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TECHNOLOGY POLICY
and
PRACTICE *in* AFRICA



EDITED BY

Osita M. Ogbu, Banji O. Oyeyinka, and Hasa M. Miawa

INTERNATIONAL DEVELOPMENT RESEARCH CENTRE

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PART I

Introduction and Framework

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CHAPTER 1

Introduction

O. Ogbu, B.O. Oyeyinka, and H.M. Mlawa

The economic crisis in Africa has defied both traditional and nontraditional approaches to economic management. The African development questions continue to pose serious challenges to governments, nongovernmental organizations, the donors, and development researchers. The search for solutions lacks consensus, partly because there are divergent views on the relative weight to be assigned to the multiple causes of problems and partly because the impacts of some proffered solutions are not fully anticipated. But there are certainly a few accepted premises: that Africa has suffered as a result of all types of hostile environments, both natural and artificial; that some international terms of trade are adverse; and that, in many countries, there are domestic management problems. Conceptually, therefore, the causes of the African problems fall into two categories: those that are external and those that are “home grown,” arising out of domestic policy mistakes. All agree on the roles of technology and, by implication, effective technology policy in influencing growth and development. But the good intentions and rhetoric have not always been matched by action. Many countries have full-fledged technology ministries, which are supposed to demonstrate the importance of technology in development and articulate an enabling technology-policy environment.

Although the evidence is of mixed value, some of the case studies in this book will demonstrate that the basic role of the government in coordinating and evaluating technology acquisition and use has remained unclear. Consequently, technology adoption and diffusion and the consequences of technology for the various productive elements of society are not fully understood by many countries when they are importing technology. The so-called white elephants and the many instances of projects abandoned after heavy initial investment point to Africa’s need for an effective technology policy.

In the policy arena, attempts to correct past policy mistakes have been made largely with the help of the World Bank-supported structural adjustment programs (SAPs). There can be no denying that the implementation of these programs in most African countries has been less than perfect. Many of the promised benefits of the program have been elusive. Again, even though we recognise the role of technology in development, the proponents of SAPs have failed to analyze or fully anticipate the implications of the program for technology. These questions are only now beginning to attract the attention of those concerned with technology policy in Africa. The assumption that “once we get the prices right, the output will follow” is no longer credible. In the agricultural sector, for instance, the aggregate-supply response to prices has been very weak (Ogbu and Gbetibouo 1990a, b). It is, therefore, important to understand how prices interact with technical inputs and the use of technology, research, infrastructure, etc., for a full appreciation of the supply response behaviour

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of the farmers. On the industrial side, the argument for the weak prognosis rests on the following:

- African manufactured products are not competitive internationally, so prospects for export will remain dim.
- Manufactured African products have a high cost because of inefficient protectionist policies and “quantitative restrictions on competing imports” (Riddell 1990).

Imports are important because along with imports come technology, technical know-how, and the modernization that competition from abroad ensures. This is the classic justification for import liberalization. SAPs have led to massive currency devaluations, liberalization of trade and financial-sector regimes, and privatization and commercialization of public enterprises. With the infusion of foreign capital, these SAPs were supposed to ensure a stable industrial sector for Africa, ready to compete with the rest of the world in the 21st century. SAPs have been around for more than a decade, and it seems that African industrial sectors are worse off than they were before the reforms. The growing dependence on imported goods is quickly eroding the weak industrial base of most African economies. In fact, many agree that African economies have been undergoing deindustrialization for more than a decade. According to Riddell (1990), “the structural adjustment policies promoted by the World Bank have been a major force preventing restructuring of industry away from the deep dependent link.”

The recent crash of the Mexican economy underscores the fact that we are still not certain of the path of optimal reform. Mexico had a 30 billion USD (USD = United States dollars) infusion of foreign capital in 1993 and was being showcased as the model for other developing countries. It is true that the economy grew, but it did not grow in the productive sectors. The inflow of foreign capital appreciated the peso, the trade deficit grew, and the crash became inevitable. It is clear that if growth is to take place in the productive sectors, an enabling technology-policy environment will be a prerequisite.

There are now serious questions about whether complete trade liberalization is optimal, given the structure of African economies and the experience of East Asian countries that took a different route. In this regard, the overall policy prognosis for the stagnating African economies is somewhat worrisome. The orthodox view, implicit in SAPs, is that Africa should expand its agricultural and extractive mineral-commodity sectors so that it can export more. Industry and technology often get nothing more than a passing mention. The continued insistence that Africa should do what it does best, that is, produce primary commodities, has lost our sympathy as a result of current evidence. This orthodox prescription may well be due to the enduring mind sets of African policy-makers and the proponents of SAPs, who regard capital flow and savings as the only necessary or sufficient conditions for generating greater additions to the existing capital stock of physical plants and machinery. In the thinking of investment experts, all a nation needs to do is generate enough capital for machinery imports, and then, through learning by doing, the recipient nation will acquire all the necessary know-how.

There are two contradictions in this kind of thinking. First, as recent history has demonstrated, Africa will find it extremely difficult to finance industrialization, development, and debt repayment because the international prices for Africa’s exportable commodities are not likely to go much higher. Even oil-rich countries, like Nigeria, are having difficulties meeting foreign-debt obligations. Yet, industrialization and the acquisition of technical know-how are now being left to the vagaries of the

market. Even in Africa's agricultural sector, the productivity level is far too low to permit rapid expansion without heavy doses of innovation in agricultural practices. This calls for rapid technology acquisition. The so-called traditional nonfarming sector of the African economy shares the same fate.

The evolutionary discontinuities reflected in the concepts of "dualism," "informal sector," "traditional agriculture," and "traditional industry" represent the failure of Africa's industry to modernize by successfully blending modern technology with age-old practices. The technologically backward sectors of the African economy are large and growing (UNDP 1993), whereas the modern sector, acquired at great costs in the 1970s and 1980s, has deteriorated through both the lack of spare parts and components to sustain them and the paucity of foreign exchange needed to modernize the obsolete plants.

This brings out the second contradiction. Many African policy-makers and their advisers probably still equate Africa's industrial problems with those described by Hobsbawn (Mytelka 1988):

The technological problems of the early industrial revolution were fairly simple. They required no class of men with specialized scientific qualifications, but merely a sufficiency of men with ordinary literacy, familiarity with simple mechanical devices and the working of metals

Many of Africa's backward sectors may well resemble the craft shops of 17th-century England, but the mechanical devices in the modern sector are 20th-century artifacts. Unlike the picture painted by Hobsbawn, modern technology requires massive investment in capital, production, and innovative capabilities. It requires infrastructure, technomanagerial capabilities, and institutional competencies. It would seem that many of the orthodox prescriptions are rooted in days gone by. Evidence from the way the 20th-century latecomers developed (and, indeed, as Germany and the United States before them did) contradicts the simplistic prescription to "get the prices right." In fact, according to Amsden (1992), Korea deliberately "got the prices wrong." Japanese bureaucrats, said Freeman (1989), "repudiated the view that Japan should be content with a future as an underdeveloped country with low productivity and income per head." On the catching up by Germany and the United States, he remarked, "It is clear that in their catching up, Germany (and the United States) relied not simply on tariffs . . . but on technology, and in gaining technological lead"

The point of this book is that technology is central to the development process. We suggest that African economies need deep technological revolutions to bring about rapid structural shifts, to break the tenacious structure of dualism, and to deepen their industry and build up their endogenous technological capability. The common denominator in most of the case studies is the conclusion that we should pay greater attention to an enabling macroeconomic environment and the ways that environment interacts with an effective technology policy. This interaction should allow for technological learning, the right technical choices, the setting up of appropriate institutions, and effective technological management for both the industrial and agricultural sectors, including those small and medium-sized enterprises that are now so vital for income and employment.

Structure and format of the book

The book has 26 chapters — this introduction, the analytic framework, and 24 case studies — and is divided into four sections. The introduction and analytic framework constitute the first section. An attempt was made to group the case studies according to the following themes:

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Part II. Technology: Choice, Transfer, and Management

Part III. Technical Change, Innovation, and Diffusion

Part IV. Gender and Technology and Technological Capability

Although these thematic categories provide some clarity, it is difficult to neatly separate the essential elements of the technological change process. In other words, we would like to believe that there is a thematic order unifying the case studies, disparate as they are in methodology and language.

As the titles will make immediately obvious, the case studies emerged from widely differing research backgrounds: engineering, economics, sociology, political economy, business studies, and science, among others, encouraging a multidisciplinary approach to research, with the objective of building the capacity for technology-policy analysis. Because of this diversity of research approaches, conclusions that generalize too much have been avoided.

Each case study was to include objectives and methodologies sections for two reasons: (1) to help the reader judge the scope and findings of the studies as individual research projects designed for policy learning; and (2) to give these studies further educative value in future research efforts, as well as making future comparative studies relatively objective.

In both the introduction and the analytical framework, sub-Saharan Africa was presented as a uniform entity. This, we admit, is certainly not so. Planning and policy design at the country level will certainly benefit from this collection. Nevertheless, a differentiated approach will have to be taken by individual countries. We consider this a modest beginning.

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CHAPTER 2

Understanding Deindustrialization and Technological Stagnation in Sub-Saharan Africa: A Framework

O. Ogbu, B.O. Oyeyinka, and H.M. Mlawa

Introduction

In explaining the decline of African industry, two related explanations always arise. The first concerns hostile and largely external influences, which result in perennial shortages of foreign exchange, spare parts, and components and in turn lead to the underutilization of capacity. The second concerns the system of incentives, which hinders industrial growth through high protectionist barriers and in turn leads to high product costs and industrial inefficiencies. There is no doubt that these factors explain in part the malaise of African industry, but they do not capture the whole story. Lall (1992) has made the structural weaknesses of industry in sub-Saharan Africa (SSA) much more central to the explanation of Africa's deindustrialization. He identified incentives, institutions, capabilities, and the right mix of policies as the means to "call forth a proper response." Our conception of the problem follows from a detailed examination of not only the macroeconomy but, more important, the microeconomy.

Consequently, our line of explanation draws on the evolutionary–structuralist concepts of the role of technology in economic development, and it is in this tradition that we anchor our search for an understanding of the performance and behaviour of the technological and industrial systems in SSA. In following the evolutionary school, we make three implicit assumptions:

- Technology is central to the development process, and long-term structural change is technology driven.
- The growth of systems is an evolutionary process; therefore, technological and organizational learning cannot be circumscribed.
- Explicit efforts and investments are essential preconditions for learning and development; that is, learning is not an automatic outcome of capital accumulation and investment.

For a systematic account of the evolutionary–structuralist school, see Rosenberg (1976), Nelson and Winter (1982), Freeman (1982), Bell (1984), Justman and Teubal (1991), and Bell and Pavitt (1993), among others.

In providing an explanation for the technological behaviour of industry in SSA, we focus on four main issues:

- the changing perspectives on technical change;
- production capacity, technological capabilities, and technological learning;
- firm linkages and industrial subsystem interactions; and
- the state and technical change.

The changing perspectives on technical change

Concomitant with the changing material conditions of newly industrialized countries (NICs) has been a marked paradigm shift in research on technical change. In the 1960s and 1970s, research focused on questions of transfer, choice, and appropriateness of techniques. The implication was that developing countries are passive recipients of technology. The positive change in the quality of life and the technological dynamism of the NICs led to a revised research agenda and, in consequence, a perceptual change in the policy analyst. The technological dynamism suggests some measure of technology creation and accumulation in those NICs.

From the 1970s, the focus of research shifted to how and why technology has been mastered and adapted in these NICs. Most of the countries that were studied accumulated technology through minor or incremental technical changes — a phenomenon that had been found in the industrial countries (Enos 1962; Hollander 1965). At present, technology accumulation through minor technical changes is taken for granted, but it does not come about by learning by doing alone.

The influential work of Nelson and Winter (1977) stated that technology accumulation strongly depends on the recipient's ability to manipulate the given technology. They suggested that technology has the required element of "tacitness" and that the buyer can never hope to obtain all the required information from blueprints, manuals, or training. This, then, compels the buyer to make certain efforts to master the technology and adapt it to environmental conditions, which, in turn, brings about minor, incremental technical changes. This process confers idiosyncratic characteristics on individual plants and sets firms on specific evolutionary trajectories. In effect, recipients of technology cannot effectively develop plants and processes without some kind of investment in the learning process, a point dwelled on extensively by Bell (1984), Dahlman and Westphal (1981), and many others. These theories and assertions are backed by detailed firm-level cases, mostly from Latin America.

Evidence from SSA differs very sharply with that from East Asia and Latin America. Instead of progressive, incremental technical change, we find almost predictable productivity decline; instead of dynamic industrial growth, we find stalled projects, project delays, and, in many cases, abandoned technological efforts. The firms are uniformly unsuccessful in most of SSA. From the Delta Steel Company in Nigeria, which has not broken the 30% capacity utilization barrier since it was established in 1982 (Oyeyinka 1988), to the textile industry of Tanzania, which continues to record a productivity slide (Mlawa 1983), the story is the same.

From the case studies in this book, two important factors may well appear to account for the dismal production record of SSA firms. First is the perception of the technological and organizational learning process as costly and automatic. Second is the technical (as distinct from the political) environment of the firms. This second point is best illustrated with some proxy technological indicators, as shown in Table 1. The indicators reveal, primarily, the state of the manufacturing industry in two blocks of countries. Block A countries are those that have made tremendous progress in technological advance, and block B represents all SSA countries, without exception. The figures are important for two reasons. (1) They demonstrate that the manufacturing technology in use in a particular environment reflects the technical maturity of that environment. (2) Manufacturing technology directly influences the other sectors of the economy. There is a big difference between a nation where the most sophisticated farm implements are hoes and cutlasses and a nation that uses tractors and harvesters.

Table 1. Value added in production for two blocks of countries.

Technological indicator	Block A ^a	Block B ^b
Total manufacturing output as a percentage of total GDP (1983)	>15	<10
Capital goods as a percentage of total manufacturing (1980)	>30	<20
Machinery sector as a percentage of total manufacturing (1980)	>15	<5
Ratio of capital goods to consumer goods (1980)	>1.0	<0.4

Source: Bhagavan (1990).

Note: GDP, gross domestic product.

^a Brazil, China, India, South Korea.

^b All of sub-Saharan Africa.

Specifically, the indicators in Table 1 reveal the relative strengths of the domestic manufacturing capacity of the two blocks, especially the strength of the capital goods sector, which provides the intricate linkage among the various subsystems, such as chemicals, engineering, transport, and services. In block A countries, the total manufacturing output, as a percentage of gross domestic product, is >15%, whereas in block B countries it is <10%. The key indicators that distinguish the technological leader from the laggard are in the area of domestic capital-goods and machinery production. Although the block B contributions to total manufacturing value added (TMVA) in the two areas are <20 and 5%, respectively, the block A contributions are >30 and >15%, respectively.

The lack of capacity for domestic capital-goods and machinery production is a singular characteristic of underdevelopment. The indicators reflect, therefore, the fact that the industrial environment of SSA is extremely weak, lacking the capacity to produce even the most basic tools for manufacturing. The lack of capacity for capital-goods and machinery production also means that even when machinery and equipment are imported, these countries lack the domestic capabilities to maintain the systems. The pervasive undercapacity of industry, the slow growth in productivity, and the incidence of white elephantism (abandoned large-scale projects) have direct connections with the weak industrial structures that the indicators reveal. In essence, although the analysis of technical change in advanced technological environments assumes these factors are parametric, in SSA the technical environment becomes a variable. Indeed, much of the firm-level *x* inefficiencies could well be traced to variable environmental factors: unstable power supply (most manufacturing firms have stand-by generators); irregular water supply (most firms dig boreholes); and erratic and inadequate supply of spare parts and consumables. This is true for small firms and, even more, for capital-intensive projects. We find in the case studies on large-scale projects that rated capacity and nominal throughput (a function of raw-material and optimal machine availability) are never attained. These two decisive factors are subject to considerable external factors, apart from organizational and technical capabilities.

We suggest that analysis of technical change in SSA must consider the technical environment. The technical environment is structurally weak; furthermore, it remains in constant flux from the point of view of firm-level planning because firms are never assured a regular source of inputs. But the weak technical environment of SSA is as much a cause of the observed failure of the SSA production structure as it is an effect of an evolutionary process. We now turn to the fundamental elements of that process.

Production capacity, technological capabilities, and technological learning

Bell and Pavitt (1993) drew attention to the important difference between production capacity and technological capabilities. Overlooking this difference has been a source of much policy confusion in the past, especially in developing countries, so this distinction is important. Production capacity refers to the resources, mostly equipment and machinery, required to produce industrial goods at given levels of efficiency and from given input combinations. Technological capabilities, on the other hand, are the skills to initiate, manage, and generate technical change. These capabilities include human resources, knowledge, experience, and institutions. The distinction between knowledge and human resources is important. Porter (1990) made a distinction between basic factors and advanced factors. Basic factors are passively inherited resources, such as unskilled and semiskilled labour, in the same category as climate and location. Advanced factors consist of highly trained, specialized labour, in the same category as advanced telecommunications. Hence, production capacity is mainly capital embodied, whereas technological capability is a dynamic resource, an advanced, change-inducing factor in creative industrialization.

Another important concept is technological learning. Learning can set a firm or industry on three broad types of technical-change trajectories (Malerba 1992):

- Production may be increased through dynamic efficiency and yield improvements. This may be brought about by actual plant modifications and incremental innovations, as well as by organization of production.
- The characteristics and physical properties of a product may be completely altered to improve its reliability and performance. This may come about through dynamic learning and through improved performance in terms of horizontal and vertical differentiation.
- Processes and products may be scaled up. This may come about in a situation of indivisibilities and high capital intensity and when there are difficulties in modifying a production process. In such a case, engineers may well resort to capacity stretching through incremental investments in technology up to a certain vintage.

The distinction between production capacity and technological capabilities is important for three reasons. First, conventional investment analysis and decisions overemphasized the importance of capital-embodied resources as the vehicle of technological development.

Second, the characteristics of a particular vintage of technology were assumed to be fixed and unalterable properties, implying that once a machine or system had been designed, it could not be subjected to further technical alterations in its lifetime. The conceptual and policy implication of such mistaken assumptions was that technological capabilities were irrelevant or, at best, a commodity that would emerge in time, through automatic learning by doing. It stopped further consideration of postinvestment learning.

