by Figure 1. Thus consider the following data on Colombia and the United States.[5] As of

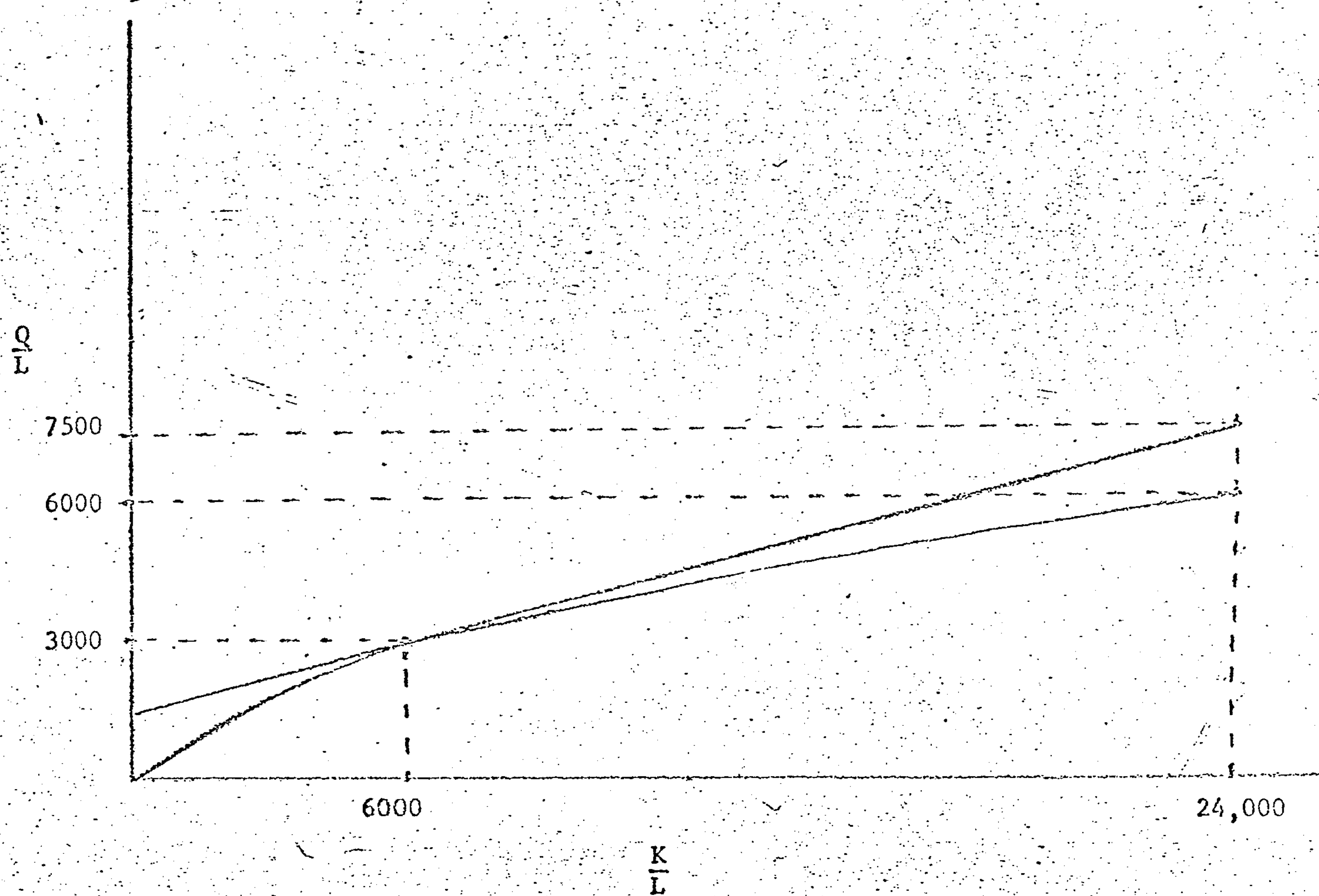

Figure 1

1964 value added per worker in Colombian manufacturing industry was about $3,000 and the capital-labor ratio was about $6,000. This provides a point on the function. The rate of return on capital averaged about 25%. This provides a measure of the slope of the function at that point under the "marginal productivity" hypothesis. The capital-labor ratio in the United States was about $24,000. Since a concave function must lie under any of its tangent lines, multiplying $18,000 ($24,000 - $6,000) by .25 yields an overestimate of how much greater Colombia's output per worker would be at U.S. capital-labor ratio. $7,500 thus is an upper bound on what output per worker in Colombia would be if the assumptions of the theory hold, Colombia's capital stock per worker were augmented to equal that in the United States, and no other differentiating characteristic (like educational attainment) change. Since U.S. value added per worker is about $12,000, differences in the capital-labor ratio are only part of the story.

The assumed concavity of the production function means that the linear approximation above is an overestimate, not an "estimate". Economists long have been attracted to a specific form of the production function that builds in concavity--a function that specifies output per worker as a log linear function in capital per worker. Under these assumptions and given the numbers it can be shown that a quadrupling of the capital-labor ratio (which would bring Colombia in line with the United States) would double productivity, a significantly smaller impact than the "overestimate" developed above (see Figure 1). For a variety of reasons some economists believe that the log linear form (in the economics literature called a Cobb-Douglas form) underestimates the concavity of the production function. In some of the more recent studies economists have shown a preference for a form with considerable concavity implying that differences in the capital-labor ratio explain only about half of the difference that is implied by the use of a Cobb-Douglas form.

One can attempt to estimate the effect upon productivity of the lower educational attainments of the less developed countries in the same manner.[6] About 30% of the work force in Colombian manufacturing industry had a secondary school education or better compared with 80% in the United States. Only 3% had attended some college compared with about 20% in the United States. It is possible to get rough figures on the average earnings of Colombian workers of different levels of educational attainment: not suprisingly the higher the education the higher the earnings. If one assumes that these earnings reflect marginal productivity one can make an "overestimate" of the effect of the differences in educational attainment on productivity. The results are roughly similar in quantitative impact to those for physical capital. Under the assumptions of the theory differences in the educational distribution explain less than 1/2 of the productivity differences. How much less than 1/2 depends on what one assumes about the curvature of the function. Again, as with physical capital, if one assumes a log linear form the answer is significantly less.

