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ENVIRONMENT, TECHNICAL KNOWLEDGE, AND ECONOMIC DEVELOPMENT IN TROPICAL AFRICA*

For out of olde feldes, as men seyth,
Cometh al this newe corn fro yer to yere;
And out of olde bokes, in good feyth,
Cometh al this newe science that men lere.

Geoffrey Chaucer
The Parlement of Foules

We can say that an economy is growing, or developing, when its total output of useful (wanted) goods and services, measured in some aggregative fashion, is increasing—total output taken to include not only goods and services purchased by consumers, but also own produce, services (including structures) provided by government, and commodities and services sold or traded to persons outside the economy. Some services, such as medical care, public health, and education, are not easily measured by the economist's *numeraire* of market value. These can be gauged in other ways, however, and if weights can be assigned in an agreed fashion may be combined in a more general index of economic product: medical care and health can be evaluated directly through statistics of mortality and morbidity, indirectly through the ratio of doctors and hospital beds to population, or amount and character of sanitary facilities; and education can be measured directly through the degree of literacy, or indirectly as the per cent of children in school or the average years of schooling.

I

A simple measure of economic achievement, widely used when estimating the success of nonhuman populations in adapting to their environment, is the rate of change in total population. In recent decades we have come to regard rapid human population growth as somehow undesirable, as a thing to be feared and discouraged, especially when it occurs outside the western world. There are, of course, good reasons for our concern, although they may stem in part from an

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urge for racial survival that is aroused when we see other competing populations growing more rapidly than our own.

To have more babies live to adulthood and to have more adults live out their life span in vigor and in health must be accepted by all men as desirable in themselves. If the consequence is that the world contains more human beings, this should be cause for rejoicing, not for despair. To be fruitful, and multiply, and replenish the earth, and subdue it, was the first charge given to man. (The rest of that charge is also pertinent to our discussions here.) Taken by itself, increase in population is a sign of increasing efficiency in the utilization of resources; only when it is accompanied by a decline in level of living, or when it prevents an urgently desired rise in level of living and alleviation of human misery, can it properly be feared. To decide on purely objective grounds whether in any given situation the values attendant upon declining mortality, better health, and increasing numbers outweigh the costs of other benefits foregone may not be possible; the comparison is essentially subjective and to be made by the populations in which these changes are occurring. It would be bold even to judge whether a long life with impaired health is better or worse than a short life in good health. On the other hand, when a population has made a choice that it is unable to implement, or when, as is too often so, the full consequences of its choice are not seen, the social scientist can be of assistance. It is important to recognize at the outset that population growth is not only a likely consequence, but often an objective of economic progress, and that population growth inevitably brings with it a heightened impact of man on his natural surroundings, animate and inanimate.

Concern about the interaction between man and his environment is an integral part of the study of economic growth. Nowhere is this more true than in tropical Africa where plentiful resources of land would permit a considerable expansion of output without any changes in agricultural techniques, if only a larger labor force were available. If man is to multiply, and if he is to subdue the earth, the earth will be changed by his dominion to minister to his welfare.

Welfare, of course, is not directly measurable, nor is it to be summed up in estimates of gross national product which provide an index of goods and services to which weights can be assigned on the basis of some system of market valuation. For welfare, or level of living, includes many things besides health and knowledge that are not measured in the market place. Furthermore, welfare is, in some sense, a net concept affected by costs as well as benefits. More than this, it is not enough to choose between present benefits and present costs; account must also be taken of future benefits and of benefits foregone. This choice is difficult enough when man's perception of his environment remains unchanged, when technical knowledge is constant; it is many times confounded when technical knowledge is growing at a rapid but unpredictable rate.

It must also be remembered that rapid economic growth is rarely, if ever, achieved without significant, sometimes radical, alteration of existing social arrangements and relationships. These modifications of the cultural environment are paralleled in the natural environment; even as many highly prized cultural attributes are likely to be lost in the social revolution accompanying economic change, so will many of the natural amenities also be destroyed. These

are among the costs of what its proponents like to call "economic progress"; whether they are too great to be borne, whether they outweigh the benefits that are expected in their train, is another choice, and not an easy one, that the human community must make.

II

The economic process is the transformation of elements of the natural environment into things necessary, useful, and pleasurable to man. In this process we identify three major components: the natural resources themselves, the knowledge and skill that change their forms, and the allocation of limited resources and skills among various uses to achieve the greatest possible total of human satisfactions.

Not all of the natural environment can be classified as natural resource; only some elements can be transformed into income-yielding assets. Other elements are burdensome or painful to man, and neutralizing their effects is part of the economic process. And many elements of the environment are economically neutral. The economic value, or usefulness, of the various components of the environment depends primarily on our knowledge and skill in identifying, combining, and transforming them. As technical knowledge changes, therefore, the character and amount of natural resources also change. Things once highly prized, like flint rock for example, may be no longer valued as raw material for tools but pass to a lower use as building material or even take on a negative value as something to be cleared from the soil before it can be put to economic use. Other things that once had no value, such as heavy soils of river valleys covered with vegetation so rank as to conceal both wild game and grazing animals, become highly productive when more sophisticated techniques are brought to bear on them.