Third, policy-makers used to conceptualize international technology transfer as being no more than a transplant of a given commodity from one geographic location to another. Investment decisions were limited to finding the requisite capital — the long-term issue of technology creation, using imported technology as the base, was hardly ever raised.

In sum, technology was seen as freely available information. It was believed that a steel plant, a petrochemical complex, or a sugar factory could be “transplanted”

in some isolated place, far removed from its prototype, and be made to function perfectly. A mistaken view of the relationship between production capacity and technological capabilities, which promoted this kind of thinking, may inadvertently have underpinned decisions that gave rise to many a white elephant. We now know that innovation and technical change are sustained, not within firms alone, but between a network of firms.

Although the central role of firms is important, one must not assume that individual enterprises are isolated actors in the process of technology accumulation. Technical change is generated out of complex interactions between firms (Bell and Pavitt 1993).

Further important lessons are that (1) acquiring technological knowledge is a cumulative process, so national technological competence cannot be changed rapidly; (2) blueprints accompanying turnkey projects are no more than road maps; (3) the buyer must travel the road alone, by his or her own efforts; and (4) technical knowledge is largely tacit and specific and can only be mastered by painstaking learning. All of this takes time.

Firm linkages and industrial subsystem interactions

An important element in industrial competence and production capacity is the system of linkages among industrial units and firms. The phenomenon of dynamic linkages, as a precondition for generating and diffusing innovation, has been persuasively established by Bell (1986), Lundvall (1992), Bell and Pavitt (1993), Von Hippel (1988), and Porter (1990), with his “clusters of industries,” and forcefully established by Rosenberg (1976). According to Bell, “technical change will often involve detailed interaction between product-centred change and cost-reducing change . . . not only within firms but also between them.” The study by Porter shows that some particular clusters often cover more than half of a country’s exports. He went on to suggest that “industry clustering is so pervasive that it appears to be a central feature of advanced national economies.” This may be so because of the systemic nature of contiguous technologies, whereby one “industry helps to create another in a mutually reinforcing process.”

Rosenberg (1976) suggested that firms be grouped together on the “basis of some features of the commodity as a final product.” In other words, processes and products within the firm, rather than the industry — taken as a Marshallian unit — should be regarded as a unit of analysis. If we focus specifically on the engineering industry, we find that there are certain functional processes that cut across industrial lines in the Marshallian sense. Functional activities, such as drilling, milling, planning, grinding, turning, and boring, lie at the heart of manufacturing and of the machinery subsector, in particular. The techniques behind these processes cut across industries — textiles, automobiles, chemicals, etc. — and, in that sense, they constitute interchangeable skills rather than unrelated activities. This is what Rosenberg described as technological convergence. In a national industrial system, these skills and processes could justifiably be regarded as industrial subsystems because they are linked between firms through subcontracting and personnel exchange (Watanabe 1979). It would seem that an important derivative of this notion of the convergence of technological processes, is what might be described as the convergence of technological capabilities, a notion that is not too far fetched, considering the importance of user–producer interactions in technical innovation (see Lundvall 1992; Von Hippel 1988).

For instance, we suggest that behind Porter’s (1990) “health cluster” or “agricultural cluster” are certain common processes and certain specific technological

capabilities that provide for learning commonalities and make technological mastery relatively easy. Porter provided examples of Swedish competitiveness in the pulp and paper industry, in wood-handling and pulp-making machinery, and in chemicals for pulp and paper making. The process technologies and skills may not be so apparent to the casual observer, although the common material, pulp and paper, runs through all the examples. Rosenberg (1976) illustrated his point with seemingly unrelated sectors, such as aluminium, electricity, and fertilizers, as examples of industries with "large numbers of interlocking, mutually reinforcing technologies." As he further observed, left on their own, these undergirding technologies are "of very limited consequences" until they are brought together in an industrial system.

The rate of technical change in an industry may well depend on dynamic linkages between firms. Underdeveloped areas may have missed out on the opportunities to acquire key technological processes and to develop the right technical environment to foster mutually reinforcing industrial subsystems and are likely to experience limited technical change or none at all. Central to dynamic industrial interactions is the capital-goods sector, especially machine tools. The capital-goods sector is needed for the realization of all innovations, whether revolutionary or incremental. The smooth functioning of large-scale, highly matured industries depends on a wide array of component manufacturers, which a dynamic capital-goods sector spawns. Apart from the production of consumer and intermediate goods, there are important learning consequences.

We suggest that the absence of a dynamic capital-goods sector in a region like SSA constitutes the most serious obstacle to dynamic industrial linkages, limiting the rate of technical change and, in the extreme case, being responsible for the absence of technical change in large parts of SSA. We have the making of a vicious cycle: no capital goods, therefore no effective linkage, therefore no technological learning therefore no technical change.

What this scenario implies is that even where demand for innovation exists in developing countries, the initial condition of underdevelopment (the absence of a strong capital-goods sector) imposes on potentially demanding firms or potentially producing firms a constraint so severe that future possibilities for linkages and technical change will be very limited. Recourse to foreign import of capital goods was at one time the only route for the underdeveloped areas if they had to industrialize. This may in effect have hindered a "natural" sequence of development — principally the sequential development of the local machinery industry — thus reinforcing this vicious cycle, or "acquilbrium trap." According to Rosenberg (1976), "the failure to achieve a well-developed capital goods sector means a failure to provide the basis for technical skills and knowledge necessary for development." In other words, suppliers in distant lands are a poor substitute or no substitute at all for local suppliers.

Let us note that complexity, of course, is relative and that for an underdeveloped area, an integrated steel plant, a petrochemical complex, or an automobile assembly plant is very complex, indeed. In other words, the vast array of parts and components that these countries import to maintain the large-scale plants is to be defined as complex. Ordinarily, investment-project documents specify parts, and some of the parts purchased from the supplier may not last longer than 2 years, which means the importing country is obliged to establish a parts-and-component base to meet these extraordinary requirements. This rarely occurs, and the seeds of large-scale plant failure are almost always sown in this way (see Oyeyinka 1988). Internal units could never hope to meet all requirements because "the truly mass-production industries, such as automobiles, are served by an extraordinary complex of relatively

small firms, each constructing very limited numbers and ranges of tooling devices” (Rosenberg 1976).

Tragically, in the past, investors conceived of these large-scale projects as *sui generis*, capable of propelling themselves forward without the evolutionary accretion of competence through technological and organizational learning. Establishing a large- or even medium-scale industrial plant in an underdeveloped area involves significant technical discontinuities. By the time the automobile plant emerged in the United States, the transition was relatively easy because “the basic skills and knowledge required to produce the automobile did not themselves have to be ‘produced’ but merely transferred from existing uses to new ones. The transfer was readily performed by the machine tool industry” (Rosenberg 1976). We may add that the transfer was made within the same technical environment, and, thus, an apparent technical discontinuity was enclosed by profound technical continuities that the established machine-tool industry had produced. It is important to mention that *short distance* in the language of technology transfer refers to the cultural, linguistic, and locational contexts. That underdeveloped areas have to resort to mass importation of capital goods indicates what technological opportunity is missing for these countries. This is true especially for SSA. In a much more fundamental sense, the understanding of technological stagnation and of the present stalemate in the evolution of African industry lies in the profound ways in which technological discontinuities — specifically the absence of the machinery-making sector — have truncated the natural sequence of industrial progress.

The state and technical change

Received theory has sought a limited role for the state in the economy and has tended to play up the virtues of a free market. In the judgment of orthodox economists, government intervention produces more damaging consequences than market failure. Yet, the history of 20th-century economic growth provides a preponderance of evidence to the contrary. The rapid structural transformation witnessed in the late-industrializing countries of Japan, South Korea, Brazil, India, and Taiwan could not have occurred without the strong intervention of the state. For Amsden (1992), economic backwardness has a strong origin in the weak role of the state in the economy: “industrialization was late in coming to ‘backward’ countries because they were too weak to mobilize forces to inaugurate economic development.” The state has an even more urgent and decisive interventionist role in modern economic growth where backwardness is relatively greater and catching up means still heavier doses of government support. Amsden presumably had in mind the increasing gap between, on the one hand, Britain, Germany, the United States, and other parts of Europe and, on the other, the colonized states of Asia and Africa. The defining event has been a change in the nature of industrial production, which was brought about by the increased scientific content of production technologies. Although scientific and technological advancement has, in many ways, made technology transfer relatively easy, the widening gap between industrial leaders and the backward areas has made it impossible for the modern state to remain passive.

The interventionist mechanisms have been as diverse as the countries studied, although these mechanisms may well be subsumed under a common analytic framework of tariff and subsidies. Undergirding the accumulated efforts of late industrializers, such as South Korea, “were subsidies offered by the state to private enterprise in exchange for higher output of exports and import substitutes” (Amsden 1992). Infant-industry protection, far from being a 20th-century phenomenon, was a

ready instrument of the state during the earlier industrial revolutions. Tariff was typically used to protect infant industries to enable firms to master technology and to accumulate technological capabilities.

State intervention has taken other forms. In late-industrializing countries, governments have sought to influence the rate, nature, and direction of technology transfer and accumulation by influencing the price and the form of technology and the structure of industry (Fransman 1986). Costs and forms of technology sometimes complement each other. But more widespread is the objective of bringing about certain kinds of industrial structures. This development of local capital goods has been a consistent objective of late- and early-industrialized nations alike. This sector is pivotal to the long-term goals of industrialization. To this end, tariff exemptions have been granted for imported machinery, and medium- and long-term credits have been offered to establish local capital-goods production. In India, industry has been subject to strong government interventions (Lall 1984).

The magnitude and intensity of the structural shifts needed for modern economic growth have inevitably been accompanied by continual social innovations, typified by the changing role of the state. The emergence of a strong role for the state in the economy and the range and depth of the interventionist instruments applied across countries may well be evidence of a profound paradigm shift with which orthodoxy has yet to come to terms. According to Kuznets (1971), "the sovereign state is an important factor in modern economic growth; that given the transnational, worldwide character of the supply of useful knowledge and science, the major permissive factor of modern economic growth, the state unit, in adjusting economic and social institutions to facilitate and maximize applications, plays a crucial supplementary role."

This crucial role manifests itself in three ways, with the state serving as (1) the clearinghouse for continual social innovation; as (2) an agency for conflict resolution, because "structural shifts mean different rates of growth for different parts of the economy, and hence for the different groups," often leading to conflicts that only the state can mediate to guarantee law, order, and stability; and as (3) a major entrepreneur providing a strong social infrastructure, the absence of which may act as a disincentive to private investment. Apart from physical infrastructure, such as transportation and communication, trained, skilled labour, such as engineers and managers, has been central to the technology and development policies of advanced and backward nations alike. Because of the revolutionary speed at which structural shifts are now occurring, the state will have to attain certain critical thresholds of organizing abilities to achieve the required mixture of market mechanisms and interventionist policies.

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PART II

Technology: Choice, Transfer, and Management

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CHAPTER 3

Management of Technological Change in Africa: The Coal Industry in Nigeria

B.O. Oyeyinka

Introduction

Coal mining began in Nigeria in 1916. Average production in the first decade was $>150\,000\text{ t a}^{-1}$ (Table 1); this reached a level of around $300\,000\text{ t a}^{-1}$ by the time World War II broke out. From the 1940s to the mid-1960s, production averaged $>600\,000\text{ t a}^{-1}$, until the Nigerian civil war (1967–1970) disrupted activities. In 1976/77, production began to decline rapidly, reaching as low as $53\,500\text{ t a}^{-1}$ in 1983. This was remarkable. Concomitantly, the sole enterprise responsible for coal mining in Nigeria, the Nigerian Coal Corporation (NCC), began an economic decline. Its operating losses in 1979 were 9.5 million NGN (in 1995, 78.5 Nigerian naira [NGN] = 1 United States dollar [USD]), and the corporation could not even meet its administrative costs. Paradoxically, in 1977/78, when it sustained its greatest operating loss, NCC's production was fairly substantial: $>190\,000\text{ t}$.

Of course, there were many reasons for the decline of the coal industry. Some factors were external to NCC. Among these were the following:

- the advent of the “oil boom” and the shift of attention from coal;
- the “dieselization” undertaken by the Nigerian Railway Corporation (NRC), which had been a major customer of the coal industry;
- the switch to natural gas and oil by several power stations run by the National Electric Power Authority (NEPA), another major customer; and
- the disruptive consequences of the civil war (the mines had been at the heart of the war zone).

But these problems did not stand in the way of other avenues of challenge and opportunity. There was a decent outlet for export to the Economic Community of West African States (ECOWAS) and Europe. In 1972, for instance, coal export was $52\,000\text{ t}$ and expected to grow, but it declined instead. There were industrial consumers like the Nigerian Cement Company (NIGERCEM), Nkalagu, which fired its cement with coal. NCC's estimates in 1988 showed a potential coal demand of $335\,000\text{ t}$ for NIGERCEM and some smaller industrial consumers. There was also a potentially high demand for coal as a source of basic and industrial chemicals and as a domestic household fuel. Finally, not all of NEPA's thermal power stations shifted to oil and gas: the Oji River project (120 MW), the Makurdi Power Station (600 MW), and the Onitsha–Asaba project (1200 MW) still needed coal.

In 1976, the year that productivity began to decline, the Nigerian government commissioned the state-owned Polish Overseas Mining Company, KOPEX, to completely modernize NCC's technology, installing fully mechanized longwall equipment, with shield support. The investment and installation process lasted 3 years

Table 1. Nigerian coal production (1916–1987).

Year	Production (long tons)	Year	Production (long tons)	Year	Production (long tons)
1916	24 511	1939/40	300 000	1962/63	615 681
1917	83 405	1940/41	318 594	1963/64	600 229
1918	145 407	1941/42	402 640	1964/45	698 502
1919	137 844	1942/43	463 978	1965/66	730 183
1920	180 122	1943/44	528 421	1966–70	Civil war
1921/22	194 073	1944/45	505 568	1970/71	264 258
1922/23	112 818	1945/46	610 283	1971/72	323 001
1923/24	175 137	1946/47	633 852	1972/73	314 457
1924/25	220 161	1947/48	551 706	1973/74	250 769
1925/26	242 582	1948/49	610 283	1974/75	257 832
1926/27	353 274	1949/50	526 613	1975/76	249 446
1927/28	345 303	1950/51	583 487	1976/77	246 192
1928/29	363 743	1951/52	566 393	1977/78	188 806
1929/30	347 115	1952/53	613 374	1978/79	153 005
1930/31	327 681	1953/54	679 437	1979/80	114 875
1931/32	263 548	1954/55	675 918	1980/81	63 122
1932/33	259 860	1955/56	750 058	1981/82	52 730
1933/34	234 296	1956/57	790 030	1983	83 461
1934/35	258 893	1957/58	846 526	1984	139 744
1935/36	257 289	1958/59	905 397	1985	151 214
1936/37	310 308	1959/60	684 800	1986	110 161
1937/38	391 159	1960/61	565 681	1987	82 487
1938/39	323 266	1961/62	596 502		

Source: Nigerian Coal Corporation.

Note: 1 long ton = 1.016 t.

and was completed in 1979. Production was expected to grow from a first-phase installed capacity of 624 000 t a⁻¹ to 1 Mt a⁻¹.

What happened was the exact opposite: the installation of the first phase marked the beginning of an incredible productivity slump at NCC. In the 1960s, productivity had been 0.6 t/person per shift (Table 2). In 1979, it was 0.09 t/person per shift. NCC abandoned the new and expensive machinery, after which productivity rose again. By 1986, it was 0.36 t/person per shift. NCC continued to be a drain on government, and, like all other public enterprises of its kind, it was placed on the list of enterprises to be commercialized.

This failure of NCC is one of the reasons for this study. There are a number of radical technical and managerial conditions that an enterprise of this kind must meet to achieve sustained productivity growth. The study should bring out the kinds of policy lessons that will be useful for similar firms in Nigeria and elsewhere.

In addition, because this 70-year-old industry is unique among the heavy industries in Nigeria, it gives us an opportunity to examine what happened over a relatively long historical period. The nexus of technology choice and productivity growth represents two sides of the same coin (Pack 1987), requiring adequate time-series data. It is left to be seen whether the age of a firm directly correlates with its technological capabilities or its ability to become a mature enterprise.

Table 2. Productivity of the Nigerian Coal Company (1960s–1986).

	Productivity (t/person per shift)	Remarks
1960s	0.60	Semimechanized longwalls with conveyor belts and single props were in use
1979	0.09	This is after the installation of the fully mechanized longwall system
1982	0.40	There has been a slight improvement, but productivity lags the 1960's values, when semimechanized longwalls were in use
1986	0.36	There has been a further decline

The research problem

There are many sides to the research problem — all with very important implications for public policy. However, the technological investments made in 1976–1979 will constitute our point of departure. We shall concentrate on the technological dimension of the investment process and define the problem as one of technology choice. To the extent that investment in new technology entails considerable foreign and local finance capital, the problem of technology choice becomes crucial. The issues involved in technology choice could be varied and complex. The decision to adopt an industrial product and process results from the combined effort of many actors and many decision centres. Some questions come readily to mind:

1. Under what terms was the foreign technology chosen?
2. What was the basis of this choice — a quest for the “most modern,” the “most sophisticated”? For instance, why was the KOPEX technology chosen over one from other firms or other countries? Was a fully mechanized longwall process really the most appropriate system for the geological conditions at the Enugu, Orukpa, and Okab mines?
3. What was the nature of the finance capital? Was it a tied loan that could compel an inappropriate choice of technology?

The offer of capital from foreign governments or international agencies is frequently tied to a few particular projects and is not available for other uses (Vernon 1977). The choice of such financing bears on the eventual configuration of the production technology, and the recipient country may well end up with an abnormally high capital–output ratio, in addition to the capacity underutilization associated with inefficient machinery and equipment. Some complaints made against major Nigerian heavy-industry projects relate to inappropriate choice of techniques; unusually high capital–output ratios, as with the iron and steel plants (see Oyeyinka 1988); and shoddiness in the arrangements for finance capital, which lead to high cost and time overruns. All of these invariably result in low-productivity operations.

Following from the above, the study proposes to trace NCC's operations over a long period to bring out the factors responsible for the observed behaviour and those responsible for the productivity performance. There are several approaches we could take. According to Pack (1987, p. 41), we can

emphasize one major obstacle (absence of “modernity”) in an occasionally tautological way, and the implicit hypotheses are largely incapable of being tested or quantified. A more fruitful approach involves the identification of the most likely major sources of deviation from best-practice productivity and the quantification of each of them where possible.