An interesting question is, are the two calculations additive? The answer is yes for both the linear and the log linear calculations. The sum of the linear extrapolations is an overestimate of the effect of bringing both physical capital per worker and educational standards to U.S. level. The sum of the two "log linear" calculations gives the consequences of changing both factors to U.S. levels if the production function was in fact log linear in both of those factors. The upshot is that togither these two factors cannot explain all of the observed productivity differences, although they may be able to explain a considerable portion.

I have discussed these kinds of calculations in some detail to familarize the non-economist with the existing mainline theory in economics and to point out that a significant portion of international differences in development levels can be explained by factors that have little to do directly with differences in science and technology. There are a number of basic difficulties with the theory sketched above that I will not go into here. Some of these will be discussed in the context of comparison of the "neo-classical" theory with the "technology gap" theory, to which I now turn.

The Processes of Economic Development: Investment and Technology Transfer

The restiveness that many natural scientists and engineers (and many economists, including myself) feel when they try to reconcile their perception of the anatomy of underdevelopment with the neo-classical theory can best be brought into focus by considering the process of development implicit in that theory. The neo-classical theory views the process of development in terms of increases in the various factors that complement labor, raise its productivity, and which change the pattern of demand and comparative advantage. Most of these factors are expanded by the deliberate use of resources for that purpose--labor, materials, and capital to build new machines, teachers, school buildings to extend education. Thus development can be viewed as the result of investment of various types. Just as cross country differences in output and inputs are interpreted as different points along a production function, growth is viewed as movement along it. There exists a substantial body of literature on growth of the developed countries, particularly the United States, within this framework. The studies of the less developed countries done within this framework have been able to account for most of growth by increases in the capital stock and education, with some interesting exceptions like Taiwan, Israel, and Japan.[7]