As technical knowledge grows and becomes more complex, the range of uses to which elements of the environment can be put expands, and the choices to be made in utilizing those elements more complex. In general, the number of elements that can be usefully employed also increases, despite the loss of knowledge of inferior uses that seems to be a regular concomitant of change. In brief, the resource base changes as technical knowledge changes.

What then can we say about the influence of environment on economic development? That it must depend on the level of technology is obvious; that it must weaken as technical knowledge becomes more complex seems reasonable, but only if the economic links among various parts of human society are strong, so that the allocation process is well performed. If this is so, correspondence between environment and economic product is more likely to be high among societies employing relatively simple industrial techniques than in those with more complex techniques. In a very broad way, this seems to be confirmed by students of the evolution of man. Can this sort of correspondence be found in tropical Africa?

Both technical and allocative knowledge, of course, vary greatly across the subcontinent, but differences between regions are less in agriculture than in manufacturing. Furthermore, the impact of modern medicine and hygiene on health and mortality is probably less in the country than in the town. If popula-

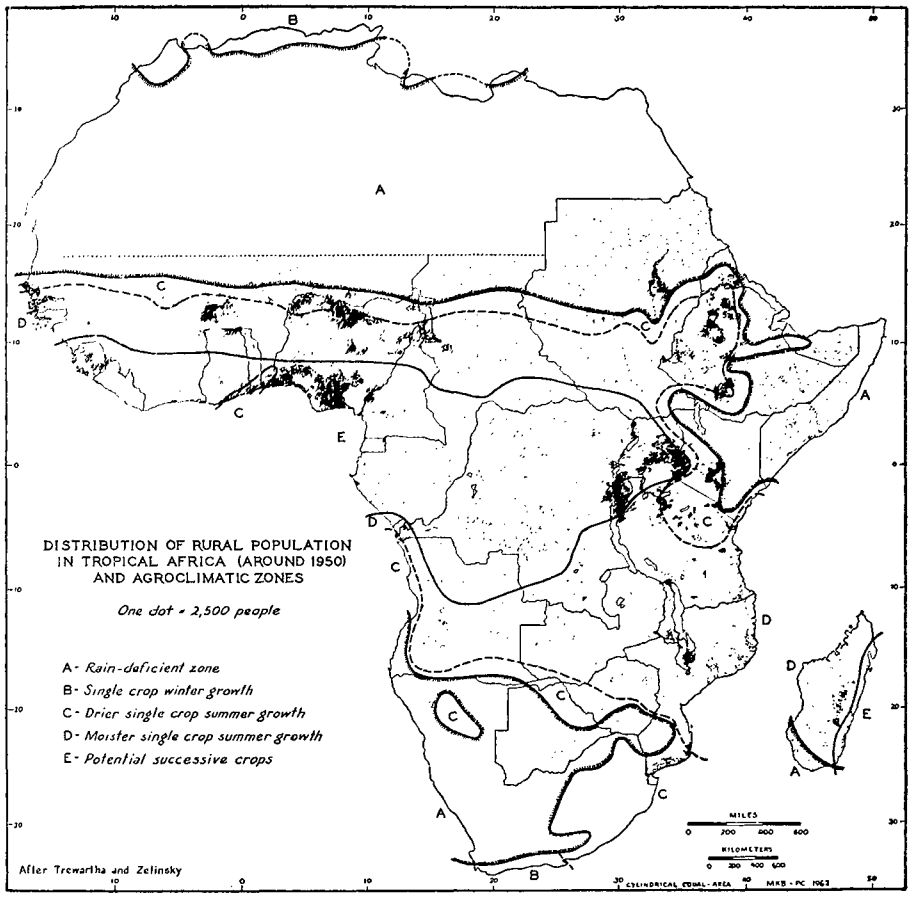
tion density is taken as one measure of the level of economic achievement, a map of rural populations might be expected to correlate with some aspects of the natural environment.

Examination of the Trewartha and Zelinsky map (*13*) of the distribution of rural population in about 1950 does in fact show that density tends to be correlated with some of the grosser features of the environment: the rain forest of the Congo Basin, the droughty regions of Tanganyika, the semidesert of northern Kenya, and the borders of the Sahara are populated relatively lightly, although the density in some of these areas is higher than might have been expected on the basis of other information; and population concentrations are associated with certain obvious natural features, such as the Senegal and Gambia Rivers, the upper courses of the Nile and Niger Rivers (but not the lower course of the Niger, nor the Benué), the shores of Lake Victoria, the highlands of Ethiopia, Kenya, Rwanda and Burundi, Malawi, and Cameroon. Other variations in population are not as easily explained by natural features: the relatively high densities in the rain forests of Eastern Nigeria and the low rainfall lands of Northern Nigeria contrast strangely with those of the riverain provinces; and explanation of the sizable populations of parts of Kwango and Kasai requires more than knowledge of the natural environment.