The “fruitful” approach suggested by Pack (1987) is more holistic and considers (1) factors at the national and industry levels; (2) technomanagerial capability at the firm level; and (3) productivity of industrial workers at the task level. For this study, the following six hypotheses were proposed:

- Hypothesis 1 — NCC’s management made little or no effort to build plant-level technological capacity to cope with the idiosyncratic nature of the plant.
- Hypothesis 2 — NCC lacked the basic knowledge and experience to operate the new manufacturing process.
- Hypothesis 3 — Both KOPEX and NCC management paid little attention to the organization of human resources during the important start-up phase.
- Hypothesis 4 — The poor performance of the new equipment is directly traceable to the initial decisions NCC made in the preinvestment phase.
- Hypothesis 5 — External infrastructural and economic constraints played a big part in NCC’s poor performance.
- Hypothesis 6 — NCC’s choice of frontier technology was not appropriate for the mine’s environment.

The research objectives

The research objectives were to examine the technical-change process in the Nigerian coal industry for the past 30 years and also look at the way NCC made a technological choice for a major investment project. The research actually focused more on the latter objective because institutional memory was insufficient for generating credible bases for past behaviour. The project was designed to capture the industrial and enterprise behaviour of NCC during a long period to allow policy-makers to make informed policy prescriptions for the expected future under rapidly changing conditions. To this end, the following questions were asked:

1. What specific technical and economic regimes led to the observed performance of NCC and the industry at different times?
2. To what extent did the industry adopt technical advances over time and what was the impact on productivity growth?
3. Human resources are crucial to the profitable operation of old and new plants. What has been NCC’s human resources policy, quantitatively and qualitatively? What has the trend been in its labour productivity?
4. What informed the huge technology investment of 1976–1979? Was it plant obsolescence, simply a drive to “modernity,” or a serious effort to achieve greater production capacity and higher efficiency? Above all, why and how did the project fail?

As well, I interviewed the users of coal and coal products for ideas that could be incorporated in policies for long-term planning and marketing of NCC’s products.

Scope of study

The study covered the following aspects:

- NCC's production records from 1916 to 1987 — This time scale was meant to encompass production records from long before the Nigerian civil war (caused a major disruption), the "boon years," the "lean years," and the period of the structural adjustment program. These milestones might help to explain the conditioning influence of NCC's environment.
- Specific technoeconomic indicators, such as productivity measures of capacity utilization, capital use, plant-use efficiency, sales, and turnovers — These indicators would chart NCC's evolutionary trajectory. Although such indicators have limitations, they can throw some light on NCC's performance.
- NCC's technical and managerial staff — Staff were evaluated to see whether they were capable of operating the mines and effecting technical change.
- NCC's stock of plant and machinery, especially the KOPEX-installed system — These were examined to see how much artefactual and other constraints affected NCC's technical progress.
- NCC's modernization efforts — NCC's efforts were reviewed to see why the modernization plan failed. The preinvestment (preparation), investment (construction), and postinvestment (production) phases were examined to extract any evident learning that could be applied in future policy-making.
- Market-mediated factors — Although firm-level factors like techno-managerial capacity and equipment efficiency may help explain plant performance, it is necessary to ascertain the importance of the additional constraints and inducements that conditioned the growth of the industry.

Methodology

The conceptual framework adopted for this study was flexible enough to capture the range of activities undertaken in NCC's technical-investment process before, during, and after the installation of its operating plants and to compare these with the activities in the typical technical-investment process, which has three phases: the preinvestment phase, the investment phase, and the postinvestment phase (Table 3).

Table 3. Activities in the typical technical-investment process.

Phase	Activities
Preinvestment: preparation	Identification of the project's technical and economic requirements
Investment: construction	Basic engineering studies; design engineering; equipment specification, procurement, and testing; supplier and capital goods selection; civil engineering works and equipment erection, commissioning, and start-up
Postinvestment: production	Plant debugging, modifications, redesign, and adaptations; process and product engineering; and so on

I collected all available technical, economic, and financial data for each phase and analyzed these to determine the project costs, financial clauses, and choice of technique, raw materials, and energy and how well these latter variables were suited to the technoeconomic environment.

It is inevitable that the choices made during the first two phases would bear heavily on the postinvestment phase. Analysis of operational data would provide useful evidence of the way the project was conceived and implemented. Data were collected to reveal maintenance capability and the quality of machinery and equipment.

In the postinvestment phase, a process plant requires certain basic technological, material, and managerial inputs to function well (see Oyeyinka 1988 for a full elaboration). These include basic feedstock (e.g., raw materials, energy, utilities); technical and organizational capacities, (e.g., operational, maintenance, and innovation capabilities); and replacements (e.g., spare parts and consumables).

The overall technical capability of an enterprise is a function of its ability to simultaneously provide all these components. To capture firm-level performance, I looked at the following parameters:

- capacity utilization, which represents the ratio of the level of output actually produced (Q_a) to the capacity output of the plant (Q_p);
- production rate, which is tonnage/hour;
- capital use or plant availability (%), which is the number of operating hours divided by the number of available hours within the period; this indicator measures plant efficiency and, indirectly, maintenance capability; and
- labour productivity, which is tonnes/person per shift.

Data collection

Nonstructured questionnaires were used to collect from NCC primary data on its technical performance. Visits were made to the mines to see the working environment. Economic and financial data were collected from both the firm and the Mines, Power and Steel Ministry. Secondary enterprise data and policy papers were obtained from other research institutes: the Nigerian Institute of Social and Economic Research; the National Institute for Policy and Strategic Studies; and the Nigerian Export Promotion Council (which collects data on export statistics).

To get a view of the two sides of the equation, the demand and supply sides, I used a set of questionnaires to randomly sample the users and potential users of coal and coal products: NEPA, NRC, and the steel plants. I was unable to visit the various NEPA installations and had to seek information from the headquarters.

Technical change in the coal industry

Coal mining started essentially as a manual process and remained so for a very long time. However, extraction of large underground reserves was limited by the presence of water. The first major technological innovation was the introduction in 1710 of Newcomen's steam atmospheric engine, which eased the water problem and made previously vast and inaccessible reserves available for industrial use.

This was the age of the industrial revolution, and coal was at centre stage. Indeed, in the first two technological revolutions, spanning the period between the 1770s and 1890s, the coal industry was a key sector (Freeman and Perez 1988). Coal, in a cluster with the pig iron (the iron and steel sector), cotton, and railway industries,

fostered dramatic new growth in textiles, chemicals, machinery, water power, iron castings, machine tools, and shipping. Coal, thus, qualifies as what Freeman and Perez referred to as a “key factor” input in the creation of a new technoeconomic paradigm.

Freeman and Perez (1988) clearly defined the “key factor” in a paradigmatic change and the conditions that must be fulfilled. To properly conceptualize the pervasive effects of the technoeconomic change the coal industry introduced at the time, one must view these effects as much wider, as Freeman and Perez emphasized, than just a “cluster” of innovations; that is, the paradigm change is

a combination of interrelated product and process, technical, organizational and managerial innovations, embodying a quantum jump in potential productivity for all or most of the economy and opening up an unusually wide range of investment and profit opportunities. Such a paradigm change implies a unique new combination of decisive technical and economic advantages.

Newcomen’s steam atmospheric engine was further refined by Watt and others, and, in time, coal production soared, especially in underground mines. The mechanization of coal mining initially covered mine ventilation, water drainage, and transport of coal to the surface.

Technical change was then directed toward increasing the productivity of the mines. The manual methods of supporting the roof and extracting, loading, transporting, and grading were replaced with mechanical methods.

Nevertheless, innovation ever since has remained incremental and focused on these key aspects of coal mining, and these have been quite certainly responsible for the observed productivity change in the industry.

Coal mines are heterogeneous because of the differences in their natural bedding conditions, such as the thickness and slope of coal seams. It follows that mining machinery has to be designed to accommodate the idiosyncratic conditions of the mines.

Hence, the incremental innovations were meant not only to foster productivity growth but also to accommodate a wide range of geological conditions. For instance, shearers and self-advancing roof supports were initially developed for flat and moderately thick seams, but much later, functionally different equipment, albeit with the same name, had to be developed for steep bedding and thin seams. In sum, although bedding conditions may require differentiated techniques, mining technologies vary little. For example, techniques for underground mining can be divided broadly into longwall and shortwall; each is suited for a particular range of geological conditions.

Not all countries with substantial coal reserves adopted the different innovations at the same time, but most investments in mechanization ended in the 1960s. By this time, “large scale application of machines to coal face operations . . . with fully mechanized longwall mining ‘system’” (Clark 1987) was in place. This new system, amenable to remote-control monitoring through microelectronics, sharply increased productivity, which rose from around 1.2 t/person per shift in the mid-1950s to 2.2 t/person per shift by 1970, almost 100%.

In other areas, information technology improved the management of collieries most dramatically, leading to great savings in labour costs. Modern technologies, such as those using X-rays, are improving the quality control in coal properties; new conveyor and elevator systems have replaced manual methods of transportation; and new ventilation techniques have been introduced.

Table 4 lists the major innovations in the industry since World War II.

Table 4. Major post-war innovations in coal mining.

Innovation	Description	Diffusion
Armoured face conveyor	Basic face equipment that mechanized face activities	Practically 100%
Hydraulic props and cantilever bars	Early roof-support system that allowed the introduction of narrow-web power loaders	Started to be introduced widely, but overtaken by newer technology
Narrow-web power loaders	Machines operating on a "Prop-free front system" that resulted in a large reduction in personnel	Incorporated in newer technology
Powered roof supports	Self-advancing jacks that reduced the amount and degree of manual labour involved in advancing a face	Practically 100% incorporated in newer technology
Shearer-loader (Anderton)	Basic machinery of all mechanized systems	Practically 100% incorporated in newer technology
Fully mechanized advancing face	A shearer-loader system but with improved safety	Practically 100% incorporated in newer technology
Prop-free front longwall mining system	A system that allows the use of power supports and application of high-horse-power cutting machines to traditional coal-face layouts	
X-ray measurement of ash content	A rapid method of determining ash content that allows automatic blending	Very widely used
Carbonization and combustion in fluidized beds		Technique still awaiting perfection, although many experimental applications in operation
Coal gasification	Starting with the Lurgi process, several modified and novel processes known	Limited application only, although several pilot plants in operation (e.g., Westfield in Fife)
High-temperature combustor for MHD power generation	Equipment that burns coal at >2000°C (part of MHD program)	Pilot scale demonstrated; depends on fate of MHD
Coal liquidation	Old (Fisher-Tropp, etc.) processes	Still in use but not economic enough, not generally applied (apart from South Africa); various approaches still in R&D phase
Coal desulfurization	Removes sulfur from emissions, but various appliances expensive	Appliances not widely used yet; better methods for preventing pollution being sought

Table 4 (concluded).

Innovation	Description	Diffusion
Better environmental control	Methods to monitor and control emissions of grit, dust, tar vapour and other gaseous constituents (including SO ₂)	Appliances not widely used yet; better methods for preventing pollution being sought
Remotely operated longwall face	Advanced system for remotely operated mining operations	Very limited introduction, but overtaken by electronic developments
Microelectronic applications	ATM and HD mechanization that use microprocessors and computers; the basis of NCB's fundamental schemes for further development	In course of wide introduction; 7 ATM and 35 HD schemes in operation in 1983
Coal for metallurgical coke manufacture	Aims at upgrading lower quality (noncoking) coal by various methods such as preheating, adding inert matter, controlled blending	Commercially applied, but not widely

Notes: ATM, advanced technomining; HD, heavy-duty.

The Nigerian coal industry: Historical background

The Nigerian coal industry was born in 1909, when coal was first discovered along the Udi Escarpment in the present Anambra State, and mining commenced in 1916. The NCC, established in 1950, handles all aspects of the Nigerian coal industry.

The extensive coal deposits in Nigeria vary in grade and structure from area to area. The reserves, shown in Table 5, are not equally distributed but have a total potential of almost 3 Gt. This supply is expected to last for well more than 100 years.

Table 5. Nigerian coal reserves by location.

State	Location	Indicated <i>in situ</i> reserves (Mt)	Inferred reserves (Mt)	Overall reserves (Mt)
Anambra	Enugu	54	200	254
	Ezinmo	56	60	116
	Inyi	20	Unknown	20
Benue	Onikpa	57	75	132
	Okaba	73	250	323
	Ogboyoga	107	320	427
Delta	Asaba	250	Unknown	250
Plateau	Lafia-Obi	22	Unknown	22
Other states			1160	1160
Total		639	2065	2704

Source: Nigerian Coal Corporation.

Subbituminous coal is found mainly in the north–south belt, stretching from the Afikpo and Okigwe area, through Enugu and Ezimo, to Orupa, Oturkpo, Okaba, Dekina, and Idah and from Afuji in Delta State northward, to Koton Karifi in Kwara State.

Lignite deposits are found in the southern belt, stretching from Umuahia to Ihioma and across to Nnewi and Onitsha. The belt extends to Asaba, Oguwashi–Ukwu, and Odiasa and finally ends near Okitipupa. The lignite deposits are found close to the surface, so mining is easier and cheaper than for the deeper coals.

Coking coals, found in the Lafia–Obi coal field, are high in sulfur and have to be processed before use.

Before independence in 1960, coal was the major energy resource. There was not much of an alternative, anyway, and this caused a steady increase in coal production, as shown in Table 1. Between 1916 and 1928/29, there was steady and consistent growth in production rates, from about 2 500 t to almost 370 000 t. NRC and the electricity suppliers in the country were the major consumers of coal in this period. The construction of the Port Harcourt – Enugu rail line was an important catalyst for the accelerated growth of coal production.

During the Great Depression (1929–1939), however, production fell to a low of about 238 000 t (1933/34) from the previous peak of almost 370 000 t (1928/29). This represents a fall in annual production of 132 000 t. Production improved tremendously during World War II, reaching 514 000 t in 1944/45.

The peak production times in the history of the Nigerian coal industry was in the late-1950s, with an average output of more than 806 000 t. Until independence in 1960, coal was a major component of the commercial energy needs of the country. The exit of the colonial masters, however, saw a very sharp fall in production, from almost 920 000 t in 1958/59 to about 575 000 t in 1960/61.

Shortly after, though, production picked up again, steadily growing until the civil war cut off production completely for 3 years (1967–1970). The mines destroyed during the war were repaired, and production resumed in 1970/71. Output rose to a maximum of about 328 000 t in 1971/72, by which time the extraction of oil and gas in Nigeria had begun in earnest. The oil boom led to an almost total neglect of the coal industry: NCC's major customers, such as NRC, started using the less bulky and much more efficient diesel oil. In addition, most of the NEPA power-generating stations abandoned coal in favour of natural gas, oil, or hydroenergy. This was not peculiar to Nigeria: the world also switched to nonsolid fuels. Other West African countries that formerly imported Nigerian coal for their railways also changed to diesel. Consequently, the shrinking market led to the gradual decline in coal production in Nigeria. However, there was still a potentially high demand for coal because most ECOWAS member states were not oil producers.

Enugu coal field

Mining in the Enugu coal field started in 1917 and is supported by the following infrastructures:

- modern, well-ventilated adits (tunnels), with belt and rail conveyors;
- a modern coal preparation and beneficiation plant, capable of handling 250 t h⁻¹ and linked by rail to the NRC rail network;
- aerial ropeway haulage connecting the two existing mines, Onyeama and Okpara, to the preparation and beneficiation plant; and

- a good road network, capable of taking heavy coal transporters, that connects Enugu and Oturkpo.

The Enugu coal field has proven reserves of 54 Mt, and each of the two mines can rapidly be mechanized to a production capacity of more than 1 Mt a⁻¹.

Okaba coal field

The Okaba coal field, where mining started in 1968, has opencast, or surface, mining. Okaba has the following advantages:

- Opencast mining is a cheaper and quicker method of mining coal than underground methods. Okaba has a proven reserve of 73 Mt, of which 19 Mt can be mined by opencast mining.
- Okaba lies close to the proposed road and rail line from Ajaokuta to Oturkpo.

Ogboyoga coal field

The Ogboyoga coal field is approximately 20 km northwest of Okaba. Its advantages lie in its proximity to Ajaokuta and its large proven reserve of 107 Mt. Because of its topography, opencast mining is limited to about 18 Mt.

Lafia–Obi coal field

The Lafia–Obi coal field has the only Nigerian coal with coking properties, but it is high in ash (31–45%) and sulfur (1 to >6%). It has been extensively explored (137 boreholes); 36 seams have been identified, but only 2 (No. 12 and No. 13) are feasible for mining. Consequently, out of 22 Mt of proven reserves, only 15 Mt is workable and only 6.42 Mt is recoverable.

The area is geologically disturbed and has many normal and reverse faults, with throws of 8–125 m. The seams dip from 1 in 14 to 1 in 2, and nowhere are they level. In-seam exploration was required to see if it was feasible to mine the coal field. This exploration was to take about 2 years, at a cost of about 16 million NGN.

Experts expect that mining may well be difficult. Because of the high sulfur content, the mine water is likely acidic and, therefore, corrosive. Based on these constraints, the capacity of the Lafia–Obi coal field may be limited to 450 000 t a⁻¹ of run-of-mine (ROM) product. Because of the poor quality of the ROM product, the coal will need cleaning. The yield of the cleaned product will be very low (about 20%), amounting to about 90 000 t a⁻¹. This is equivalent to about 7% of Ajaokuta's initial demand. Consequently, the Lafia–Obi coal field would provide only a fraction of the blend of coals needed for Ajaokuta if this field is ever mined.

Description of production techniques

NCC once had three drift mines near the town of Enugu. These were the Okpara, Onyeama, and Ribadu mines. However, Ribadu Mine was closed, so only the first two were pertinent to this research. Okpara Mine, the largest of the two, is about 10 km south of Enugu. The Okpara Mine includes the Okpara New Mine, the Okpara East Mine, and the Okpara West Mine. Okpara East, the largest of the three, is northeast of the Olowba River at the head of Okpara Valley. The available mining area is about 9.2 m² and lies to the west of the Hayes Fault. The Onyeama Mine, on the other hand, has an area of 10 m², has an estimated 20 million t of coal, and lies 12 m west of the Asata Fault.