This description of the "process" of development, whatever its merits in terms of statistical fit, seems inadequate or misleading to observers of less developed countries who have been impressed by the vast differences in technological capabilities. The discussion of "process" seems to highlight that differences in aggregative measures of capital stock and educational attainments somehow do not capture fully the apparent lack of capability in less developed countries to set up and operate an electronics products factory, run a railroad, keep the telephone system going, deal with epidemics. Expansion of capital and education fails to characterize adequately all that is needed to acquire these capabilities. Part of the difficulty with the neo-classical theory may be that in the form above it is too aggregative; it represses the importance of scientific and technical skills by lumping them under education and capital. But I think there is more to it than that; the implicit dynamics do not ring right. In my judgment the problem boils down to two sets of questions. First, is there something involved in "changing" the way an economy operates that transcends the difference between the equilibrium characterizations of the initial and terminal positions? Second, is there something about a nation's scientific community that is particularly important in the change process? I believe the answer is yes to both of these questions.

Before considering the poor countries and their development it is useful to refer briefly to a debate that has been going on among economists about economic growth in advanced countries, particularly the United States. The issue is the relative importance of, and analytic treatment of, technological change in the growth process. As suggested above there is a school of analysis that is attempting to account fully for growth within the neo-classical theory. Research and development is visualized as a form of investment that enhances the quality or productivity of other inputs.[8] Other people have argued that this view represses the dynamics of the process and thereby obscures rather than clarifies. Thus in the neo-classical view the returns to education are determined by the relative availability of complementary inputs such as unskilled labor and capital. This obscures that highly educated people in research and development management and production are largely involved in creating new technology, making decisions regarding its merit, finding out how to use it effectively, getting the bugs out, and routinizing its operation so that people with lesser training can operate it. Once the new technology is created, selected, put in place, and has become familiar, the advantages of scientific and technical expertise is greatly reduced. Or consider the conditions under which there are high returns to new investment. The neo-classical view stresses the availability of other factors. The "technical change" view stresses the availability of unexploited investment opportunities largely due to the creation of new technological opportunities. Put another way, in the neo-classical view changes in the factors of production are seen as permitting the economy to sustain different points along a fixed production function. In the technical change view certain factors are seen as generating new attainable points and enabling the economy to move along an evolving production function.

Several of the recent studies in effect brush this distinction under the rug. In these studies a considerable portion of growth is accounted for by improvements in the quality of capital and increases in the supply of persons with high levels of education. The implication some have drawn is that technical change has been much less important than thought earlier. This may be very misleading. The improvements in the quality of capital themselves are probably in good part the result of new technology. The high remuneration to educated persons that give large explanatory weight to their augmentation is, if the technical change view is correct, intimately connected with their contribution to the creation and implementation of new technology. If the pace of technical change had been slower we would have experienced neither the observed large increases in capital quality nor the maintenance of high returns to educated people in the face of their relative growth.

While this discussion might not appear to have much connection with the processes of development in poor countries where the creation of new technology is not central in the process it does have a connection. The link can be seen by considering recent findings on the pattern of international trade in manufactured products and the light these findings shed on the pattern of comparative advantage in the less developed countries. Recent research has shown that a very large proportion of U.S. manufacturing exports are in new products that other countries have not yet begun to produce in quantity. With a lag other manufacturing nations pick up and employ U.S. technology and gradually cut the United States out of export markets. With a greater lag eventually less developed countries begin to adopt and employ the technology if it has not already become obsolete. This pattern is not easily explained by the implications of the neo-classical theory viewed as a theory of comparative advantage. It is consistent with the technical change view of the economic growth process.[9]