M. K. Bennett, in 1962, attempted an agroclimatic mapping of all of Africa that may be set against the population map of Trewartha and Zelinsky in a search for overall correlation (*1*). Bennett identifies zones where rainfall is sufficient for different types of agriculture: (1) single-crop winter growth (Mediterranean littoral and Cape of Good Hope only); (2) single-crop summer growth; (3) moister single-crop summer growth; and (4) potential succession crops. When the distribution of major food crops is mapped against these zones their agricultural significance is confirmed. Banana-plantains, rice, manioc, and yams are rather narrowly confined to Zone 4; the millets, sorghum, and maize to Zones 2 and 3. Comparison of Bennett's zones with population density, however, does not show clear cut correspondence (see map). Major population clusters occur in each of the three tropical zones, as do areas of very sparse population. In general, however, Zone 4 (E on the map) seems to have the highest density when account is taken of the large populations in southern Nigeria, Rwanda and Burundi, and around the shores of Lake Victoria, although this zone includes the thinly populated Congo rain forest, where perennial swamps perhaps should be excluded. It might be inferred, then, that warm areas with high rainfall and without clearly marked dry and rainy seasons are best able to maintain human populations in the African tropics.

Comparison of population distribution with other attributes of the natural environment would undoubtedly suggest additional relationships beween economic performance and resource base. M. R. Bloch's map showing the availability of salt in pre-colonial Africa, for example, suggests a possible connection between the high cultures of the West African savannas and the salt deposits of the central Sahara, although it is hard to accept his statement that because of the scarcity of salt "inner Africa was able to support only a thin human population" (*2*).

Examination of the major population groupings makes it clear that more than



climate, and more than natural environment is at work. These other determinants are of two kinds: technical knowledge, and allocative or organizing efficiency. The dense populations of the Guinea Coast result from a combination of both, employed in a physical environment not too dissimilar from the relatively empty lands along the Congo. Similarly, although the physical environment of Zone 2 *permits* the establishment of a heavy human population like that of Northern Nigeria, it is necessary to turn to consideration of technology and of political and economic organization to understand how in fact such a large community came into existence at this place.

III

Present day distribution and density of population in tropical Africa reflect the influence, among others, of two profound changes in the determinants of economic productivity—one, a change in technology; the other, a change in economic organization. The greatest technical change of modern times almost certainly was the introduction of a complete new set of food crops from the Americas. Perhaps the ultimate effect of improved medical and hygienic knowl-

edge may be greater, but this knowledge still is narrowly shared, whereas experience with the New World crops has long since spread throughout the continent.

We can only conjecture how the new crops altered human populations and their physical environment, but enough is known about the characteristics of the food plants to make conjecture plausible. In manioc the African farmer found a crop that gave him more food calories per acre than any crop he had known. Furthermore, it cost no more in labor effort—perhaps less—than the traditional crops. In areas where irregular rainfall and drought, or plagues of locusts, were an ever present threat to food supply, manioc afforded protection against hunger and famine. Its general adoption throughout the equatorial belt must certainly have saved many lives and resulted in a rapid increase in population. Superior yield and ease of processing permitted maize to displace the traditional sorghums and millets over much of the eastern and southern grasslands and provided a new cereal, often the only cereal, to forest-dwelling populations. The New World beans and peanuts supplied high quality protein to supplement dwindling supplies of animal protein as increasing populations hunted out the areas near their villages. Peanuts, too, brought a major source of vegetable oils in the fat-poor regions of the savannas.

If the conjecture is right that manioc, maize, beans, peanuts, and other American crops permitted a considerable increase in the population of tropical Africa, this added population in itself must have altered the natural landscape and the nonhuman population profoundly. Some of the new crops may have affected the environment more directly. Because manioc will produce economic yields on land so depleted in plant nutrients as not to be suited to other crops, its adoption in a foodcrop complex may cause land to be held under cultivation longer than before, requiring longer fallow periods to bring fertility back to previous levels. When combined with the increased populations that manioc makes possible, the result may be almost continuous cropping, as in southern Togo and part of Zambia; it may also, by guaranteeing a supply of calories but not of proteins, substitute protein hunger for true hunger, so that larger populations survive but at lower levels of health and vigor, as in some parts of the Kwango. Maize cultivation may lead to somewhat analogous results. Although this crop will outperform the millets and sorghums when rainfall is sufficient and properly distributed, it suffers more from deficiencies in moisture supply; farming communities that have shifted heavily to maize may find that the incidence of famine, or its severity, has increased. Cultivation of maize in pure stand can also result in heavy losses of soil through erosion.