Research findings

From records of operations and maintenance, I tried to document details of NCC's inadequacies and trace these inadequacies to the decisions made in the earlier phases of the project. The project can best be described as a series of failures resulting from the constraints that attended it right from start.

Machinery and equipment failures

Equipment failure was pervasive and frequent. The following examples taken from operational records illustrate what happened almost daily at the mines:

1. The conveyor chains, made of high-carbon steel (a brittle material), broke down incessantly.
2. The shearer-loader combines were not fitted with a plow, resulting in inefficient loading on the chain conveyor. It is worth noting that the plows were actually paid for and were in stock at the time.
3. The shearer drums were in fixed positions and, therefore, could not be altered to the shifting configurations of the roof and the floor of the seam.
4. Overall, there was so much system mismatch that it led to an unusually high rate of mechanical wear and tear.

Geological and infrastructural weaknesses

The geological problems were very severe. Very little was known about the characteristics and nature of the mine waters, the constraints the fault patterns would have on the longwall layout, or the roof and floor pressures. One consequence was excessive weight on the powered roof supports along the face line. The undulating seam floor made it impossible to establish a definite gathering ground for mine water. This posed severe problems to longwall operations and also created excessively acidic mine waters. Within 2 months of operation, the Polish pumps began to break down as a result of the excess acid in the water. The pumps were made of cast iron and not easily repaired.

The operations also suffered considerably from inadequate transportation. Railway wagons needed to evacuate the coal were in very short supply, and the resulting dumping of coal created blockages in the coal bunkers. Nominal production targets could not be met, and what was produced could not find its way to the consumer. Power supply was inadequate, and outages were more the rule than the exception. The estimated production loss resulting from power outages alone was about 21 000 t in 215 h. Power outages also created severe flooding problems because the pumps were inoperative most of the time.

Human resources deficiency

As already pointed out, different stages of technology acquisition demand different levels of technical competence. Although a broad engineering and economic knowledge base may well suffice in the preinvestment phase, specific competence is needed as the project progresses to the investment phase. For instance, the formation of a commissioning team facilitates the rapid transfer of knowledge at the start-up stage. This is the stage at which all design imperfections become obvious. This is the stage at which engineers and management get to understand the special character of the technical system.

There is no evidence that NCC even conceived of a commissioning team, and there was no awareness of the complexity of the human resources requirements for

what was, in fact, a new system. Even the Polish engineers at the site were of very limited use to operation and maintenance. It is unclear whether KOPEX did in fact deploy its most competent engineers. What may well have undermined the effort of the KOPEX engineers, if, indeed, they had the requisite capabilities, was the extremely poor supporting infrastructure.

Analysis of research findings

The general findings

This section will focus on the period 1976–1982, the period during which the major investment was made. However, to provide a context for analysis, the physical output preceding the period is given below:

Period	Average output (t a ⁻¹)
1960/61–1966/67	645 000
1967/68–1969/70	Nil (civil war)
1970/71–1975/76	281 000

At the time of the first phase of the installation of the Polish equipment, a nominal production target of 3.7 Mt was set for 1976/77–1981/82. For the 6 year period, only 831 830 t was produced, representing a capacity utilization of 22.5% (see productivity figures in Table 2). The dismal physical outputs were reflected in the financial performance of the firm. NCC's liquidity problem was so severe that regular overdraft spending was needed to cover operating costs.

Human resources

Table 6 lists the elements contributing to NCC's failure, along with the consequences of NCC's actions and inaction. The first element on that list is human-resources development. At the time of the technical change, junior staff made up 87.5% of total human resources at NCC; professionals and management staff, 12.5%.

Today, direct-production staff are mostly junior-level and illiterate members. The few professional staff (who mostly supervise) are not directly involved in production; most are in the head office. Although NCC has the negative characteristics of an old establishment, that is, it has an aged work force, the firm completely lacks the positive characteristics of acquired technological competence. Our findings show that the senior staff of the firm are mostly illiterate mine hands, who have no alternative means of livelihood.

Partly as a result of the mining techniques but more as a result of overstaffing at the junior-staff level, productivity growth has in the main been negative. Two factors were readily identifiable:

- The firm, because of its poor financial state, has been unable to pay retirement benefits to those who should have been discharged long ago.
- The miners' union is against the mass layoff of workers.

The older workers, who are in the majority, are resistant to new techniques or are unable to adjust to new ways of doing things. Because process, or organizational productivity, depends very much on the quality of skills directly available for production, this component of the elements of investment capability scores very low as an input into NCC's organizational productivity.

Table 6. Elements of investment and production capability versus NCC's action (or inaction) in the acquisition of KOPEX technology.

Element of investment capability and purpose	NCC'S action (or inaction)	Consequences
<i>Human-resources development:</i> to prepare for start-up	No special training was undertaken; there was no proactive strategy for start-up personnel; aged and illiterate staff were in the majority	No start-up lessons were learned; start-up was chaotic
<i>Preinvestment feasibility studies:</i> to identify projects and potential feasibility of alternative design concepts	No prefeasibility study was undertaken	Physicochemical properties of mine were unknown
<i>Detailed studies:</i> to make tentative choices among design alternatives	No detailed studies were undertaken	NCC was limited to only one choice
<i>Basic engineering:</i> to supply core technology in terms of process flows, material and energy balances, specifications of principal equipment, and plant layout	Basic engineering function was surrendered to supplier of the technology	All flow A and flow B technologies without any technical inputs from NCC came from KOPEX, whose knowledge of the physical environment was very limited
<i>Detailed engineering:</i> to supply peripheral technology in terms of complete specifications for all physical capital, architectural and engineering plans, construction, equipment, and installation	Detailed engineering function was surrendered to supplier of the technology	
<i>Procurement:</i> to choose, coordinate, and supervise hardware suppliers and construction contractors	No search was conducted for alternative supplies: no efforts were made to master procurement skills	Project cost too much; inappropriate machinery was selected;
<i>Embodiment in physical capital:</i> to accomplish site preparation, construction, plant erection, and manufacture of machinery and equipment	Approach was passive	
<i>Start-up and commissioning:</i> to attain predetermined norms	No proactive strategy was formulated for start-up	Seed of future undercapacity and declining productivity was sown here
<i>Production management:</i> to oversee operation of established facilities	NCC flaws were mainly here	Human resources deficiency and poor infrastructure revealed weak production-management skills

Table 6 (concluded).

Element of production capability and purpose	NCC's action (or inaction)	Consequences
<p><i>Production engineering:</i> to provide information required to optimize operation of established facilities, including</p> <ul style="list-style-type: none"> • raw material control • production scheduling • quality control • maintenance and troubleshooting to overcome problems encountered in operations • adaptations of processes and products to respond to changing circumstances and to increase productivity 	NCC relied very much on KOPEX engineers and experience. KOPEX engineers were unable to cope with both maintenance and more serious technical problems	Spare parts were unavailable; complete system collapsed; finally, government cancelled investment program and KOPEX was sent home
<p><i>Export development:</i> to find and develop uses for possible output and to channel outputs to market</p>	NCC's effort is unknown	Combination of weak internal capabilities and inadequate export facilities prevented NCC from taking advantage of export potentials

With the acquisition of new technology, a firm must provide some training in key areas of design and operation, both locally and in the home base of the technology supplier. There was no attempt to systematically train the staff: it seemed that NCC relied solely on "training by operating." With the skill level that NCC is saddled with, it is not surprising that the acquisition process turned out to be a costly experiment.

It is important to mention that the firm had no specific human resources strategy for start-up. A strategy is necessary to reap the benefits of start-up calls for multidisciplinary engineering and technical pools of skills for scheduling, operation, and maintenance. The assignment of start-up teams may well go beyond the routine of ensuring a smooth takeoff. Because they have the knowledge, members of a start-up team tend to assume leadership of future technological investment necessary to make adjustments. Troubleshooting tends to imbue the engineer with the confidence needed to face future challenges. Design formulae, procedures and routines, and theoretically determined specifications may well undergo radical alterations during commissioning and start-up. Active participation in start-up operations contributes to evolutionary technological mastery. Therefore, the neglect of this critical subphase may well have contributed to the observed failure of NCC. Because the firm had no deliberate strategies to capture the experience needed for start-up, perhaps it did not plan to acquire that kind of technical knowledge. The firm may also have been unaware of such a need. If the firm was aware, the human resources structure of NCC leads one to the conclusion that the firm was without the capacity to plan for such an endeavour.

Prefeasibility and detailed studies

A feasibility study and a detailed study were not done before money was committed to the KOPEX project. As indicated in Table 6, the feasibility of the project would have been ascertained by consideration of alternative design concepts. A feasibility study would have included a geological study to determine the conditions of the mine water. As it turned out, nothing was known about it. Detailed study would have revealed the tectonic character and dimensions of the mines. For instance, because these steps were not taken, the longwall supports (props and shields) that KOPEX supplied were a mismatch for the NCC mines. These systems are more suitable for deeper mines, such as found in Britain, West Germany, and Poland. The system failed completely in a situation where the overlying roof was about 50–200 m, a characteristic of near-surface mines. The structural configuration of the Nigerian mines created rock pressure, a phenomenon that is absent in Poland, where the equipment originated. If detailed studies had been done, stronger longwall supports to counterpoise the heavy loads in the overlying rocks would have been designed and installed. As part of the detailed study, an economic study would have been undertaken.

In the end, the total capital investment came to \$55 million USD. Based on the rated capacity of the mines, the cost per tonne installed was about 90 USD, compared with about 20–40 USD t⁻¹ in most industrialized countries, including South Africa. This cost excluded training. Detailed studies would have given NCC the information it needed to decide whether to accept this kind of cost and, indeed, whether it was wise to go ahead with the investment. As it turned out, the NCC invested in a costly experiment; worse still, the experiment failed.

Procurement and start-up

Only a brief comment is called for here because some aspects of start-up were discussed in “Human Resources.” Following the pattern established right from the conception of this project, no cost–benefit analysis was undertaken and no competitive tenders were invited. Technical and financial alternatives were not considered. The activities ordinarily engaged in by firms during the period of procurement — that is, choosing, coordinating, and supervising suppliers — became the sole prerogative of KOPEX, and it decided what it wished to supply to the NCC.

During commissioning, there were about 100 Polish engineers on site, but I was unable to obtain details about their qualifications and experience. According to sources at NCC, however, “these chaps were just as confused as we were, or even worse, they could hardly deal with any of the technical problems we had.”

Productivity dropped drastically during start-up, which is abnormal. Any serious equipment manufacturer would have ensured that an optimal level was reached during this phase. If a performance-guarantee test shows a failure of the equipment to conform to the expected norms, a manufacturer risks penalty payments and jeopardizes future contracts with the client and with other clients, as well. For these reasons, it is ordinarily expected that productivity will be at a very high level during this phase of the project. It may be argued that structural imbalances and design inadequacies made the job of the Polish engineers more difficult. But this could not possibly explain all the problems. What calls into question the competence of these “experts” was their inability to make adaptations to solve mundane engineering problems. NCC’s maintenance records show how small technical problems tended to overwhelm the engineers. Throughout the performance-guarantee period, the system never attained anything near its nominal output, and because NCC had never considered any penalty clauses, KOPEX got away with the nonperformance of its obligations.

Production capability

The elements of production capability are listed in Table 6. More often than not, an engineer will interpret the transfer of production capability as the transfer of technological capability *per se*. Indeed, technology transfer through a turnkey arrangement is incapable of providing anything but the elements of production capability. Extra effort is needed, and, in most instances, separate contractual agreements will be required for the acquisition of technological capability because turnkey projects deliver “packaged” facilities.

The start-up of NCC clearly signalled the future production trajectory of the firm. Preparation for commissioning was inadequate because preparation for production management and engineering was inadequate. Not much information was available on the details of quality control and production scheduling: however, maintenance records show that very little was achieved. NCC failed woefully at maintenance and elementary innovations for the following reasons:

- NCC lacked a competent maintenance crew. NCC’s technical pool was clearly deficient in quality, not in quantity.
- Compulsive repairs took the place of planned and corrective maintenance (the objective of planned maintenance is to remove technical flash points before trouble occurs).
- The investment package made no allotment for the pervasive technical and structural problems that emerged at commissioning.
- There was a dearth of local spare parts suppliers, and this adversely affected maintenance and procurement.

The central problem underlying NCC’s failure was the fact that the investment decisions were completely surrendered to the supplier. If NCC had been in charge, it could have specified the semimechanized or the fully mechanized longwall technique; it could have brought the characteristics and idiosyncrasies of the mines to the notice of the suppliers; and it would have been in a better position to negotiate better prices and determine which combinations of equipment would have better served the firm.

The market and the views of coal users

NCC also had to contend with demand-side problems:

- *Factor 1* — The major coal users “dieselized” their operations.
- *Factor 2* — The overall industrial environment forced major users to cut back on production and, thereby, reduce their consumption of coal.

For almost two decades, NCC has had three major customers: NRC; NIGERCEM, Nkalagu; and NEPA. Table 7 reveals that demand picked up for a few years after the end of the civil war (1970), but then there was a gradual decline until the mid-1980s. Indeed, for NRC and NEPA, coal consumption became quite negligible. NRC’s demand pattern reflects factor 1. For NEPA, represented by Oji River Power Plant, factor 2 comes into play. At this thermal power plant (the main coal user of the NEPA installations), only one of four furnaces is operational, and even this does not operate at optimal capacity. NIGERCEM, Nkalagu, has similar problems with capacity under-utilization. The combined coal demand in the domestic and export markets does not amount to much. This certainly raises a question about the modernization project, which increased the nominal supply capacity of the mines to several times the domestic demand. NCC officials contend there was a significantly higher export potential, but this claim is hardly borne out by the facts. The export figures show an

Table 7. Coal sales (1970–1988).

Year	Sales (t)					
	NIGERCEM	NRC	NEPA	Domestic	Export	Total
1970/71	—	22 470	1 830	2 174	—	26 474
1971/72	59 201	90 915	17 252	7 785	4 300	179 453
1972/73	120 617	128 557	13 403	8 118	51 649	322 344
1973/74	148 730	74 528	54 142	8 449	16 000	301 849
1974/75	146 334	47 309	52 062	8 994	18 800	273 499
1975/76	140 211	64 101	56 261	11 153	24 599	296 325
1976/77	115 121	69 109	63 401	10 480	6 101	264 212
1977/78	113 587	36 225	63 528	13 021	13 884	240 245
1978/79	126 495	3 933	43 190	12 353	4 500	190 471
1980	94 413	1 783	12 117	6 370	—	114 683
1981	67 385	3 464	13 743	4 577	—	89 169
1982	n.a.	2 484	10 316	6 485	—	19 285
1983	32 807	3 086	9 809	8 459	—	54 161
1984	51 452	1 857	5 349	3 871	11 080	73 609
1985	86 110	1 391	5 040	4 159	5 000	101 700
1986	74 988	1 565	2 648	4 673	39 552	123 426
1987	90 301	757	2 311	4 608	—	97 977
1988	73 996	296	1 298	3 625	—	79 215
1989	73 800	150	659	3 875	—	78 484

erratic demand pattern. If, indeed, this demand had existed all along, the firm would have had enough reason to push for higher export, as one of its main constraints was shortage of foreign exchange.

However, there was no certainty that with the high capital–output ratio (NCC's capital investment was extremely high), the firm's product would have been competitive on the world market. It is also doubtful that NCC would have had the facilities to exploit that market. This is all conjecture, of course, but there is an even more fundamental misconception pertaining to the potential demand from the domestic iron and steel sector. Enugu coal has a noncoking character and is mainly suitable for steam raising, as in thermal power plants. The use of Enugu coal in steel production would be limited: the coal would have to be blended with coals of superior coking quality. The demand for coal in Ajaokuta is potentially high, but NCC is a long way from being able to meet this demand.

From discussions with domestic users, it appears that the future of coal may depend on the external market. Far from switching to coal, cement companies, such as West African Portland Cement Company have connected their facilities to the major domestic gas line. This trend is likely to be followed by other users. The major attraction of gas is that it is a clean form of energy. In addition, transporting coal far from its point of production adds to the overall cost of the product. These are the major concerns of the potential domestic consumers of coal.

Conclusions

The NCC technical-change effort was hastily conceived and badly executed. The firm and its supervising government agencies did not formulate explicit strategies to acquire, assimilate, and adapt technology. Increased productivity seemed to be the major reason for the acquisition; the acquisition of technological capability did not

seem to be important. The practical difficulties inherent to technology were paid scant attention, and the entire transfer process was jeopardized.

NCC thought of the transfer process as being simply a matter of transporting a piece of hardware from Poland to Nigeria. But Nigeria ended up with a white elephant.

The firm did not conduct an international technology search before making a choice. It did not carry out any prefeasibility activities or detailed studies. Consequently, it failed to consider physicostructural limitations, which later created bottlenecks in the operation. There was no systematic search for alternative suppliers. No competitive tenders were requested. There was, therefore, no basis for negotiating either the technology package or the price. In the end, NCC ended up with a system that was technically unsuitable and inappropriate for the Nigerian environment, and it cost three times the world market price.

Despite its age (NCC has been in operation since 1916), the firm has not accumulated any significant investment and production capabilities. This turned out to be a great hindrance to technical change, embarked on in 1976–1979, and to the firm's ability to mature in the long run.

Technology management and policy

Two distinct themes, encapsulating several issues, emerged from this case study:

- the macroeconomic policy and the physical environment; and
- the management of technical change at the firm-level.

First, technological investment and attendant activities shift to the firm level the moment a supplier is selected. Second, the role played by supervisory agencies, critical as they may be, sometimes results in irreversible decisions, and the role, therefore, is hardly ever linked to subsequent investment decisions.

This study did not explicitly set out to investigate the macroeconomic influences on the project. But my findings and those of previous studies on Nigerian industries illustrate the important effects of macroeconomic policy and the physical environment on a firm's development.

Macroeconomic environment

We find a conceptual parallel in the way physical infrastructure and knowledge infrastructure were defined by Justman and Teubal (1992). In their view, infrastructure goes beyond the provision of, for instance, power and communications equipment. Infrastructure includes coordination and information exchange at the early stages of the project and beyond, "to all situations where the economy must make far-reaching decisions concerning structural change." Therefore, in acquiring technology, it is important to consider the interdependence of investment and physical infrastructure, the coordination of resource accumulation and use, and the provision of enough trained engineers (knowledge infrastructure), and the necessary financial, export, and marketing infrastructures.