The theory of technological lead and product cycle suggests a quite different analysis of international differences in productivity than is implied by the neo-classical theory discussed in the preceeding section. The technological lead of the United States (with occasional competition from a few other countries) must be recognized explicitly. The U.S. lead can, at least partially, be attributed to its "endowments" of managers, scientists, engineers and just plain innovative and flexible people. More generally, the position of any country in the diffusion hierarchy may well be a function of factor endowments, particularly supply of sophisticated managers, technicians, and easily trainable labor. But there is no reason to believe that these factors enter in a way that one would try to force them to enter in analysis if one followed the traditional neo-classical approach. For viewing the economic development process as a diffusion process naturally leads one to abandon the two basic assumptions of the neo-classical model--that all countries are on the same production function, and that markets are in equilibrium and competitive such that the returns to particular factors reflect their marginal productivity in the traditional sense.

This point of view also suggests a quite different perspective on the nature of the development process in poor countries. In the neo-classical theory there is a snese in which the less developed countries are adopting the technology of the rich, but the sense is that of two people walking down the same path because it is the only path. The "diffusion of technology" view sees the rich countries followed by the poor countries because the former is providing the technology and the model for development. This is a much more active view of technology adoption or transfer. And it calls attention to a variety of mechnaisms repressed in the neo-classical theory.

As I indicated above there has been far less adherence to the neo-classical theory among economists studying the less developed countries than among those studying advanced ones. Among the variety of partial models of development alluded to earlier are many that view development of the less developed countries as a process of structural transformation transcending simple gowth of capital and labor. Some of the early (post war) development models focused on the fact (in most less developed countries) of significantly higher average labor productivity in manufacturing than in agriculture and viewed the shifting of labor towards manufacturing, constrained by the rate of capital formation, as the heart of the development process.[10] It now is apparent that this view masks the vast differences in productivity levels among both manufacturing business firms and farms. The structural shift view of development seems correct but would appear to involve a much more general switch over from traditional technologies to modern both in manufacturing and in agriculture.

As the product cycle view of international trade indicates, to a considerable extent the more modern manufacturing technology being adopted by the less developed countries is directly or indirectly imported from the advanced countries. The manufacturing development process appears to be characterized by intra-sector dualism.[11] While rapid industrialization in many (but not all) of today's less developed countries began only in the post-World War II period, this did not mean that they started with no manufacturing sector at all. Rather if the few countries that have been studied from this point of view be a guide, they long have had a quite diversified manufacturing sector providing a variety of goods for domestic consumption using traditional technologies, sometimes augmented with some more modern power equipment. In addition there often were a few modern firms or sub-industries, often foreign owned, and often producing goods for export. The wave of post-War industrialization has been superimposed upon this traditional structure of craft industry. Today in many of the less developed countries one can identify two roughly separable groups of firms. One group, generally newcomers or a few old firms that have transformed themselves, consists of firms that are roughly similar to typical firms in the same industry in the more developed countries--somewhat smaller, with somewhat lower value added per worker, capital per worker, and labor quality--but using roughly the same kind of technology and recognizable as the same kind of animal. The other group is comprised of the traditional small craft firms using significantly less in the way of modern equipment, quite different (and less related to formal education) skills, and creating a far lower value added per worker. To a considerable extent these two groups of firms differ in terms of their products. Within the so called metal products industry the craft firms produce pots and pans, the more modern firms produce parts for, say, washing machines and refrigerators. But in many cases there is more direct competition. Craft firms produce shoes and furniture largely by hand or with simple power tools, modern firms produce competitive products using much more power equipment and mass production organization.

As development proceeds the modern sector will expand relative to the traditional and improve its efficiency. The pace at which this will happen will depend in part upon the resources that the society invests in new plant and equipment and in creating the relevant skills. But it will depend as well on the more complex structure of incentives, constraints, and mechanisms that encourage and facilitate the entry of new firms using modern technology, the adoption of better technology by older firms, and more generally the expansion and improvement of the modern sub-sector. Part of this structure involves the capabilities of the mechanisms for interjecting in the right places and spreading the relevant technological knowledge. I take it that these are the mechanisms that give operational meaning to the concept of "technology transfer".