This particular widening of natural limits on economic production, following the introduction of the New World crops, has essentially been completed. It was achieved by the opportunistic transfer of techniques developed elsewhere into a similar and congenial environment. The technical changes now possible in tropical Africa have a different genesis; they result from the purposive, rational application of the massive scientific knowledge and methodology of the twentieth century to the alteration of environment to suit man's ends. This technical revolution, which is only beginning to have its impact on the economic problem, spreads so wide the bounds that resource endowment places on production as to make them a matter of little technical concern. To the new technician it must

almost appear as if man could mold his environment into any form he wishes.

Investigations of the efficacy of commercial fertilizers when applied to African soils and of the possibility of higher yields from improved plant varieties provide some intimation of the possible impact of the new technology on African economic production.

The story of the early misinterpretation of lush tropical growth as evidence of great soil fertility is familiar to most students of tropical Africa. When attempts to bring African lands under cultivation by methods that had been used elsewhere failed, because these soils were in fact low in plant nutrient content and susceptible to rapid degradation, the period of enthusiasm over the apparently boundless prodigality of nature was followed by one of equally exaggerated discouragement. Results obtained by applying barnyard manures and cover crops were disappointing, and it was widely believed that because of the peculiar nature of tropical soils—in particular, their acidity—it would be extremely difficult, if not impossible, to increase their fertility by the application of mineral fertilizers. It was not until after World War II that extensive investigations of fertilizer response were undertaken. The results were exciting; crops grown on tropical African soils reacted to the addition of nitrogen, phosphorus, and potash in the same fashion as crops grown elsewhere. The same principles that had led to greatly increased output in western Europe and North America could serve as the basis for similar achievements in Africa. The danger now may be that the pendulum of opinion will swing too far again in the opposite direction, and that a second period of excessive enthusiasm may follow the one of excessive pessimism. It is hard not to share this enthusiasm when one hears reports of five- to ten-fold increases in cocoa yields achieved in Ghana by moderate applications of fertilizer combined with reduction in shade cover.

Just as important as the new findings by soil scientists are the new products of the plant breeders, and in fact each reinforces the other, for increased supplies of plant nutrients can be more effectively exploited by new plant varieties, and many of the new varieties need increased nutrient supplies in order to realize their full potential. Research leading to the development of higher yielding varieties of export crops is of long standing and has had notable successes. In 1951, for example, well-managed oil palm plantations in the Belgian Congo were producing 800 to 1,000 kg. of oil per hectare (perhaps 3 to 5 times that obtained by smallholders); improved crosses then undergoing field trial were yielding 1,500 kg., and higher yields were in sight. By 1962 field-tested varieties were producing 3 tons of oil per hectare, with much higher yields possible.

Domestically consumed foodcrops have so far received less attention than export crops, although maize hybrids developed for some localities display much higher yields than the strains now cultivated. A new synthetic hybrid now being multiplied in Kenya, for example, when grown under fertilization in field trials, has yielded up to 140 bushels per acre, compared with typical yields in the area of about 18 bushels (9, p. 101). Their optimum utilization, of course, will come only with the general use of mineral fertilizers. One of the most interesting new developments in plant breeding is the establishment of programs in East and West Africa for improvement of the millets and sorghums by scientific breeding and selection. These important food grains of the grasslands have been largely

neglected by African research; their improvement could have a sizable impact on productivity in the savanna regions.

If the greatest technical change in Africa in modern times was the introduction of a complete foodcrop complex from the Americas, the greatest organizational change, and closely interrelated with the technical one, was the introduction of the agricultural and mineral products of Africa into the markets of Europe and North America. It is this change that has enabled the people of Africa to increase their economic productivity far above subsistence levels and to provide a basis in wealth, organization, and skills for the construction of modern economies. It of course has a technical component in improved methods of transporting goods from hinterland to port, but the more important part was the development of a market trading system to assemble the produce of thousands of small producers, bring it out to the coast, and embark it on ships for distant markets.

Adoption of the New World crops led to horizontal or duplicative expansion of existing societies and caused only minor alterations in social structure, but the development of export industries required and provoked more profound social changes. They were probably least severe in areas where farmers were able to engage in production of small amounts for sale as an additional agricultural activity, employing labor previously idle or engaged in nonagricultural activities. Sometimes this meant a reduction in domestic manufacture of products now become available through the market, but in general, the production of export crops seems not to have been at the expense of foodcrops (*10*). Even this minimum alteration in the economic order, however, required a basic change in the producer's willingness to trust unknown producers to supply him with part of his consumption requirements through the anonymous workings of the market. Farmers like those of southern Ghana and Western Nigeria who made the production of export crops their principal economic activity became more deeply immersed in the market mechanism and learned to accept increasing depersonalized provision of consumption goods, even to the extent of obtaining a large part of their food supply by purchase. All these changes, however, were essentially minor when compared to the alteration in values and personal relationships experienced by those who took up wage employment in the cities, plantations, and mines.