We know that a firm in the process of technology acquisition must do at least two important things:

- deploy either internal or external human resources (external capabilities could be within the nation or outside it); and
- exploit certain critical infrastructures, which may be internal or external to the firm, but preferably external if the firm is not to carry the burden of a huge, unproductive investment.

From this study and others, we know that the largest proportion of knowledge infrastructure (broad and specific) has been obtained outside the nation. In the case of NCC, the dependence on external human resources was total.

Although the role the physical infrastructure played in the failure of NCC was only tangentially related to persistent power outages, the shortage of railway wagons, and so on, other studies (Esubiyi 1992; Oyeyinka 1988; Amdi, this volume) revealed that these phenomena are not sporadic or isolated. They are a pervasive problem and pose a significant challenge to the operation of firms and the acquisition of technology. It is because the external environment was deficient that, for instance, Ajaokuta Steel Company had to build its own power plant and machine shops, Delta Steel had to acquire its own foundry, and cement firms in Nigeria had to develop internal fabrication facilities. For the same reason, a lack of critical inputs (spare parts and consumables) forced NEPA to completely shut down its system several times. Constraints of the physical environment can, therefore, be likened to what Hughes (1983) described as "reverse salient." *Reverse salient* has a military origin and customarily refers to a section of an advancing battle line that is continuous with other sections of the front but has fallen behind. *Reverse salient* refers to an extremely complex situation in which individuals, groups, material forces, and historical factors have idiosyncratic causal roles. It also refers to delays in the growth of systems and other enterprises as they evolve toward a goal. Hughes talked about organizational, financial, and physical reverse salients. Contemporary analogies of reverse salients are "drag," "emergent friction," "systemic inefficiency," "bottlenecks," and "technical imbalance."

Constraints posed by the following constitute forms of reverse salient in the evolution of Nigeria's technological system, as well as that of most developing countries:

- poor ancillarization (shortages and long lead times for the delivery of spare parts and consumables);
- lack of coordination of production, distribution, and services;
- inadequate provision of utilities, such as those for power, transportation, and communications; and
- lack of human resources with the broad and specific kinds of knowledge needed to define and execute projects.

Firm-level management of technology

Under the theme of firm-level management of technology, two main issues are intricately interwoven: NCC's trivialization of investment decisions in both the investment and the production phases; and its inadequate development and use of human resources.

Concurrent with technological activities are streams of technical and managerial decisions that are pivotal to the successful outcome of the project. Three sets of decisions are needed:

1. those concerning the terms of reference, the kinds of outputs expected from the investment, the types of information needed, etc.;
2. those concerning the experience and qualifications required of the firms, individuals, and organizations needed to carry out the specific tasks; and
3. those concerning the evaluation of reports submitted, their specifications, and fine-tuning on the basis of the findings.

Each decision — including, especially, the early decisions — sets a boundary around future actions. For instance, a decision to adopt a semimechanized technique excludes a later choice of a fully mechanized longwall technique for the life of the plant. Plant suppliers will manufacture facilities to order, which are invariably unadaptable to any other system and any other geological conditions. The ways technical systems acquire characteristics may well jeopardize future operations through suboptimal decision-making, as has been demonstrated by this project; no further elaboration is required.

The story of NCC's investment efforts teaches us how decisions should not be made:

1. When decisions about requirements for human resources with broad and specific knowledge are trivialized, a firm may end up with critical deficiencies in operational, maintenance, adaptive, design, and R&D capabilities.
2. When decisions about specific terms of contract agreement are trivialized, a firm may have problems with replacement capacity and technomanagerial capabilities.

The interconnection of human resources and the firm's ability to maximize learning cannot be overstated. Indeed, the kinds of technological knowledge and how well they are learned remain, as Hoffman and Girvan (1990) pointed out, the real challenge in managing technology at the firm level.

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CHAPTER 4

Technological Acquisition and Development in Zimbabwe: The Hwange Thermal Power Station

Benson Zwizwai

Introduction

The objective of this study was to examine the process of technology acquisition and development in Zimbabwe, at the Hwange Thermal Power Station. Also of interest were the implications for local industry and Zimbabwe. The study focused on the contractual arrangements at the power station, identifying the major participants in its construction and assessing the degree and extent of local technical capabilities in operating, maintaining, and repairing the power plant. To some extent the study also explored the constraints on capabilities within local industry and the development of such capabilities to supply the requirements of the station. To place the case study in a wider context, it examined the policies relating to technology in Zimbabwe, the international structure of the power-equipment industry, and the effects these are likely to have on efforts to build an indigenous technical capacity.

Study approach

The first step was to review the literature on technology acquisition. I then examined the relevant secondary information and constructed the historical background of the project through newspaper reports and annual reports of the former Electrical Supply Commission (ESC) relevant officials. I relied on official documents, such as the *Three-Year Transitional National Development Plan 1982/83–1984/85* (Government of Zimbabwe 1982) and the *First Five-Year National Development Plan* (Government of Zimbabwe 1986), and interviews with officials from various government departments for an overview of the technology policy of the country. Finally, I made three visits to the power station and carried out extensive, structured and unstructured interviews with management and several employees at various skill levels.

The study sought to answer the following questions:

1. To what extent did local industry participate in the construction of the power station?
2. What factors inhibited further local participation?
3. Are there any measures to increase such participation?
4. Did the Hwange project improve local technical capabilities in power-equipment production?
5. Does government have a clear policy on procurement of plants and machinery to develop local industry?
6. To what extent are local human resources being trained to reduce reliance on foreign expertise and to ensure effective technology acquisition?

The initial hypothesis was that the limited participation of local industry did not necessarily reflect a weak technological base in Zimbabwean industry. This hypothesis was based on the fact that Zimbabwean industry is relatively advanced compared with that in most countries in sub-Saharan Africa, particularly the metal working subsector, which forms the basis of a capital goods sector. Zimbabwe has an integrated iron and steel industry. Therefore, the limited participation of local industry to some extent reflects the lack of a procurement policy to promote local industry.

The situation at Hwange

In the late 1960s, the chairman of Wankie Colliery, Sir Keith Acutt, said in his annual report for the Anglo-American Corporation (AAC) that he was prepared to offer financial assistance to install a steam generating unit at Hwange. The chairman had predicted an electric power shortage "within a few years." The hydroelectric station at Kafue, in Zambia, was about to start. The same annual report showed that AAC's coal sales during that year had dropped by 10% to a low of 3 Mt. In addition, the chairman expected a further drop in coal sales to Zambia when the road lift to Livingstone ended and the Zambia Siankandobe Colliery came into production.

In August 1968, Sir Frederick Crawford, a director of AAC, made a strong plea for the construction of a thermal power plant at Hwange. He evoked both political and economic arguments and pointed out that Rhodesia needed "cheap power to continue to develop its primary and secondary industries." The establishment of the thermal plant "would be in keeping with the current trend for greater self-reliance in industry and mining, keeping us independent of external suppliers or pressures and would also be the mainspring for increased employment internally."

Like Sir Acutt, Sir Crawford could "foresee" a power shortage in the country by the 1970s. At that time the country's generating capacity, including half of Kariba's and all the thermal stations' production, totalled 690 MW. But Sir Crawford predicted that before the end of the 1970s, demand for electricity would exceed 1000 MW. He argued that the country electricity requirements (before the North Bank Station was built by Zambia) would call for more thermally produced power. If this was to be done cheaply, there was a strong case for centralizing generating capacity at the coal fields. However, no possibility for hydro schemes was considered.

The Minister of Transport and Power, Mr. Roger Hawkins, and ESC commissioned consultants to investigate the possibility of installing a large thermal power station at the Wankie coal fields. The consultants worked closely with AAC on the project. In 1972, the consultants recommended that a 1250 MW power station be constructed at the coal fields, and estimated that the cost of the power plant would be 240 million ZWD (in 1995, 8.51 Zimbabwe dollars [ZWD] = 1 United States dollar [USD]). Rhodesian industries, it was hoped, would receive massive orders for the construction and equipping the power station. Most transmission materials, including structures and conductors, were to be made in Rhodesia. Steel, cement, and engineering firms in the country were to make equipment for the boiler plant, and the electrical engineering sector would contribute auxiliary transformers and switch gear.

The recommendation of the consultants was accepted by ESC and approved by the government. Stage I (four 120 MW units) commenced in 1973/74. Civil engineering, mechanical, and electrical contracts were signed, and the work started.

In 1975, because of sanctions, the overseas contracts were deferred indefinitely. News about the project was unavailable because of a security blackout until 1980. In that year, the ESC general manager announced in the ESC annual report (ESC 1980) that almost 670 million ZWD had already been spent on the Hwange

Thermal Power Station. He revealed that despite the indefinite deferment of overseas contracts that had occurred in 1975, "civil works continued unabated using local finance and materials, and the main structure, namely the turbine house cooling towers, chimneys, control and administration block were completed [by 1980]." The overseas contracts were resuscitated in January 1980.

When the project continued in 1980, it was estimated that additional costs to complete stage I would amount to 250 million ZWD, and an extra 350 million ZWD would be needed for stage II. Stage I, comprising four turboalternators with four boilers and an ancillary plant, was expected to produce a total output of 480 MW. In other words, each set of alternators would have a capacity of 120 MW. At that stage, the turboalternators and boilers, etc., had still to be manufactured, shipped, erected, and commissioned.

Stage II was to be much bigger, both in terms of financial investment and generating capacity. Its initial output was planned at 800 MW, with an option to extend it by another 400 MW. It may be useful at this point to compare the country's generating capacity at that time with the planned capacity at Hwange, to give some idea of the extent of the contemplated project. The total generating capacity of the country (excluding the Hwange project) stood at 960 MW, which was well below the planned capacity of Hwange (>1200 MW.)

Since the Hwange project resumed in 1980, costs have gone up considerably. When news about the project was released in February 1980, *The Sunday Mail* reported that it would cost about 235 million ZWD to complete stage I and that another 350 million ZWD (at 1979 prices) would probably be needed for stage II. In April 1980, the ESC general manager announced that the total cost of the Wankie Thermal Power Station would be around 800 million ZWD. In August, the chairman revealed that construction costs for the station had soared to 1000 million ZWD.

The spiralling costs at Hwange were passed on to consumers. In early 1983, Central African Power Corporation (CAPCO), a statutory body constituted jointly by Zambia and Zimbabwe to be responsible for operating and distributing bulk electricity power supplies from all power stations in Zimbabwe, announced a 60% increase in the bulk-supply tariff in the fiscal year ending June 1984, when the full costs of stage I would be felt.

The increasing price of electricity could also have been partly a response to World Bank pressure. The chairman of the Harare City Council Finance Committee announced in January 1981 that the World Bank was pressing for a quadrupling of Zimbabwe's electricity tariffs within 3 years as a condition for granting World Bank aid for the construction of stage II. The World Bank representatives claimed that Zimbabwe's electricity was "ridiculously" cheap and electricity was a "luxury" fuel.

Because of increasing costs of constructing the power station, the government decided to reconsider whether it was really necessary to go ahead with stage II after the completion of stage I. In January 1981, the government commissioned a team of consultants to reappraise the future requirements for additional power and recommend the least costly method of providing it. The international consultants, Mertz and McLellan (M&M), produced six options for hydroelectricity developments and five for coal-fired thermal plants in a report presented to the Ministry of Industry and Energy Development. The report recommended that phase I of stage II of the Hwange project be undertaken and that the South Bank Power Station of Kariba be extended. Hwange phase I would consist of two sets, generating 220 MW each, and would cost about 188 million ZWD. The extensions to Kariba South would consist of two sets, generating 150 MW each, and would cost about 108 million ZWD. The recommendations were approved by the government, and construction was completed.

The decision by the Zimbabwean government to go ahead with the expansion of the Hwange Thermal Power Station was not welcomed by the Zambian government. Before the completion of stage I, Zimbabwe was importing 40% of its electric power from Zambia, at a monthly cost of 213 million ZWD. In fact, Zambia had developed a surplus of electric power prior to Zimbabwe's independence, which to some extent strained the relationship between the two countries, especially within the context of regional cooperation in economic development.

Observations

This brief historical description shows that the idea for the project originated with AAC, which was keen to exploit the huge resources of coal at Hwange. The self-interest of the company is borne out by the fact that the idea of a thermal power station was raised at a time when AAC's Wankie Colliery was suffering financially from declining demand, and further decline was expected. The power station would not only boost the demand for coal but constitute a steady, ready, and guaranteed large market for the AAC. In addition, the power station would use coal with a high ash content, a type that was being discarded but the ESC would still have to purchase.

Although the price of coal for the power station was still being negotiated in 1973, *The Rhodesia Herald* made rough calculations of the magnitude of gains that would accrue to AAC as a result of the power station. Making the assumption that the coal-price agreement would allow for a profit margin of \$0.43/t, the article calculated that the working profit from coal mined for the power station would increase fivefold, from 32 000 ZWD in 1976/77 to about 1.7 million ZWD in 1982. The company would also benefit from lower unit-production cost because of larger scale operations.

The consultants who carried out the initial feasibility study for the project worked closely with AAC, whose interest was at stake. These consultants had carried out the more recent assessment of Zimbabwe's future power needs, with a view to finding the most economical way of meeting those needs. It should not come as a surprise that expansion of Hwange was recommended, without much attention given to some alternative sources of electricity supply, e.g., Cabora Bassa.

Contractual arrangement at the power station

To clarify the role of the consultants in the construction of the power station, it is necessary to provide a picture of the nature of the relationship between the Zimbabwe Electricity Supply Authority (ZESA), which controls the power station, and the consulting engineers and the contractors, that is, the companies involved in the construction of the project, whether local or foreign. This relationship has strongly influenced the process of technology acquisition, both at the power station and in Zimbabwean industries supplying inputs to Hwange.

The Hwange Thermal Power Station is owned by ZESA, a statutory body established by an act of Parliament. ZESA is vested with the powers of generating, transmitting, and distributing electricity in Zimbabwe. Before independence the power station fell under ESC. However, ESC did not have statutory powers to generate electricity in Zimbabwe. At that time, the organization of the power sector was fragmented, with CAPCO being solely responsible for electricity generation and transmission in the country. ESC and the electricity departments of the city municipalities of Harare, Bulawayo, Mutare, and Gweru were responsible for distributing electricity. This form of organization resulted in an anomalous situation: despite the fact that ESC owned and operated the Hwange Thermal Power Station (when it became operational), it did so on behalf of CAPCO — the only organization

that could generate and transmit electricity — and then resold the electricity to ESC for distribution. The situation was corrected by the formation of ZESA in 1985/86, which took over ESC and acquired the electricity departments of local authorities.

When ESC originally constructed the power station, it appointed the M&M as consulting engineers for the project, at both stage I and stage II. M&M was very central to all the operations at Hwange, and for that reason, it is necessary to precisely define its position not only during the initiation but also during the construction and subsequent operation of the project.

When construction of the power station resumed after independence, after having been suspended because of sanctions, M&M assisted ESC by preparing the documents necessary for ESC to apply for approval in principle of M&M's general proposals for the execution of the project. At the preconstruction stage, the duties of M&M included the following:

- investigating data and information relevant to works that had been prepared by either M&M or others;
- making any survey of the site that might be necessary to supplement information already available;
- advising ESC on the need to carry out any geotechnical investigations to supplement the information already available; and
- advising ESC on the suitability of persons or firms tendering and the relative merit of their tenders, prices, and estimates.

At the construction stage, M&M was responsible for the following:

- advising ESC on the need for special inspections or testing;
- advising ESC on the appointment of site staff;
- preparing any further designs or drawings;
- examining contractor's proposals;
- preparing formal contract documents relating to accepted tenders for inspecting and testing during manufacture and installation of electrical and technical machinery and the plants supplied for incorporation in the works;
- arranging and witnessing efficiency and acceptance tests on site to ensure that the project was executed according to the contract and in accordance with good engineering practices;
- checking contractors' claims and issuing certificates for payment to the contractors;
- delivering to ESC the records and manufacturer's manuals needed to operate and maintain the works; and
- advising on disputes or disagreements between ESC and the contractors.

In addition, M&M coordinated the transportation of all equipment and materials to Hwange and had to ensure that delivery was made by the contractors in the most efficient, economical, and practicable manner. M&M gave all the necessary instructions and supervised the construction of power station.

The copyright on all drawings, reports, specifications, bills of quantities, calculations, and other similar documents provided by M&M (others were supplied by contractors) would remain M&M's for the duration of the agreement and for 12 months thereafter, although ESC had a licence to use such drawings and other documents for the purposes of constructing the power station. After 12 months, the copyright would belong to ESC.

It should be emphasized that the position of M&M vis-à-vis ZESA has not been static. For a long time, M&M had held the monopoly on all engineering consultancy in electricity generating and transmission in the country. However, now ZESA is beginning to build capabilities within itself and is taking steps to improve its contractual relationship with M&M. It was almost natural and automatic that M&M would be the consulting engineers in any project undertaken by ZESA. But in their contract on the appointment of consulting engineers for the Kariba South extension, ZESA made it clear that the appointment of M&M would terminate with the completion of phase I and that ZESA had no obligation to appoint the same consulting engineers for phase II. M&M had to accept that ZESA might issue M&M's enquiry documents from Kariba to any other consulting engineer(s) appointed for phase II.

Nature of the contracts

This section discusses some of the conditions in the contracts between the contractors and ZESA. The contracts were fairly standard, and discussion will focus on the common issues bearing on the development and acquisition of technology at the power station and in the relevant subsector of Zimbabwean industry. Again, it will be clear that M&M's role was of critical importance.

When a contract was signed, all the work was to be done according to specifications or to the reasonable satisfaction of the consulting engineers. M&M was entitled, at all reasonable times during manufacture, to visit the contractor's premises to inspect, examine, and test the materials used by, and the performance of, the contractor or subcontractors. After manufacture, components of the plant were delivered to the site, with authorization from M&M. Once the work was complete and tested, the M&M issued a take-over certificate.

In general, the contracts were very specific about the work to be done and the quality specifications. Contracts usually required the design of any work to ensure satisfactory operation under the atmospheric conditions prevailing at the site. Continuity of service was the first consideration, so the design had to facilitate inspection, cleaning, and repairs.