In many less developed countries one observes the same kind of dualism in agriculture as one sees in manufacturing, and in many countries the agricultural development process seems characterized by the same expansion of new modern entities and attrition of old that marks manufacturing development. However it appears that in agriculture, modernization of old farms as contrasted with entry of new is more important than in manufacturing. Perhaps relatedly in at least a few countries the kind of dualism experienced in manufacturing development has not characterized agricultural development which rather has been marked by the roughly in pace improvement in efficiency of most (or at least many) farms.

Further, unlike in manufacturing agricultural development has been marked by a number of disappointments when a strategy of simple "technology transfer" has been adopted--the attempt to increase productivity by replacing traditional methods with those used in developed countries. Success often has required considerably more modification and special tailoring of technology than has usually been required in manufacturing. Clearly agricultural development is neither a simple investment process, nor usually is simple technology transfer mechanisms a sufficient complement. Rather, it appears to require organization and effort to develop the right kinds of new technology. I take it that these mechanisms give operational meaning to the concept of "technology adaptation".

The mechanisms of technology transfer and adaptation are complex involving many different kinds of inputs, relationships, and institutions. Important among these are those that involve the national and international science community. It is in its contribution to making these mechanisms work more effectively that the developmental role of the national science community can be sought.

The Role of National Science Policy

Earlier I posed the question; to what extent can the low level of science in the less developed countries be considered causal? There certainly are apparent causal links that run from availability and activity of scientific and technical personnel to the pace and character of economic developemtn. It is not clear, however, if the return to putting resources into augmenting scientific capabilities is high relative to other forms of investment. This of course hinges on the second question that I posed; to what extent and at what cost is it possible reliably to expand and enrich a nation's scientific and technical capabilities?

It seems important at the outset to set down some points of agreement between those that take a strong "neo-classical" position and those that take a strong "science is important" position. One is the importance of improving and expanding the educational system in less developed countries, and rapidly and greatly increasing the educational attainments of the population. I presume that all would agree that scientific and technical education should play an important role in this general educational enhancement. I think all would agree that at least a few people are needed with very high levels of training, and that many with moderately high levels of training are needed in industry, agriculture, public utilities, to operate the weather forecasting system, undertake resource surveys, etc., as well as in the educational system itself. However there may be some strong differences regarding the relative emphasis upon science versus other fields, and on the balance that should be struck between achieving widespread middle level competence versus educating a few to the highest levels. I shall return to these issues shortly.

Economists have been prone to make a sharp conceptual split between routine operation and innovation. Particularly where people with strong scientific and technical training are involved in operation the split in fact is not all that clear; the evidence is clear that a lot of innovation comes from wrestling with ways to improve performance and solve problems on the job and not in a separate research and development operation. However conscious research and development efforts are a major source of innovation in many fields. To what extent and in what areas is R and D important for the less developed countries? A second area of general agreement would appear to be the high value of a national R and D effort in agriculture and health. As suggested earlier soil type, temperature, rainfall conditions, the insect and pest population, etc., tend to be unique to the country and the sub-area in question, hence seeds, fertilizers, and practices that go well in one place (particularly the developed countries) may be ill adopted to another. Experience suggests that better technologies are possible and need to be specifically developed and tested on site. Experience also suggests that agricultural research and development needs to be complemented by education of farmers to prepare them to be able to assess and use the new technology, and extention to provide detailed knowledge and assistance. And the new agricultural scientists, extention agents, and teachers need to be taught as well as the farmers. Experience in the United States and elsewhere also suggests that the broad field of agricultural experimentation proceeds best when the applied work interacts with basic work in various fields of the life sciences, chemistry, ecology, agricultural economics and sociology, etc. That the package of research, extension, and education typically recommended by U.S. agricultural scientists is roughly that of land grant structure in the United States suggests that there may be some rationalization in the argument; nonetheless the package seems pcssible to put together and while the costs are not inconsiderable a case can be made that the returns are likely to be high. Very similar kinds of arguments appear germane in the fields of health and medicine. The special characteristics of the national and local environment seem to call for a national program of medical schools, institutions for training other kinds of health personnel, applied research, and the basic science support base.