These were major changes indeed, but they have opened the way for even greater ones which may eventually permit the same sort of revolution in allocative efficiency as seems to be in store in the technical realm. In fact, realization of the technical potentialities depends in large part on further refinement of the economic organization itself.

The technical revolution makes it possible to overcome almost any environmental limitation, but at a cost. High among these costs are those incurred in improvement of the human agent. The critical role of technology as a widener of the perceived resource base implies a need for research to identify new techniques and for training to put them to use. It is not enough to know that the research methodologies of the western world are also applicable in Africa; they must now be employed to yield solutions to peculiarly African problems.

Earlier experience with the blind transfer to Africa of production techniques

that had been successful elsewhere led to recognition that the traditional agricultural methods had evolved in harmony with the physical determinants of production. The agricultural development schemes of the Congo, for example—the *paysannats indigènes*—relied more heavily on changes in organization than on changes in techniques to achieve increased output. Research and development of the kind now required to release economic production from the confining bonds placed on it by environment are costly, but the potential benefits are great enough to warrant a considerable expansion of the present effort. The situation in agricultural research in Africa today is made particularly critical by loss of expatriate scientists; without a special effort to reinforce the existing organizations, research facilities may actually decline, as they have in the Congo, and much of the progress made after World War II may be lost.

The lag between knowledge and practice is usually long, but in some parts of Africa it has seemed to be infinite. The value of research findings, however great, remains potential only, until they are transmitted to men who will use them in productive practices. Agricultural research stations in many parts of tropical Africa are now the repositories of knowledge that could profoundly alter productivity, but they have encountered continuing difficulty in putting this knowledge to work. Both continued research and expanded and more imaginative educational programs will be required if the new technology is to achieve any part of its possibilities.

Economic production is the exploitation by man of his environment. At the present stage of knowledge the quality of the human agent appears to be a more important limitation than the quality of natural resources. The individual's efficacy in production depends upon his will, his knowledge, and his physical capacity. The will to produce more can be stimulated by knowledge and by health, but its basic strength, however conditioned by culture, probably varies more within a society than between societies. Knowledge has economic significance both as it includes knowing how to produce efficiently and knowing how to employ effectively the proceeds realized from the sale of one's products. Health is basically determined by nutrition and pathology.

The impact of endemic disease in tropical Africa can be sharply reduced by known techniques, many of which do not require the conscious participation of the population. The incidence and seriousness of others can be reduced only through education and individual action. Nutrition, on the other hand, is primarily a matter of total productivity—of income—and of consumption habits. Technical knowledge enters both in increasing available income and in using this income to improve nutrition. The nature of the relationships between resource base, knowledge of production techniques, economic organization, consumption habits, and child health has recently been studied in a set of Western Nigerian villages by Collis, Dema, and Omololu (*3*), and in Pankshin Division, Northern Nigeria, by Collis, Dema, and Lesi (*4*). In the western villages they found the "nutritional standards of the various groups studied [to] reflect their agricultural prosperity, the quality of their land, and the influence of climate and economic factors" (*3*, p. 226). Particularly interesting are their comments on two cocoa villages. West African cocoa farmers are typically prosperous and relatively healthy individuals, (cf. *5*, *7*), but in these two villages "the people

were apathetic to a marked degree, seeming hardly to have the energy to come forward and talk to us, but rather sat or lay about while their children looked sickly, weak, and undernourished" (*3*, p. 221). Whether the poor quality of diets in these villages was due to general poverty or to ignorance and improvidence is not clear; certainly the value of foods consumed was low as compared with other healthier villages. The authors of the study find the cause in the social disorganization of the cocoa villagers, which they attribute essentially to imperfect adjustment to the market economy (*3*, pp. 223–24):

> The reason for this is that it is not enough to introduce a highly paying cash crop to an illiterate peasantry and expect them to profit by it. What happens is that it tends to kill their traditional life, merely putting money in their pockets for a short period in the year, during which time they enjoy themselves. When the money gets scarce, months before the next harvest, they find themselves short of everything . . . with money running out they can only buy the cheapest food, e.g., cassava and yams. Also the cocoa season is short and the cocoa farmer has very little to do for the remaining part of the year but sit around. Such idleness is not the refreshing rest that comes after labor, but sterile boredom in which man's mind and body degenerate, leaving him unhappy and discontented.

Not all cocoa growers are like the inhabitants of these two Nigerian villages; when they are, the fault would appear to lie not in nature but in man. (Most surveys of West African cocoa-growing villages reveal a remarkably complete adjustment to the modern economy.)

In the northern villages on the Jos Plateau the investigators found nutritional status to be good, but an "appalling child mortality" of 54 per cent in the sample taken, which they attribute simply to lack of medical care. They state that "Modern medical science has almost all the answers to the ills these people suffer from. If this knowledge could be brought to the people in such a way as not to disrupt their traditional life, in other words with sympathetic understanding, their health and particularly the health of their children could be improved more than 100 per cent" (*4*, pp. 152–53).