Some months before the completion of the plant, M&M was to be supplied with copies of general instructions for operating and maintaining the plant. Operating instructions had to detail all normal start-up, running, and shut-down procedures, emergency operating procedures, and any recommended precautions to prevent the plant from deteriorating during periods of nonoperation. The maintenance instructions had to include a schedule of spare parts, with reference numbers and procedures for ordering replacements. On completion of the contract the contractors were obliged to furnish M&M with copies of all final drawings needed for the efficient maintenance of the plant and for all the parts to be dismantled, reassembled, and adjusted. Depending on the complexity of the work, the contractor was obliged to keep a competent representative at the power station for some time after a take-over certificate was issued.

A picture of the power station

This section describes the actual working of the Hwange Thermal Power Station. This should provide the nontechnical reader with an insight into what happens in thermal power generation.

The Hwange power station can be broadly divided into three major components:

- a boiler section, consisting of coal feeder mills, primary air fans, induced-

draft fans, forced-draft fans, and air-seal fans (secondary air burner, oil burners, pulverized fuel burners);

- a turbine section, comprising turbine, condenser, extraction pump, feed heaters, air injectors, auxiliary steam manifold, boiler feed pump, and de-aerator; and
- auxiliaries, made up of compressed-air system, ash plant, coal plant, water supply system, water treatment plant, hydrogen-generation plant, cooling water system, and fire-fighting system.

The coal used in the power station is transported from the opencast mine of Wankie Colliery by a conveyor-belt system to the coal store. From there, it is carried again by conveyor belts to boiler bunkers for storage. In the conveyor system, the coal is guided from one belt to the next by chutes. From bunkers, the coal is transferred to the volumetric feeder, which feeds the coal mills (pulverizing mill) at a controlled rate. The coal mill is very important: this is where the coal is ground into a very fine powder — pulverized fuel — before it is sent to the boilers. The quality of the pulverization should be high for efficiency of operations. If the pulverized coal is coarse, there will be a high rate of wear and tear on the pipe system.

On start-up of the boiler, the pulverized coal is ignited by oil burners. Air is drawn from the top of the boiler house by forced-draft fans and passes through an air heater into the combustion chamber; it is drawn off and blown by the primary air fans through the mills to convey the pulverized coal to the combustion chamber.

The combustion chamber is completely lined with water wall tubes. The water heated in these tubes passes to the water-and-steam drum, where steam is separated and then travels to the super heater, where its temperature is raised further. From there it is supplied to the turbine, through interconnecting pipe work. The steam has a pressure of 8.9 MPa and a temperature of 518°C. The steam passing against the turbine blades causes the turbine to rotate (controlled by its governor at 3000 rpm).

The operational efficiency and life span of the turbines can be affected by moisture. High-pressure valves control the water level in the boiler drum, which is equipped with gauge glasses for monitoring the water and steam levels. If the water level in the boiler is too low, the water level in the pipes along the boiler will be too low and the high temperatures in the boiler will melt the pipes. On the other hand, if the water level in the boiler is too high not enough high-pressure steam goes into the turbine and the water may damage the turbine blades.

The turbine is coupled to the generator, the rotor of which is large electromagnet, whose rotation produces an electric current in the copper winding of the stator. This electric current is fed to the national grid through a transformer, which increases the voltage of the electricity produced.

After passing through the turbine, the steam, now at low pressure and temperature, reaches the condenser, where it is condensed back into water as it passes over a number of tubes in which cold water is circulating. This process warms the water in the tubes. The water is cooled down again for further use by being sprayed into the lower levels of the cooling tower. An upward draft of the air within the tower cools the warm water as it falls to a pool at the bottom. From this pool, it is pumped back to the condensers.

The condensed steam, meanwhile, is pumped by an extraction pump through low-pressure heaters to the deaerator, where dissolved oxygen is removed to prevent corrosion of metals in the boiler. It is then sent by the boiler feed pumps through high-pressure heaters and an economizer to the steam drum, where it enters the water wall tubes as part of this continuous cycle.

The flue gas leaving the combustion chamber passes over the superheater, economizer, and air heater, giving up heat, and then to the precipitator, where dust particles are removed. The gases are drawn through the boiler by the induced-draft fans and discharged into the chimney. Coarse ash is collected in an ash hopper under the combustion chamber, and fine ash is collected in the precipitator hoppers. This ash is conveyed hydraulically from these hoppers to the disposal area.

Major suppliers and contractors

An interesting feature of the Hwange Thermal Power Station is the large number of contractors who participated in its construction. Table 1 lists the companies that won major contracts. These firms also subcontracted portions of their works.

Table 1. Main contractors at Hwange Thermal Power Station.

	Stage I	Stage II
Boilers	ICAL, part of ICS (South Africa)	Babcock Power (UK)
Turbines	MAN (Germany)	KVS (USA)
Generator	Alsthon Atlantique (France)	Ansaldo (Italy)
Switchgear	Ansaldo (Italy); GEC, Cogelex (France)	Ansaldo (Italy); GEC (France)
Auxiliaries	Babcock (UK); Mother & Platt (UK)	Babcock (UK); Mother & Platt (UK)

From Table 1, it is clear that construction of the power station involved companies from many countries. Local companies were very much involved in the civil engineering works. Local companies like Roberts Construction and Belmont-Glendingning won the housing and extension services contracts; WJ & RL Gulliver received the contract for the construction of the ash dam; and Grinaker, in a joint venture with Roberts Construction, constructed the main foundations and the superstructure of the power station.

The involvement of local companies in the civil engineering reflects the development of the country's capabilities in this field. However, the mechanical engineering, electrical engineering, and transmission contracts went mostly to foreign contractors, although some went to local companies, such as Bestobell (ventilation and air conditioning), Drake and Scull (vacuum cleaning plant), South Wales Electric (auxiliary transformers), and HWS Constructors (lighting). Different companies were contracted for similar sections of stage I and stage II of the power station. For example, ICAL (South Africa) constructed boilers in stage I, whereas those in stage II were constructed by Babcock Power (United Kingdom). MAN (Germany) was the major contractor for the turbine sections in stage I, whereas KVS (United States) was responsible for the same section in stage II. It is also interesting to note that the sources of financing were mainly the World Bank and the constructors themselves.

Design of stages I and II

The design of stage I was outmoded, especially that of the coal mills. This is partly explained by the fact that the construction of this stage of the power station was postponed by almost a decade. The power station was supposed to have been operational by about 1972. The stage I coal mills are not only old fashioned, but also technologically complex and difficult to maintain.

The stage II mills are more modern but use a far simpler technology. Each stage II mill consists of a big container with mill balls. Coal goes into this container, which rotates; the coal and the hard steel balls hit each other, and in this way the coal

is ground. These steel balls are easy to manufacture, requiring only very hard steel.

The process in stage I is different. In each mill, there are two huge rollers on a table. As the table rotates it turns the rollers, crushing the coal. Altogether, the stage I mills have 64 segments for the tables and 32 roller tires. Table segments take about 1 year to wear off, and rollers take about 6 months. Certain parts of the hydraulic system have to be imported from South Africa.

The power station is currently using diesel oil for start-up. Power stations elsewhere use light oil for start-up, then switch to medium oils and then to heavy oils to correct flame stability. Heavy oils are cheaper than diesel, but if heavy oils are to be used, it will be necessary to install heaters to heat the oil to increase its viscosity.

Modifications to the mill

The hardness of the coal is a factor that should have been considered when the material for making rollers and the rotating table were chosen. The mill is designed to reject hard foreign bodies, so hard coal will also be rejected. When the stage I mills were put into operation, they had a very high rate of rejection of coal, which was very uneconomical, taking into account the cost of purchasing the coal and transporting it through the conveyor belt system. There was also a high rate of wear and tear on the armoury, which led to leaking of the pulverized fuel.

Modifications were made to reduce the amount of rejected coal and to reduce wear on the armoury. The gap in the valve that injects air into the mill to carry the pulverized fuel had to be reduced. The wear on the armoury occurred because some foreign particles and heavy coal remained suspended, continuing to butt against the armoury, before eventually falling down the rejection route. The valve modification increased the velocity of the air. Particles were blown back rather than left suspended, with the result that the rejection rate was reduced to negligible levels and the life span of the armoury was increased. However, it meant that the mill was forced to grind almost everything, but consumption remained at acceptable levels.

The original suppliers came up with their own modifications. First, they reduced the distance from table to top ring. This reduced the amount of coal between table and roller, which reduced the power consumption in the motor. Second, they changed the shape of the armoury.

Other modifications

Conveyor belts transport the coal from the opencast mine to the power plant. Chutes direct or guide the coal from one belt to the next belt, but the chute system was not well designed because the chute plates wear out quickly. The chutes had to be redesigned. First, a Zimbabwean company analyzed the material composition of the plates. Then drawings were made for a local company to do the manufacturing using harder steel which does not wear so easily.

In addition, the system of pipes carrying pulverized fuel was wearing out at a much faster rate than expected, particularly in the corners. Either the material composition of the pipe system failed to meet specifications or the specifications were not high enough. Different material was recommended for a trial, and two corners were reconstructed with the new material. The boiler was run to see if the new material performed better than the old.

Availability of spare parts and consumables

At initial installation and test runs, maintenance costs for a power station are relatively high. Obviously, at the initial start-up, problems will be experienced, and these may

be caused by the use of components that do not meet the required specifications and the operators' lack of familiarity with the plant. As adjustments and corrections to components are made and operators gain more experience with the plant, running costs are reduced. Eventually, the station gets to a point where it begins to operate smoothly, running costs reach a stable minimum, and the technicians become experts. However, as the equipment ages, breakdowns are more frequent, operational efficiency goes down, and average running costs start going up. At this stage, the availability and smooth procurement of spare parts and consumables become extremely important.

Spare parts

Spare parts for the boiler feed pump include the following: bearings, balancing springs and piston, pump impellers, couplings, valves, gland packing, joint gaskets, volume-to-volume seats in feed pump connections. There have been many leaks in valves, and the problems appear to be in the design; material composition may be different from that prescribed in manuals.

Spare parts for the fuel-oil system include bearings, safety valves, and screws for pumps. Problems were experienced with bearings, and the station fabricated some at the workshop, but they do not last. The problem is likely to be in the material. Oil burner hoses, which connect the oil pipe to the burners, are imported. Field and Technical Services is trying to manufacture parts for repairs. For the life span of the power station, which is projected to be 40 years, 2560 burners will be required. Gaskets are supplied by Bestobell. Electrical cords are imported — they cannot even be repaired locally and are actually sent back to the original manufacturer for repairs. NEI Central Africa (part of ICAL, which built the boilers) supplies Hwange with boiler parts. It orders from Kent.

If the system of pipes carrying pulverized fuel wears out, parts can be obtained from O'Connolly, which has already manufactured them.

The turbine lifespan is long, and no problems are expected in the first 20 years. IPTC recently formed a company in Harare to supply turbine parts and has a franchise with the manufacturing company. Other turbine parts will have to be imported, though, and so will high-pressure vessels and high-pressure valves. However, 20 years is a long time, and with planned industrialization programs, the plant may acquire its own capabilities in this field. Low-pressure valves can be obtained locally, and it may be possible to encourage some local companies to manufacture high-pressure valves for the water-pumping station from the Deka line.

Some of the turbine pumps can be manufactured locally, but boiler-feed pumps are complicated and may have to be imported for a long time to come. The ash-slurry pump and cylinder grinders will be manufactured locally by O'Connolly (drawings have already been submitted).

Consumables

We now turn our attention to consumables — propane gas, hydrogen, carbon dioxide, methanol oil, and asbestos packing — and some of the problems the power station faces in the procurement of these.

Propane gas, which is used for lighting burners, is ordered from South Africa. The power station sends the cylinders to a company in South Africa, where they are filled and sent back. However, the company faces foreign currency problems and often fails to meet the required orders in time or in sufficient quantities. Oxyco, in Harare, refills hydrogen and carbon dioxide cylinders. However, it can only do about 12 cylinders at a time. This creates problems: at times, the power station may require as many as 24 cylinders all at once. Methanol is imported from South Africa through

Chemplex (Bulawayo). When there are delays in supply and, hence, a shortage of methanol at the station, more hydrogen will be used. In the absence of unforeseen circumstances, it takes about 2 months to get methanol from South Africa.

Oil is one of the biggest problems, given the high consumption at the power station. The station uses HHP 46 oil, which is not available from Shell BP. The firm does have total substitute oils and is prepared to guarantee their efficient performance, but it insists on a contractual arrangement.

Asbestos packing is imported, although Zimbabwe produces and exports asbestos — it is used throughout the country in all industries that use steam. What is required is the machinery and technology to compress the packing. ZESA imports the packing through Bestobell; however, a role of asbestos blanket, about a half metre thick, was 2000 ZWD in 1986.

Workshop

The power station has a workshop that mainly does maintenance. It is equipped with machinery imported from the United Kingdom, the United States, and South Africa. It has bending machines, a circular-bend saw, surface grinders (different types), lower press, bench drilling machines, reciprocating hacksaws, lathes, vertical drilling machines, and milling, rolling, slotting, and shearing machines. The workshop is capable of undertaking repair work on its own machinery but has to purchase consumables, such as drills, saws, and blades. Because of the shortage of consumables in the workshop, some machinery lies idle for long periods, an inefficient use of the huge financial resources that were invested in purchasing the machinery.

Human resources

The human resources at Hwange Thermal Power Station at its inception were predominantly foreign. Engineers and technicians were recruited from the United Kingdom; artisans and plant operators were recruited from India. The massive recruitment of foreign personnel even at low skill levels was justified by the size of the Hwange Thermal Power Station; existing power stations in the country were smaller.

In keeping with the government's policy of reducing dependence on expatriate labour, ZESA embarked on a concerted drive to recruit and train local personnel. Training, in general, is going on fairly smoothly. Within a period of 3 years, the number of Zimbabwean engineers increased from 3 to 60. The majority of the graduate engineers have general engineering training, and most acquired the relevant skills to be promoted to positions of responsibility.

At the time of this study, all but 10 unit operators had been replaced by Zimbabweans.

Technical development

In anticipation of the large training requirements for technical personnel, ZESA established a training school at the power station. It would have been ideal for the first-year apprentices at the power station to spend some time acquiring theoretical knowledge, which they could then apply on their jobs. Unfortunately, the local technical colleges were not fully equipped to offer specialized training for the electric power sector. The government, therefore, gave ZESA (then ESC) the mandate to work with Electricité de France to develop a training system for the electricity sector in Zimbabwe. This led to the building of the training school in Harare, which accommodates 220 students. Unfortunately, the training school at Hwange was not very useful because there was a shortage of staff.

As a result, first-year apprentices engaged at the power station were without theoretical training. It became very difficult to provide the apprentices with systematic training: the training was determined by the specific circumstances and problems at the power station at any given time. The major problem with the on-the-job training was the language barrier — foreign workers preferred to communicate in their mother tongue. This became an obstacle to Zimbabweans actively seeking to acquire certain skills.

Zimbabweanization

Zimbabweanization of the power station has been taking place slowly because of the high staff turnover, mainly a result of salary differentials between parastatals and the private sector and between Zimbabweans and foreign staff. The salaries of foreign staff are about three times those of Zimbabweans employed at the same levels and with equivalent academic and professional qualifications and experience. In addition, the foreign staff enjoy other privileges, such as company cars and a holiday ticket to their home countries. The frustration faced by qualified Zimbabwean engineers, technicians, fitters, and others has led them to leave for the private sector. The search for greener pastures has assumed a new dimension in recent years, with several qualified personnel crossing borders to such countries as Botswana and South Africa.

The instrument maintenance department, in particular, has faced problems in recruiting, training, and retaining Zimbabweans and is, therefore, dominated by foreign staff. The difficulties in recruiting Zimbabweans in this department arise from the fact that no other company in the country has a range of instruments like that at Hwange. To make matters worse, even the established colleges in the country have problems training instrument technicians.

International structure of the power-equipment industry

To establish the role Zimbabwe plays in supplying the needs at Hwange and the potential for developing local capabilities in the manufacture of power equipment, it is necessary to get a clear picture of the international structure of the power-equipment sector. A country's ability to enter this industry is determined not only by conditions internal to the country but also by international realities and constraints.

A review of the international power industry also helps us identify problems likely to be encountered by any nation attempting to develop this sector. International experience is a source of lessons and strategies.

Structure of the industry

The market for heavy electrical equipment is a very imperfect one. On the supply side, 12 transnational corporations (TNCs) (based in developed countries) and their subsidiaries and affiliates account for a large share of total world production and trade in this industry. According to Surrey and Cheshire (1972), there are about 250 manufacturers of power and distribution transformers in the world. These manufacturers employ about 720 000 people, 75% of whom are employed by 10% (25) of the firms, and these firms account for all the exports. The leading companies in the power industry include General Electric and Westinghouse (United States), General Electric (United Kingdom), Siemens and Allgencine Electricitate Gesellschaft (AGE) (Germany), Hitachi (Japan), and Brown Boveri (Switzerland). Other French, Japanese, American, Swedish, and Italian companies participate but in more specialized lines.

Production of large units is highly concentrated in the leading firms, and these firms dominate the world market. These firms enjoy considerable technological

advantages in the production of turbogenerators, turbines (both steam and gas), and high-pressure pipes. Gas turbines, which require specialized technologies, are produced by, or under the licence of, General Electric, Westinghouse, and Brown Boveri. But in smaller plants, the technology is more accessible, even to producers in some developing countries.

All the dominant power-equipment manufacturers were established during the early development of the industry and contributed considerably to it. These firms devote large sums to sustaining research and development (R&D), which has led to considerable technological innovations. Further, technological capabilities have been acquired by international cross-licencing among the leading companies. The lead in technology has strengthened the position of the established firms and discouraged entry by newcomers.

In Europe and Japan, a major factor in development of the power sector was the acquisition policy of power parastatals, which guaranteed protection to local industry and virtually excluded imports of equipment. Further, in most cases, the companies concerned received full backing from their governments in several ways:

- Governments supported the industry by funding R&D.
- Some governments granted local private companies long-term purchase guarantees for electrical equipment.
- Other governments provided manufacturers access to expensive testing equipment at subsidized rates.
- Governments encouraged mergers in the industry when overcapacities developed.
- Governments encouraged and supported exports by giving loans to other countries under the condition that those countries purchase power equipment from the donor countries.