These qualitative arguments based partly on ad hoc theorizing and in part on experience suggest that some of a nation's development efforts should be put in these activities. They do not answer quantitative questions like how much of a country's efforts should be put into agriculture and health versus manufacturing and other sectors. Nor do they answer within the agricultural and health programs of a nation how much should be allocated to building up scientific and educational capabilities in these fields as contrasted with efforts in irrigation, purchasing machinery, buying fertilizer, allocating trained medical personnel for dealing with present health problems with known methods versus research and teaching, etc., or, within the science package, how much applied and how much basic. They also pose questions of organizational policy. I do not have any ideas on these questions I wish to discuss here.

The questions I would like at least to pose are first, do these arguments extend to other sectors particularly manufacturing, and second, do they provide support for a policy of strongly encouraging the development of a significant basic research community.

The bulk of the applied research and development in the technically advanced countries is not in agriculture or health but in manufacturing industry. However, unlike agriculture and medicine, technology developed in the advanced countries apparently can be applied with only modest modification in a less developed country, and in fact is being applied. While the special circumstances of the local environment--in particular small scale of operation, nuances of local materials, the high cost of capital, lack of skills in the work force, low wage rates for overabundant unskilled labor--makes technology modification desirable, in manufacturing, imported technology is at least viable and generally very profitable. Further in manufacturing industry, in the advanced countries, there is a reasonably well worked out private system of technological communication and assistance that has obviated the need for an industrial analogue of the agricultural extension service, and such a system already is growing up in the less developed countries. These mechanisms include direct investment by foreign companies, patent licensing, privately negotiated consultative arrangements, technical assistance from suppliers of machinery and materials, sending young engineers and managers abroad for training and experience. To a considerable extent the lack of need for adaptive R and D and existence of private mechanisms of technology transfer would appear to reduce the need for national investment in industrial research and development, and technical information services. Further, a case can be made that if such investments are important they will be profitable and naturally forthcoming through private aegis.

Of course that profit can be made without modifying technology is no argument that there aren't positive net benefits from efforts at industrial R and D. National governments and international agencies often have seen it worthwhile to establish in the less developed countries industrial R and D facilities, productivity centers, etc. To my knowledge however, we have very little useful evidence on the performance of those that have been in operation. The many laudatory comments that one can read are based largely on lists of "achievements" with little or no effort to assess their importance, and often on no more than that the organization has survived thus far. Both the arguments and evidence for an active policy of supporting the establishment of an industrial R and D effort in a less developed country continue to be sketchy.

One of the research tasks to which I would assign high priority would be a detailed examination of industrial R and D in the less developed countries, both public and (where it exists) private. As suggested above many applied R and D facilities have published lists of their accomplishments. These of course need to be scrutinized, but more important their impact needs to be evaluated. The evaluation needs to consider the specific economic benefits such as productivity enhancement and cost reduction, export yield, etc. But more broadly it seems important to examine the extent to which a national industrial research and development policy and availability of local engineers and applied scientists can reduce dependence on foreign corporation for modern technology, the relative effects of these two means upon employment, income of nationals, exports, etc.

Here the Japanese case seems particularly worth examining in detail. Also Mexico's and India's experience with public applied industrial R and D.

The discussion above has viewed science as instrumental and rather specific in its impact in that it is assumed that a country can opt for a policy of scientific effort in support of agriculture, health, manufacturing or other particular sectors or toward particular national goals. There is of course a considerable body of thought that argues that this perception of the problem is narrow minded and short sighted. It is argued that while the sectoral philosophy occasionally pays lip service to basic research, it does not recognize adequately the extent to which both good applied research and good science teaching require an environment of strong basic research. The range of science fields that must be taught even to those that do applied research in a narrow field is rather wide. Further, higher education is needed for technologists in almost all fields. Thus the higher educational capabilities of a nation require that basic research not be constrained to those fields directly under the applied research effort. More broadly, it is argued that the "applied research" philosophy neglects the extent to which the evolution of a national science community is an important input to the changes in values, perceptions, and skills of a nation's population that are required for development, and ignores the fact that the development of a nation's science community is an important end in itself.