IV

Implicit in the concept of economics and economic organization is that it deals not with individuals but with organized groups; the Robinson Crusoe model, so popular in earlier years with teachers of elementary economics, does not in fact touch at the core of economics at all. The objective of economic organization, it is true, is to allocate limited resources among various uses so as to achieve the greatest possible total of human satisfactions, but this allocation is conceived of as occurring within a group, or an economy, and as involving greater or less specialization of economic roles among the group's members. In discussions of economic development the group may be a community or a region, although it is most often thought of as comprising all members of a nation state, primarily because the nation is the decision unit capable of reconciling or choosing among the manifold economic goals of its members and of implementing its decisions.

When economic organization is viewed in terms of national economies,

even economies as small as some in tropical Africa, it is at once apparent that it is concerned with the mobilization of diverse resources and diverse skills. Within Togo's 22,000 square miles are to be found deciduous rain forests suitable for cocoa, saltwater swamps and lagoons, relatively dry short-grass plains, and tree and grass savanna; and the nature of foodcrop production varies systematically from north to south. Within its boundaries, too, are to be found at least 18 distinct tribal groups. In Rwanda and Burundi, with a combined area about equal to that of Togo, no less than 25 "natural regions" are distinguished according to elevation, temperature, rainfall, terrain, and soils, and at least four major foodcrop zones. Such variety of natural resources and the inevitable variety of individual talents to be found in populations of a million or more—even within relatively homogeneous cultures—produce variations in the ease and cost with which individual commodities can be produced in specified localities, the absolute advantages in production that are the first basis of economic exchange. The dramatic effect on total productivity of the opening of trade between previously isolated communities, or of the sudden reduction in transport costs when a road, railway, or river route is opened to traffic, is familiar to all students of economic change. With trade, no community need be limited to the resources present in its immediate vicinity; instead, it can employ resources available any place in the trading network. To these increases in output which result simply from more efficient utilization of the endowment of resources and talents that exist when trade is opened must be added those which result from the impact of economic intercourse on the existing technology and even on the resource base. Economic isolation usually means cultural isolation as well; once broken, technical knowledge flows with commerce, enlarging the total pool of information available throughout the trading area. At the same time, the encounters between different techniques frequently result in innovations that are improvements on both. The changed economic environment may also create new technical problems as well, thus adding a further spur to productive inventiveness.

If the natural environment itself is not changed, certainly man's perception of it is. When refined salt is available through trade, salt-yielding plants cease to have economic value; when meat, as well as hides and skins, can be sold at a distance, the economic character of livestock alters; when iron ore can be brought in to be smelted near coal deposits, minerals take on new values; when fertilizers can be carried to farmlands at a reasonable price, the location value of worked out lands becomes more important and natural fertility less.

Economic intercourse may also intensify man's willingness to produce by widening the variety of goods he can obtain with productive effort, and by reducing their cost. The converse of this proposition was demonstrated frequently enough in the periods of shortage during and immediately after World War II to make further argument unnecessary.

The importance of economic organization in implementing technical achievement is apparent when we consider ways of increasing the economic production from agriculture, tropical Africa's principal industry. Present output is limited essentially by the size of the labor force and by the number of crops that can be taken before yields fall so low that it is more economical to bring new land under

cultivation than to continue cultivating the old. Soil scientists have demonstrated that by appropriate addition of plant nutrients yields per acre can be increased, and, at the same time, the period under cultivation can be extended and the time in fallow shortened, thus reducing the labor inputs required to clear new land. The technical solution is at hand, but application of it awaits the time when the value of the increase in yields becomes significantly greater than the cost of the fertilizers which will make it possible. This might be considered as equivalent to saying that the increased output will be forthcoming when there is need for it, but this will be true only if need for product and real cost of input are accurately reflected in prices. Under present conditions they probably are not.

Very little has been done to learn how efficiently farm products, particularly foodstuffs destined for domestic consumption, are distributed; it is highly probable, however, that costs could be reduced by provision of some of the services generally available in the advanced economies and by state intervention to reduce uneconomic restraints on trade. Similar opportunities undoubtedly exist for reducing the costs of purchased inputs; their marketing is further complicated by the insistence of some governments on themselves supplying farmers with fertilizers, pesticides, and improved seeds. These state monopolies, although set up from motives of service rather than of profit, have all too frequently impeded, rather than facilitated, the flow of products. A familiar complaint of agricultural officers is that after having persuaded farmers of the merits of fertilizers or pesticides, they find that through administrative error adequate supplies are not available when and where they are wanted. Without passing judgment on the relative merits of private and state enterprise, it can be stated with confidence that reduction of distribution costs is now the essential condition for bringing many technical innovations effectively into play.