An important feature of the power-equipment sector is the collusion or collaboration among the leading producers. Until the 1930s, the companies used patent pools to divide the international market among themselves. These were later replaced by a formal cartel, the International Electrical Association. Most of the European producers are members. The cartel members have a system of sharing export markets, which are the developing countries.

There are also economic factors that help to explain why the industry is dominated by a few large producers. A study by UNCTAD (1978) points out that the purchasing policies of most public utilities appear to place considerable weight on the technical standards of the equipment, the prestige of or previous commercial relations with the supplier, and delivery conditions. The price appears to be only of minor importance — demand for electricity tends to be price inelastic, thus enabling the utilities to pass on high costs to consumers. Product differentiation and the loyalty of consumers to the products of existing firms act as barriers to new firms. Other barriers exist in the form of absolute cost disadvantages because existing firms possess secret know-how. In addition, the financial requirements for entry into this industry are extremely high.

On the supply side, because of the irregular nature of demand for electrical equipment, the high fixed-cost structure of the industry, and falling demand, the industry has been characterized by overcapacity since the 1960s. The resources required for investment in special machinery and testing equipment and the long gestation period to capitalize on such investments discourage new entrants into this industry. This situation is reinforced by low demand relative to existing international

capacity.

What prospects do developing countries like Zimbabwe have for developing local capabilities in this line of production? Historically, TNCs have established sales offices in developing countries; in some cases, the TNCs have also set up local assembly operations for power equipment. In some large developing countries, TNCs have responded to import-substitution policies (which shift the emphasis from imported inputs to locally manufactured substitutes) by expanding their assembly operations to include manufacturing facilities. However, in most cases, the manufacturing has been small scale. Where medium-sized equipment has been produced, this has been done with a high import content. A few developing countries and newly industrialized countries, such as Brazil, Argentina, India, and the Republic of Korea, have made significant progress in the manufacture of large power equipment.

Policy implications and recommendations

Diversity of suppliers

Because Zimbabwe is a developing country that is still trying to consolidate and develop its industrial base, it is recommended that, for projects such as the Hwange Thermal Power Station, it narrow its range of suppliers. Of course, this calls for careful screening of tenders at an early stage, giving serious consideration to issues such as quality, price, and the involvement of local industry through subcontracting. The benefits of narrowing the range of suppliers are twofold. First, problems in procuring spares internationally are reduced; second, the learning process will be much easier for local technical staff.

Difference in design

For Zimbabwe, which has a limited market, it is wiser to go for standardization of design. This provides a wider scope for local industry to either diversify or invest in new lines to respond to a large demand, unlike a situation with different designs, which leads to limited market opportunities for a wider range of products. Therefore, what emerges from this study is that if a number of similar projects are to be undertaken in Zimbabwe, then the design of these projects should be similar to allow domestic industry to reap maximum benefits.

International bidding

We now turn our attention to international bidding. This is rather complex, since there is a need to balance the short-term price and the long-term benefits of developing local industry while conducting checks to ensure the efficiency of that industry. The very existence of World Bank guidelines, which provide for a 15% domestic preference margin, is a realization of the long-term benefits likely to accrue as a result of giving preference to local companies, especially in developing countries. Zimbabwe should deliberately give preference to domestic suppliers where the long-term benefits exceed the short-term costs.

Development of local capabilities

The recommendations concerning the development of local capabilities are directly derived from the experiences of those countries that have managed to develop the power-equipment sector. Those countries entered the power-equipment industry through a very deliberate planning process. This process involved government assistance, such as providing services that are too expensive and too essential to depend on the profit motivation of private companies. The government provided

testing equipment at subsidized rates, protected domestic industry, guaranteed orders, and funded R&D. Because of the international structure of the power-equipment industry, an open market approach will not enable Zimbabwe to enter this sector. Therefore, it is recommended that the government should actively assist the industry in developing capabilities along this line.

Unpackaging

Unpackaging is obviously desirable because it provides the potential for local industry to get into those fields that are less technologically complex. The benefits of unpackaging are evident at two levels: the foreign-exchange requirements for imports for both construction and spare parts are reduced; and unpackaging allows for easier learning and acquisition of technology. The study, thus, recommends that in cases like the Hwange project, where contracts are very detailed and specific, Zimbabwe should take advantage of this and have those components manufactured by local industry.

Transparent technology policy

Up to now Zimbabwe does not have a clear technology policy. A document was drafted for discussion about 5 years ago (Government of Zimbabwe), but the outcome is not clear. Government does recognize the importance of building a strong domestic technological base and, hence, the importance of having a technology policy as a guide. Because Zimbabwe does not have a transparent technology policy, it is not surprising that the government makes decisions that are very inconsistent and that, at times, actually undermine progress in developing the local technological base. To avoid this, it is important for government to draw up a clear technology policy, which will be a basis for all decisions related to technology.

Implications of the Economic Structural Adjustment Program

The recommendations of this study should be viewed in the context of the general thrust of current government policy. Government has decided to embark on the Economic Structural Adjustment Program (ESAP), to be phased in over a period of 5 years, beginning September 1990. The adoption of ESAP reflects a change in the government's philosophy of development. The major element of ESAP is trade liberalization. There are other policies accompanying this, but these are mainly aimed at ensuring the success of trade liberalization, which reflects the government's determination to steer the economy according to an export-led growth strategy. The complementary policies include deregulation in labour laws, price controls, and investment procedures. However, the bottom line of ESAP is that government has adopted the open-market system to determine resource allocation.

This raises a question about some of the ESAP policies and the applicability of the recommendations of this study to ESAP. The very phasing in of ESAP over a period of 5 years reflects the government's uncertainty about its sequencing of the program. Also, ESAP is very general, especially the policy for trade liberalization; this allows for flexibility and provides room for further contributions to the ultimate design of the program. As the Government of Zimbabwe is committed to ESAP and its underlying philosophy, it follows that some of the recommendations emerging from this study would require a certain time frame; this applies mainly to issues such as protecting and giving preference to domestic suppliers and providing assistance in the form of subsidized testing equipment. It is important to note that such measures are compatible with ESAP if it is aimed at developing local industry (and, of course, the rest of the economy). The recommendations of this report should be viewed as inputs

to ESAP, aimed at ensuring that the program in no way unduly suppresses local industry, which can become competitive with a protected learning process.

Conclusions

Government does not have a clear procurement policy designed to develop local industry. As a result, the participation of local industry in the Hwange Thermal Power Station project has been limited, especially in stage II and in components other than the civil engineering works. Again, because of lack of policy, the government failed to take advantage of the detailed and specific nature of the supply contracts that gave scope for unpackaging.

Decisions regarding plant size and plant design should have been based on the need to develop local industry. It should, however, be pointed out that ZESA is now making every effort to reduce dependence on overseas suppliers and rely on local industry for spare parts and consumables.

The contracts between ZESA and the suppliers were drafted in a manner that ensured good work and was conducive to effective technology acquisition, especially skills related to operating and repairing the plant configuration. ZESA established a training school in Harare, and it is also sponsoring engineering students at the University of Zimbabwe. Unfortunately, ZESA is experiencing problems retaining skilled human resources. Although training is vital, staff retention is equally important — because it is usually the experienced and more capable personnel that tend to leave for greener pastures. Therefore, a comprehensive human resources development program should address issues affecting staff retention, mainly a matter of salaries, fringe benefits, and other working conditions.

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CHAPTER 5

Choice of Technology in Small-Scale Enterprises

Catherine Ngahu

Introduction

Private-sector development as a suitable alternative for promoting sustainable and balanced growth in Africa has attracted considerable attention. Many governments and development organizations have focused on the promotion of small-scale enterprises (SSEs) as a way of encouraging broader participation in the private sector. The promotion of SSEs and, especially, of those in the informal sector is viewed as a viable approach to sustainable development because it suits the resources in Africa.

A number of factors have helped to direct the attention of development agencies to the merits of SSEs. For instance, at the peak of the economic crisis in the early 1980s, the SSE sector grew tremendously and exhibited unique strengths in the face of recession (Grey-Johnson 1992). The sector continued to grow, despite hostile economic, regulatory, and political environments. The entrepreneurs in this sector came to be regarded as highly opportunistic and innovative. They emerged spontaneously to take advantage of opportunities that arose in the changing business environment. Moreover, they demonstrated great creativity in starting enterprises with minimal resources. It has been suggested that most technological innovations and product diversifications in Africa come from this sector (Juma et al. 1993). The SSE sector has been described as the most accessible and competitive of African economies (World Bank 1989).

SSEs have characteristics that justify promoting them in a development strategy. They create employment at low levels of investment per job, lead to increased participation of indigenous people in the economy, use mainly local resources, promote the creation and use of local technologies, and provide skills training at a low cost to society (ILO 1989).

The sector plays an important role in various African countries. According to the ILO/JASPA "African Employment Report" (ILO/JASPA 1988), the sector makes a significant contribution to the gross domestic product in Liberia (34.6%), Nigeria (24.5%), Kenya (19.5%), and Benin (17.7%). In Kenya, the sector is expected to play a key role in employment creation. Employment projections for 2000 indicate that 75% of urban jobs are expected to be in this sector, along with 50% of all rural employment (ILO 1989). The sector currently employs 40–60% of the urban labour force and contributes 25–33% to total urban incomes.

However, it is generally recognized that SSEs face unique problems, which affect their growth and profitability and, hence, diminish their ability to contribute effectively to sustainable development. Many of the problems cited have implications for technology choice. These problems include lack of access to credit, inadequate managerial and technical skills, low levels of education, poor market information, inhibitive regulatory environments, and lack of access to technology (Harper 1974; ILO 1989; House et al. 1991).

This article addresses the constraints faced by SSEs in making technology decisions. I consider the factors that influence technology choice at the enterprise level and suggest interventions at the policy level to facilitate the decision-making process. In particular, I aim to illustrate how technology decisions are constrained by problems faced by SSEs in other areas of management. The chapter incorporates findings from a study on choice of technology in SSEs in Kenya (Ngahu 1992).

Choice of technology

Technology choice has important implications for growth and productivity in industry. The use of technology is always tied to an objective. Because various types of technologies can be used to achieve an organization's objectives, the issue of choice arises. The concept of technology choice assumes access to information on alternative technologies and the ability to evaluate these effectively. Moustafa (1990) asserted that effective choice is based on preselected criteria for a technology's meeting specified needs. Further, it depends on the ability to identify and recognize opportunities in different technologies. The expected outcome is that the firm will select the most suitable or "appropriate" technology (AT) in its circumstances.

The concept of AT has been a subject of debate for many years. Stewart (1987) contrasted two general views. First, welfare economics defines AT as a set of techniques for making optimum use of available resources in a given environment. Second, social scientists and those working in AT institutions associate AT with a specific set of characteristics. According to Stewart, the characteristics defining AT normally include "more labour-using, less capital-using, less skill-using, making more use of local materials and resources, and smaller in scale."

It is also sometimes emphasized that AT should not affect the environment negatively and that it should fit in with the socioeconomic structures of the community. The suggested characteristics are too numerous, which implies that a technology can be appropriate in some ways and inappropriate in others. Kaplinsky examined the trade-offs involved in the choice of technology and found that mechanized production can, at times, turn out an inexpensive, higher quality product for consumers, whereas normal production of a lower quality and higher cost product generates more employment (ATI 1987). This illustrates the dilemma involved in evaluating technology and raises the question, Appropriate for whom? This article is concerned with the gaps in knowledge, skills, or resources that hinder effective choice of technology at the enterprise level. In this context, the term *appropriate* is used loosely to mean technology that is most advantageous to the enterprise's purpose and circumstances.

Small enterprises

The heterogeneity of the SSE sector complicates the problem defining it. The concept is defined in different ways, depending on the purpose of classifying firms as micro, small, medium sized, or large. Technologically, the sector is said to use low-level inputs and skills, to have much greater labour intensity, to produce lower priced products, and to operate on a small scale. The study on which this article is based focused on enterprises in the carpentry and hair-care subsectors employing fewer than 20 employees. It covered micro and small enterprises operating at various levels along the formality-informality continuum. The "Private Sector Diagnosis Survey" (USAID 1989) found that most small enterprises in Kenya had fewer than 20 employees.

Factors influencing the choice of technology by SSEs

Entrepreneurs decide at the enterprise level which technologies to use. The main factors influencing their choice of technology include the objectives of the firm, the resources available, the nature of the market, and their knowledge of available technologies (Stewart 1987). Moreover, the entrepreneurs need technical and managerial skills to choose, adapt, and effectively use technology.

Additionally, one would be in a better position to choose a technology if one were able to assess the demand for the firm's products, estimate the rate of change in the market that may call for change in technology, gather information about alternative technologies, and estimate the potential return on investment for each alternative. However, many entrepreneurs in this sector lack the education, training, management experience, and other competencies needed to respond to these issues. Because of their economic and organizational characteristics, many SSEs lack information about technologies and have no way of gauging the appropriateness of those they are aware of (Neck and Nelson 1987).

Macropolicies also affect technology choice at the firm level through the overall socioeconomic, political, and legal forces. It has been suggested that general socioeconomic environment, industry-specific regulations, taxes, subsidies, trade and financing policies, science and technology research, and dissemination policies tend to favour large-scale enterprises (ATI 1987).

Problems hindering the effective choice of technology by SSEs

The literature indicates that SSEs face unique constraints that hinder the effective choice of technology. Many SSE owners or managers lack managerial training and experience. The typical owner or managers of small businesses develop their own approach to management, through a process of trial and error. As a result, their management style is likely to be more intuitive than analytical, more concerned with day-to-day operations than long-term issues, and more opportunistic than strategic in its concept (Hill 1987). Although this attitude is the key strength at the start-up stage of the enterprise because it provides the creativity needed, it may present problems when complex decisions have to be made. A consequence of poor managerial ability is that SSE owners are ill prepared to face changes in the business environment and to plan appropriate changes in technology.

Lack of information is a key problem affecting SSE's access to technology. Harper (1987) suggested that technologies used by SSEs in developing countries may be inappropriate because their choice is based on insufficient information and ineffective evaluation. Neck and Nelson (1987) suggested that ignorance is a key constraint affecting the choice of technology by SSEs. Further, level of education is relevant, as it may determine the entrepreneurs' access to information. Generally, the ability to read and write, exposure to a broader world, and training in the sciences enhance one's ability to understand, respond to, use, and control technologies (Anderson 1985).

Lack of access to credit is almost universally indicated as a key problem for SSEs. This affects technology choice by limiting the number of alternatives that can be considered. Many SSEs may use an inappropriate technology because it is the only one they can afford. In some cases, even where credit is available, the entrepreneur may lack freedom of choice because the lending conditions may force the purchase of heavy, immovable equipment that can serve as collateral for the loan. Another related problem is the lack of suitable premises and other infrastructure.

The national policy and regulatory environment has an important impact on

technology decisions at the enterprise level. The structural adjustment programs (SAPs) currently implemented in many African countries are aimed at removing heavy policy distortions, which have been viewed as detrimental to the growth of the private sector. However, much as these policies may in principle favour SSE growth in the long run, concern has been shown about the ability of the SSE sector to increase production and create more jobs under conditions of declining demand (Henk et al. 1991). SAPs tend to severely affect vulnerable groups in the short run and have been associated with the worsening living conditions in many African countries (USAID 1991). Furthermore, severe cutbacks in government services, such as health and education, force many small-business owners to draw more money from their businesses to meet these needs, thus hindering investment in technology and business expansion. In addition, the resulting reduction in employment and real wages leaves many potential customers without the ability to buy, thus reducing demand.

Some evidence from the field

This section highlights the findings of a study carried out on the SSE sector in Kenya. The survey used a random sample of 140 SSE's operating in the carpentry and hair-care subsectors in Kenya. The two subsectors are largely dominated by small and micro enterprises. Interviews were conducted with owner and managers of SSEs. The literature survey included a review of policy documents outlining government policy objectives for SSE development and technology issues in Kenya (for a detailed report of this study, see Ngahu [1992]).

The findings of the study correspond to those in the literature. Most of the SSE (78%) were individually owned, and the others were partnerships. The SSEs had not grown much over the years. More than 51% had fewer than 5 workers, and only 22% had more than 10 employees. Sixty-three percent of the owners surveyed had secondary education. More than 60% had some kind of training in a technical area of business, but only 13 and 12% had any training in general business management and marketing, respectively.

Most tools and equipment used in the two subsectors were imported from Europe or Asia. In some cases, even simple tools, such as brushes, hammers, and tape measures, were imported. In the hair-care subsector, the chemicals, materials, and equipment were mainly imported. The tendency to rely on foreign sources and the large-scale industrial sector for supply of equipment sometimes led to an incompatibility of the needs and capacities of the SSEs. Wangwe (1993) suggested that SSEs are trying to avoid risk by avoiding unproven technologies.

To get information about products, tools, equipment, and processes to use in business, many SSEs rely heavily on friends, competitors, and training courses. More than 64% of the respondents indicated that friends were their main source of information on available technologies. Other sources include training courses, magazines, and sales people. The high reliance on friends as a source of information may explain the similarities among products and services from this sector. Both subsectors serve markets that are clearly segmented, and technologies in enterprises serving the same market were very similar. The key method for technology choice in these enterprises seemed to be simple imitation based on observation.

Although imitation strategies have unique merits for small firms because they serve to minimize risks, imitation can be risky in the absence of adequate market information. Many SSEs lack information about consumer demand and competition. Moreover, they lack the skills and resources to conduct market research. As a result, many imitators find themselves in a congested market. The similarity of their

products, coupled with the tendency to serve the same market segments, erodes any competitive advantage. This forces them to compete by reducing prices, which in turn reduces profits and opportunities for growth. Most SSE owners were influenced by customer expectations and tastes, current trends, and the technology that competitors were using. Generally, the technologies adopted in both subsectors were labour intensive.

Most respondents expressed concern about high prices, inability to determine quality, lack of information about serviceability, and lack of alternatives. They also raised the issue of inadequate infrastructure, high taxation on equipment, lack of access to credit, and lack of appropriate training courses.

The government policy on the use of technology in the production of goods and services is to encourage “the application of technologies that minimize wastes and exhibit recycling possibilities; the use of local and renewable materials; the use of local talents and inputs wherever possible; and the active development of innovations and inventions” (Government of Kenya 1989). Although the policy objectives appear explicit, it is not clear which policy measures or government interventions have been intended to affect the process of technology choice by SSEs.