Since most sophisticated proponants of strong educational push with "applied research" in selected fields philosophy accept the need for at least some basic research particularly in areas where basic knowledge is inadequate to the task, and see the development of the nation's capabilities for education in science and technology as an important objective, I take it that the issue in question is whether a sizeable special effort should be made to develop the scientific capabilities of a nation independently of any well if broadly defined needs for applied research and education. Those that argue the positive side often propose that a scientist, or a man with considerable training in science, is a superior general purpose problem solver, and that the nation's need for him transcends jobs that one might normally define as scientific or technological. This possibly is true to some extent. But economists, lawyers, graduates of schools of business administration, and other professionals might counter that they too have credentials as general purpose problem solvers. Further, the "general purpose problem solver" argument doesn't support the claim that very advanced levels of scientific training are needed, and an associated strong program of support of basic research.

I find the arguments in favor of building up a strong basic research capability unpersuasive. The kinds of correlations between science and GNP discussed earlier provide no support at all. However I think we must admit, or rather stress, that we know very little about the connection between basic science in a less developed country and its economic development. What evidence really is there that a strong national basic research effort is essential to good applied research and teaching? It is apparent that most industrial applied research and development and most applied agricultural research and experimentation proceeds with very little contact with basic research and indeed with little input from recent basic science. To what extent do the kinds of applied research that are important in less developed countries seem to require signigicant basic research underpinnings? We know that the bulk of the engineers and applied agricultural technicians in the United States were not trained in schools noted for their strong basic research. How strong a training in basic science really is required for applied research and development personnel in the less developed countries? How important is what level of scientific education in entrepreneurship? To my knowledge very little, if any, research has been done on these questions. I do not think we even have a detailed accounting of what scientists and engineers are actually doing in the less developed countries. Here I think Japan, India, Mexico and Israel would be particularly rewarding studies.

Footnotes

[1]Of the many books describing the anatomy of underdevelopment I would recomment J. Bhugwati, The Economics of Underdeveloped Countries, McGraw Hill 1966, as particularly concise and clear.

[2]See for example S. Dedijer, "Underdeveloped Science in Underdeveloped Countries," Minerva, Autumn 1963, and D. Price, "Measuring the Size of Science," Proceedings of the Israel Academy of Sciences and Humanities, vol. IV, #6, January 1969.

[3]For a good technical survey see C. E. Ferguson, The Neo-Classical Theory of Production and Distribution, Cambridge 1969. For a capsule version and critique which underlies much of my subsequent discussion see R. R. Nelson, "A Diffusion Model of International Productivity Differences," American Economic Review, December 1968.

[4]The most important early study was by K. J. Arrow, H. B. Chenery, B. S. Minhas, and R. M. Solow, "Capital-Labor Substitution and Economic Efficiency," Review of Economics and Statistics, August 1961. A more recent study comparing more developed countries is E. F. Denison, Why Growth Rates Differ, Brookings, 1967.

[5]To see this worked out more carefully see Nelson, ibid.

[6]The principle early study here is A. Krenger, "Factor Endowments and Per Capita Income Differences Among Countries," Economic Journal, September 1968.

[7]See for example A. Maddison, Economic Progress and Policy in Developing Countries, George Allen & Unwin, 1970.

[8]See for example D. Jorgenson and Z. Griliches, "The Explanation of Productivity Change," Review of Economic Studies, July 1967.

[9]For an excellent example of research within this genre see G. C. Hufbauer, Synthetic Materials and the Theory of International Trade, Harvard 1966.

[10]Perhaps the most prominent example is G. Ranis and J. Fei, "A Theory of Economic Development," American Economic Review, September 1961.

[11]See Nelson, ibid., for a detailed quantitative analysis of the points sketched in this and the following paragraph.