The rearrangement of productive agents that is the object of economic organization is not restricted to natural resources; in numerous instances the distribution of human population too is far from optimum, in some places too thin, in others too dense. For the distribution of African populations in 1960 still reflects in large part the technology and economic organization of 50 or 100 years ago, as well as the influence of historical circumstances and other non-economic factors. Rearrangement of these populations is underway, but major permanent migrations may be necessary to achieve optimum combinations for production. Areas of severe land shortage still exist side by side with under-utilized lands; population density in many areas is too dispersed to make modern transport and communications economic; and it is still possible to say of some areas, as one of my students did recently of the Sudan, "The Sudan has a population problem. It is too sparsely populated. The five persons per square kilometer constitute an inadequate source of labour for the rapid development of a country that depends on irrigation agriculture" (*11*).

These redistributions of resources and persons, the development of improved economic links throughout the economy, the acquisition of new skills, and establishment of new industries can profoundly alter the patterns of comparative advantage existing when trade began. New technology flowing in along trade lines, development of new service and supply industries, opening up of mass

markets to take the products of large-scale industries, all reduce the importance of the original resource endowment. When Arthur Lewis made his recommendations for industrialization in Ghana in 1953, he provided what has come to be regarded as a classic example of the application of the law of comparative advantage to economic planning (*12*), employing as his basic criteria the relative costs of transporting the raw and finished product, the cost (not wages) of labor, the size of the market, and the economic environment, by which he meant essentially the availability of supporting services, from telephones to machine shops. (He considered these services and labor separately because they represent productive resources that cannot easily be transported.) On the basis of these criteria he classified the prospects for 38 industries as favorable, marginal, or unfavorable.

Several industries which Lewis put in the marginal or in the unfavorable category, however, are included in the Ghana Seven-Year Development Plan that was approved ten years later (*6*). Although some appear to have been included for noneconomic reasons, the selection of others illustrates two ways in which comparative advantages may be altered: one, technical, the other, economic. It is not implied that Lewis's analysis was static, but he was considering immediate choices and was little concerned about industries that might become profitable after certain alterations in the economy were completed.

Lewis placed soap manufacturing in the doubtful category, despite the large domestic market, because Ghana produced neither vegetable oils nor caustic soda in quantity; paper making was specificially rejected because Ghana's forests contain only hardwoods; and sugar refining was rejected until an irrigated sugarcane plantation could be established. All three of these industries are in the Plan. Oil for soap manufacture will come from oil-palm plantations to be established for this purpose—in effect, this is an alteration of the economic organization; Lewis's proposed sugar plantation will be developed, presumably, in part at least, with water from the Volta Dam—again a change in the economic environment; and an attempt will be made to develop a paper industry using pulp from sugarcane fibers, rice straw, or sorghum straw—a change in the contemplated technology. Another manufacture, candles, which Lewis placed in the doubtful category because Ghana did not produce the raw material, presumably thinking of paraffin from petroleum, might have been included in another technology in which candles were made from tallow.

The way in which changes in economic organization may affect production decisions apparently dictated by technical considerations may be illustrated by developments in some of the major tropical export crops.

V. D. Wickizer, in an article published in 1960 (*14*), discussed the relative suitability of eight major tropical export crops[1] for production by smallholders or by estates. Of these eight, only tea appeared to him to be essentially a crop ill-suited to smallholders, but he also cites sisal as a type of minor export crop that is best produced by plantations. He names cane sugar, bananas, and coffee, however, as crops for which "productive advantages for export are generally con-

[1] Sugar, bananas, coconut-palm products, oil-palm products, cocoa, coffee, tea, and rubber. Rice and maize were excluded because exports are a small part of total output; cotton, tobacco, and citrus because exports come chiefly from nontropical countries.

sidered, under today's conditions, to lie with the plantation" (*14*, pp. 52–53). Crops in which the large operations have an advantage are those requiring expensive capital equipment for primary processing and high technical skills for growing and harvesting. Specifically, "If a tropical export crop must be planted on a large scale to provide a marketable bulk or quantities sufficient for economic quality processing, it is clearly better suited to large-scale plantation enterprise than to smallholder production.... Fermented 'black' tea [the principal tea in international commerce] requires machine manufacture and this, together with the strict requirements of successful cultivation, makes the crop eminently well-suited to plantation production" (*14*, p. 63). Large capital investment in processing is necessary because technical considerations dictate that minimum unit costs can be achieved only with plants of large capacity; large volume is required to permit full utilization of this capacity and because the economic organization cannot market small quantities efficiently; and inadequate dissemination of technical knowledge and farming skills makes it desirable to distribute these scarce skills possessed by only a few managers over as large an output as possible.

The case for plantation production seems strong. In fact, however, there is no absolute reason why the individual or organization that owns the large plant must also engage in farming; large-volume production can be obtained through the market mechanism,[2] and smallholders can be educated to become as skillful producers as European managers. Wickizer tells us that "direct cultivation of the soil by the owner of the [sugar] central is exceptional in the Philippines" (*14*, p. 71), and recent experiences in improving the farming techniques of cocoa growers in Ghana and coffee growers in Kenya demonstrate the success of education in disseminating technical knowledge. Black tea is now being produced successfully by smallholders in the Nyeri district of Kenya, where 1,200 small farmers deliver the leaves to a central factory(*8*, p. 122).

In agriculture most advantages arising from technical economies of scale probably can be achieved by a variety of farm organizations; the farm need not be large because some necessary machines are large. In manufacturing, however, economies of scale still make large operations preferable in many industries, and the economic organization must accept limitations placed on it by technical considerations until technology is able to produce small processing units that are just as efficient as large ones.

V

Most countries of tropical Africa have adopted economic development plans of one sort or another, varying in complexity and resoluteness of planning from little more than multiple-year governmental budgets to elaborately detailed schemes for achieving national goals. The objectives of these plans are mixed. They include the preservation of national security, the establishment and maintenance of national unity, the legitimization of new national governments, and national prestige. Prominent among the goals of all plans, however, and of principal importance in most, is a rapid rise in the economic well-being of the popu-

[2] It is at least possible that consumer preference for black tea is also a result of the market mechanism, i.e., of the promotional and marketing efforts of black-tea producers.

lation. To increase national product is the first necessary step, but it is also necessary to decide how the increment in product, or in fact the total product, will be shared among the members of society. This involves decisions not only about *who* will benefit, but about *when* they will benefit. It is not enough to agree that steps will be taken to raise national product to higher levels; the problem involves agreement on the way in which this increased product is to be distributed over time.

As caretakers of a communal, or national, heritage—ultimately as guardians of the species—the national planners' responsibility extends to distant future generations. By specifying what population is to be maintained at what level of living, it might be possible to formulate rational plans for utilization of perceived natural resources over periods of centuries—it might be possible, that is, if technical and economic knowledge were assumed to be unchanging. Fortunately they are not. The impending technical revolution is the most recent manifestation of an expanding perception of the world that is certain to continue, barring nuclear war or other global disaster. Economic knowledge has achieved much less, but it is not unreasonable to hope that the future will see breakthroughs in this and other social sciences similar to those that have already occurred in the natural sciences. A planning model for the future, therefore, must allow for changes in our knowledge of the composition of the earth, of ways in which its constituents can be transformed into things useful to man, and of ways to allocate resources and products to maximize their social value. Each kind of knowledge is changing and will continue to change; each is influenced by changes in the other.

If we are to judge from historical experience, the continuing expansion of technical knowledge will make the future value of natural resource assets less than the values assigned to them on the basis of present information, either because additional resources capable of fulfilling the same functions will be identified, or because more efficient ways of employing the present resources will be worked out. This in itself suggests that the present value of future availability of many resources should be discounted in order to allow for changes in technology and economic organization. If this were the only reason for shifting emphasis from future to present use, however, it would be a sanguine economist who would counter the macaber pronouncements of some conservationists with Micawber's promise that something will turn up. In fact, much more compelling reasons may persuade the economist to accept seemingly reckless exploitation of nonrenewable resources. In the growth process, it may be necessary to consume one resource in order to build the capital plant and economic organization or to create the human population capable of further exploitation of the environment and construction of an economy of high productivity. Just as the depletion of the forests of the American old northwest made possible the rapid construction of dwellings and other structures needed by a growing middle western population, so the extensive cutting of firewood along African rivers and railways may be preferable to long delay in improvement of transport. To export the resources of the ground in the form of mineral ores, or in the form of coffee, peanuts, and cotton, may not be improvident if this is the only way to obtain rapidly the capital goods and the skills required for economic development. This kind of exploitation may some-

times be a matter of survival, too, involving the unavoidable gamble that if the present danger is met, some way may be found to overcome the future one.

On the whole, it is probably better to tend toward optimism rather than pessimism. It is still not good practice to live on capital unless that is the only way to survive into a period when the creation of new income may be possible. On the other hand, it is folly not to employ capital in new productive ventures, even though some may fail. For the new countries of tropical Africa this may mean a prodigal expenditure of natural resources in order to obtain the means for rapid economic advance. If our science were less imperfect than it is, we might be able to determine which mining of resources is essential, which fruitless. In any event, we should make every effort to identify and explain the possible costs of destruction of forests, of erosion and soil depletion consequent on large-scale exploitation of grasslands, of destruction of aquatic life and loss of recreational areas because of pollution of lakes and streams, of the loss of mineral resources because of quick pay-off mining and pumping of oil, of the destruction of irreplaceable herds of wild animals, of smog, of slums, of flimsy dwellings and inflammable towns. We should at the same time remember, however, that every one of these costs results from an attempt to create income, and that the present value of this income may be incomparably more important to the long-term economic welfare of the society than the future value of the costs entailed in generating it. Only if we do can man effectively exercise his dominion over the fish of the sea, and over the fowl of the air, and over every living thing that moves upon the earth.

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