Policy implications

SSEs are obviously incapable of sourcing, evaluating, and adapting technologies effectively. The government policy should, therefore, aim to develop these capabilities in SSEs through supportive institutions. Policy can encourage the development of assistance programs to facilitate SSEs’ access to resources, information, training, and technology. Further, policy should promote the development of technologies appropriate for SSEs. Although it is possible to develop policies designed to improve the circumstances of SSEs, it may be more feasible to support the development of technologies compatible with the SSEs’ circumstances.

Policies should aim to encourage and promote the development of local technologies. Emphasis should be on the promotion of the local tool industry to reduce reliance on imports. SSEs are said to face a “liability of smallness.” Because of their size and resource limitations, they are unable to develop new technologies or to make vital changes in existing ones. Still, there is evidence that SSEs have the potential to initiate minor technological innovations to suit their circumstances. However, for SSEs to fully develop and use this potential, they need specific policy measures to ensure that technology services and infrastructure are provided. Further, research and development institutions that are publicly funded should be encouraged to target the technology needs of SSE.

The problem of access to information may be attributed to the inadequacy of SSE support institutions. This points to the need for a supportive policy to encourage the establishment of documentation centres and information networks to provide information to SSEs at an affordable price. Market characteristics significantly influence technology choice. The government can facilitate the SSEs’ choice of technology by creating an environment that is conducive to fair competition.

The crucial focus of policy should be an enabling environment for technology decisions at the enterprise level. There is a need to go beyond statements of policy objectives and to take specific and consistent measures to ensure that the policy objectives will be achieved. There is a need to address the overall policy framework to ensure that the policy instruments are consistent with key objectives. In some cases, there appears to be an obvious contradiction between policy and implementation.

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CHAPTER 6

Technology Modifications and Innovations: A Case Study of Rice and Cassava Processing in Sierra Leone

J.G.M. Massaquoi

Introduction

Most developing countries have recently abandoned the old industrial development strategy of import substitution, putting more reliance on development programs that bring about an equitable distribution of wealth and emphasize export performance. Sierra Leone is no exception. The country's experience with the import-substitution industrialization policy has obviously not brought about the desired development. It is, therefore, expected that whenever a properly and carefully formulated industrial development strategy is adopted it will emphasize the improvement of export performance of both agriculture and industry while increasing the production of consumer goods for the growing domestic market.

One industry that could become very important in such a strategy is food processing. This will readily suit the import-led, free-market strategy: increased agricultural production and income will generate demand for industrial goods and services. Food processing and other agro-industries will obviously enforce a linkage with agriculture. At the moment, there are very few formal large-scale food-processing industries in the country. Most food processing takes place in the informal sector. Some of it isn't even done on a commercial scale. In the absence of any formal industry for the production of local foods, knowledge of the technological capabilities of the informal sector may provide a planning basis for the formal sector. Indeed, when the formal sector is establishing processing industries for local food products, it needs to tap the indigenous knowledge of the production process. Experience has also shown that the indiscriminate use of certain technology in food processing, although it may result in the same product quality, could have an adverse effect on known "traditional" qualities that the entrepreneurs need to be aware of. Further, the development of future food products, leading to the enlargement of the industry and improvements in quality, will depend on the existence of technological capabilities.

This paper discusses technological capabilities in the informal food-processing industries, focusing on the two most important food products: cassava and rice.

Rice and cassava products in Sierra Leone

Rice and cassava are the two most important food crops in Sierra Leone. In quantitative terms, their processing represents the largest informal food-processing activity. Rice and cassava are grown in every region.

About 600 000 t of rice is consumed annually in the country. At least 2% of this is processed into various products:

- rice pap — a thick porridge prepared from rice flour;

- rice *akara* — a form of doughnut prepared from rice flour and banana;
- rice bread — similar to *akara* but baked rather than fried; and
- rice *kanya* — a blend of roasted rice flour, peanut butter, and sugar.

Rice flour is an intermediate product in every processing operation, and because the shelf life of all the final products is very short, it was recently recommended that rice flour be promoted to encourage the growth of rice processing (Massaquoi et al. 1990).

Large quantities of cassava are also produced in the country. Current estimates put its production at well more than 120 000 t a⁻¹. Because of cassava's rapid deterioration after harvest and because of the need to reduce the toxicity of the tubers, cassava is usually processed before marketing: nearly 90% of the cassava that enters the market is in the processed form. Thus, cassava processing is a major informal activity. There are three main cassava products:

- *fufu* — fermented cassava pulp;
- *gari* — parched cassava pulp; and
- *tui* — dry cassava flour.

Only *fufu* and *gari* are widely consumed in all regions of the country.

Objective

The objective of this study was to acquire some knowledge of the local technological capabilities in cassava and rice processing, with a view to making recommendations on enhancing technological innovations. This overall objective was broken down into various tasks:

1. Identify the technologies used in each of the activities: the equipment required, the skills involved, the sources of skilled human resources, and the methods of acquiring skills.
2. Identify and appraise the levels of technical change and innovation that have taken place in the various technologies.
3. Examine the major constraints facing the development of technologies in the industry.

Methodology

Technology is specialized knowledge used to transform inputs (raw material, labour, and capital) into outputs (products and services). Technological capability is the set of skills needed to

- identify the problems and the relevant technologies for solving the problems;
- adapt and modify the technologies;
- select suitable raw materials;
- make changes in the products; and
- undertake product and production innovations.

In the case of production processes (Cooper and Sercovitch; SPRU 1977), abilities are needed for

- operation;
- modification of a given system;
- initiation (start-up) of a system, based on existing technologies; and
- innovation (or development of new production systems).

Similar classifications were proposed by Westphal et al. (1984).

To assess technological capability, we need to identify its indicators. A strong point emphasized in the literature is that evidence of technical change is indicative of technological capability. Technical change includes modification and adaptation of any technology and the introduction of a new production process or product.

There are two possible study approaches. One is to directly assess the evolution of the technology, taking note of all the changes that have occurred during a certain period and the sources of these changes. The other is to examine the changes in factors that are influenced by technical change. Such factors include productivity, employment, product quality, profitability, and diffusion of technology. The latter method was used by Smith (1984) in assessing the technological capabilities of the Sierra Leone National Petroleum Refining Company.

In this study I take the first approach, which is the evolutionary approach. The activities for achieving my objective included a literature review, administration of a questionnaire, and data analysis. The nature of information I sought in the questionnaire was similar to that sought by Amin (1989) and Khundler (1989). The questionnaire covered the following:

- general background
- machinery stock (How many machines are involved in the operation? What are the sources of these machines?)
- machinery upgrading (What changes have been made to the machines used over the years?)
- changes in raw materials (Over the years, have there been changes in the varieties of rice and cassava used in the operation? What motivated the changes?)
- changes in the production process (Has there been any deviation from the standard method for preparing the products?)
- product innovation (What new cassava or rice products have been added to the list in recent years?)
- human resources potential (Who is a skilful processor? Are skilful processors readily available? How are skills acquired?)

The study covered five villages in the Southern Province. Fifty-four cassava processors participated in the study. The survey on rice was mainly in the Freetown area.

Finally, in the analysis of the questionnaire responses, the emphasis was not on the level (quantitative measure) of technological capability but on the evidence of the existence of such capability. This distinction was necessary because the sampling was only in specific regions and a quantitative measure of the regional level of technological capability could be misinterpreted as national.

Cassava products and processing technology

Fufu

During the investigation, two common, traditional methods of *fufu* processing were identified. In one method, the cassava is first peeled and then washed. The washed cassava is grated and fermented for a couple of days. During fermentation, the pulp is dewatered by applied pressure. In the other method, the peeled whole cassava is first fermented and then pressed into pulp. The latter method eliminates grating and, it was also learned, leads to poor product quality.

Gari

The processing steps for *gari* are similar to those for *fufu*, except that the final stage is the roasting of the pulp. It is possible to produce *gari* by either of the two *fufu*-processing methods, depending on whether a grater is used. However, I discovered that all *gari* processing done in the study area involved some form of grating. This is similar to findings of others in the West African region (Kwatia 1988; Adeboye 1989; Adjebeng-Asem 1989). It was learned that *gari* produced by simply fermenting whole cassavas followed by pulping and parching had very high fibre content and poor taste.

Tui

To process cassava for *tui*, the peeled cassava is washed and cut into chips of various sizes. The chips are dried and ground into flour. This product and its production technique are very similar to those in southwest Asia (Steghart and Wholey 1984).

Hardware for cassava processing

The manufacture of cassava products follows procedures consisting of several unit operations, some of which are used for more than one product. The unit operations are peeling, fermentation, (grating or chipping), drying, milling, and roasting or parching (i.e., browning of material over a fire).

Peeling removes the outer coating of the tuber. This is a very important operation because it considerably detoxifies the remaining tuber (80% of the toxic cyanide is concentrated in the outer coating). Peeling is done with a sharp knife.

One method of fermentation is to soak the peeled tubers in a big container for 3–5 days. The only equipment needed for this type of fermentation is a large, open container. The more common, traditional fermentation technique involves the pulpy materials that come from grating. The pulp is put into woven sacks. Stones and logs are placed on the loaded sacks for a period of 3–5 days to squeeze out the water. The only "hardware" is the sack. Recently, modifications were made to this technique. The changes were in the way the sack of pulp was pressed. The innovative method sandwiches the sack of pulp between two wooden planks, which are tightly drawn together.

Three different types of grating hardware were identified. The choice of hardware was determined mainly by the availability of capital. Many cassava processors still use the manual method of pulverizing the cassava by rubbing it against a perforated, rough metal plate. Another piece of hardware is the hand-operated mechanical grater. A motorized mechanical grater is the third type. The only existing hardware for cutting cassava into chips is a sharp knife. It is a tedious operation and is in need of innovation. Chips are usually sun dried on mats spread either on the ground or on an elevated platform. The traditional equipment used for milling cassava chips is the mortar and pestle. This is very labour intensive and the main hindrance

to the supply of *tui*. Motorized grinding mills are also used in urban areas. The equipment used for the roasting operation is an iron tray sitting on a stove. Sieving is done with a perforated iron plate.

Skills required in cassava processing

There is very little skill involved in cassava processing. Only a knowledge of the steps involved and of the duration of the activities is essential. Mechanical grating, which usually involves some technical skills, is done on a contract basis by grater owners.

Selection of raw materials

There are several cassava varieties. The varieties are distinguished on the basis of the colour of the peel and the taste. Some varieties are highly toxic but have a high yield per hectare. Others have low toxicity and low yield. The processors tend to select the high-yielding toxic variety if they are sure that the processing will effectively reduce the toxicity.

Rice products and processing technology

Rice flour

Rice flour is only an intermediate product used in the preparation of other rice products. According to the report by Massaquoi et al. (1990), rice flour is now sold as an intermediate product because it has a longer shelf life than the final products. Mechanical grinding of the grain is the method adopted in the urban area. The traditional method is wet grinding in a mortar: the grain is first soaked in water to soften it, and then it is pounded in a mortar with a pestle. The wet pulp is dried and roasted for preservation.

Rice bread

Rice bread is prepared like the conventional banana bread, with the rice flour replacing the wheat flour in the recipe. The ingredients are rice flour, banana, baking soda, sugar, salt, cooking oil, and water. The recipe is an important resource — a major component of the technology — and determines the quality of the product. The final operation is baking in an oven.

Rice akara

Akara is a form of pancake. It is prepared by frying a dough prepared with rice flour, sugar, banana, baking powder, cooking oil, and water. Once again, the recipe is a major component of the technology.

Rice kanya

Kanya is a delicious blend of rice flour, peanut butter, and sugar. Roasted (parched) rice flour is ground together with roasted groundnuts and sugar in a specific combination. *Kanya* is the most popular commercial rice product.

Rice pap

Rice pap is boiled rice flour, with lime and water added for taste. The preparation involves little or no skill.

Hardware for rice processing

The following unit operations were identified in processing the various rice products: grinding, mixing, parching, baking, and firing. Two types of hardware are used for grinding: the mortar and pestle for small-scale wet grinding and the mechanical milling machines for large-scale dry grinding (in urban areas). The mill owners do the milling on a subcontract basis. The machines are powered by either an electric motor or a diesel engine. Mixing is usually done with a wooden stirrer in a big bowl. The browning of rice flour or peanuts over a fire usually requires a stove and a shallow pot. The stove is usually a three-stone open fire. The hardware for baking includes a gas or electric oven, converted by the informal-sector metal workers to charcoal, and covered containers, heated on a three-stone stove. Frying is done over an open fire.

Skills required in rice processing

Little or no skill is required in rice processing. The preparation of any of the products involves only the knowledge of the recipes. Even the mechanical grinding is subcontracted to mill operators, who have skilled labour to maintain and repair the machines.

Selection of raw materials

The selection of appropriate raw materials is one of the abilities constituting technological capability. It was discovered during the study that rice processors do not prefer parboiled rice. This occurs because nonparboiled rice can be readily milled. The processor can distinguish the different varieties of rice from their appearance.

Technology adaptations, modifications, and innovations in cassava and rice processing

This section brings together survey evidence of the nature and extent of technological capability. For detailed analysis, I identified five major indicators of technological capability:

- machinery usage;
- machinery upgrading;
- changes in method and (or) system of production;
- changes in raw materials; and
- skills upgrading.

A summary of the observed level of usage of machines in the various processes is presented in Table 1. A summary of the observed changes in machinery, production, and raw materials is presented in Table 2.

Machinery usage

Table 1 shows the total number of unit operations involved in each process. Nearly all processes are carried out manually. Even those processes that involve the use of a machine use no more than one. The use of machines in some cases is made through a linkage with other informal-sector entrepreneurs who operate mills or graters. They carry out certain operations for the food processors on a subcontract basis.

Table 1. Machinery usage.

	Cassava processing			Rice processing			
	<i>Gari</i>	<i>Fufu</i>	<i>Tui</i>	<i>Akara</i>	<i>Kanya</i>	Flour	Pap
No. of unit operations ^a	6	5	5	3	3	1	2
Max. number of machines in entire process (type)	1 (grater)	1 (grater)	1 (mill)	—	1 (mill)	1 (mill)	—
Locally fabricated machines	Yes	Yes	No	—	No	No	—
Evidence of completely manual operations	Yes	Yes	Yes	Yes	Yes	Yes	Yes

^a A unit operation is a processing step (e.g., peeling, grating).

Table 2. Summary of findings on technical changes.

	Cassava processing			Rice processing			
	<i>Gari</i>	<i>Fufu</i>	<i>Tui</i>	<i>Akara</i>	<i>Kanya</i>	Flour	Pap
A. Hardware upgraded							
Machines home-made	Yes	Yes	No	No	No	No	No
Any machine(s) altered	Yes ^a	Yes	No	No	No	No	No
Net result of change							
Increased production	Yes	Yes	—	—	—	—	—
Improved quality	No	No	—	—	—	—	—
B. Method and (or) system of production changed							
Method changed recently	Yes	Yes	No	No	Yes	No	No
Net result of change							
Increased production	Yes	Yes	—	—	Yes	—	—
Improved quality	No	No	—	—	Yes	—	—
System reorganized	Yes	Yes	Yes	No	No	Yes	No
C. Cheaper alternative raw materials substituted							
New material used	Yes	Yes	No	Yes	Yes	Yes	Yes
Net result of change							
Improved quality	No	No	—	No	No	No	No
Motivation for change	Cost	Cost	—	Cost ^b	—	—	—
Production method changed to match raw material	No	No	—	No	No	No	No

^a Dewatering press and grater.

^b And availability.

Machinery upgrading

In cassava processing, some changes have occurred in the equipment used for grating, fermentation, and dewatering of the pulp (i.e., the press). The graters have changed from manual ones to mechanical ones operated by hand and to mechanical ones operated by internal combustion engines. The press has changed from a sack of pulp under a big stone to a wooden clamp, which sandwiches the pulp. No change was reported in the hardware.

Changes in method and (or) system of production

In cassava processing, the only evidence of changes in production methods was for *fufu* and *gari*. The processing methods have changed to achieve increased production rates, without any additional expense. However, the quality of the product has suffered.

In rice processing, the introduction of dry grinding (machine milling) for the preparation of rice flour is an innovation. In the traditional method, rice is produced by wet grinding, followed by drying and (or) roasting. The innovation increases production rates and gives a longer shelf life (J&R Enterprise, personal communication, 1991).

The system of subcontracting certain activities to other informal-sector entrepreneurs is common among urban *kanya* processors. In particular, the grinding and blending are done by machines, on a contract basis. This is an important technological capability because it demonstrates that the processors were able to recognize grinding as a major problem and were able to develop a solution to it. This solution was obviously selected from a range of other options, which would have included purchasing machines, hiring machines, and subcontracting the activity to other entrepreneurs.

Changes in raw materials

To reduce costs, all the processing operations have, at some time, gone through a change in the variety of raw material used. Cheaper varieties that do not adversely change quality were used.

Skills upgrading

Because the level of skill involved in cassava and rice processing is minimal, there is no need for skills upgrading. However, knowledge of recipes in rice processing is essential. Similarly, the knowledge of production methods and duration of activities in cassava processing is very important; knowledge upgrading to improve product quality and production rates was observed. In the case of rice processing, this upgrading entailed mainly changes in recipes, whereas in the case of cassava, it involved changes in duration of activities and production methods.

Conclusions

Technological capability in the informal food-processing sector is very low. The use of machines is not extensive, and major changes have not occurred in either the hardware or the processing. It can be concluded that cassava processing (particularly of *gari* and *fufu*) is more dynamic, with regular and beneficial changes in the processing steps and hardware.

On the whole, the level of technological capability is higher in cassava processing than in rice processing. This high level of technological capability in the informal cassava-processing industry has contributed to the transformation of cassava

products from snacks to main meals. Today, processed cassava products contribute significantly to the staple diet of Sierra Leone. *Gari* and *fufu*, whose processing was found to have the highest accumulation of technological capability, have become the second most important national foods, after rice grain. On the other hand, rice products have remained occasional party snacks.

Even among rice products, the one that has made the greatest impact is *kanya*. The processing of *kanya* was found to have the highest level of technological capability among those of all the rice products. The processing has changed, replacing wet grinding with dry grinding. Where operators cannot afford the machines, they contract out the grinding operation to other entrepreneurs.

Finally, an important conclusion drawn from this study concerned the relationship between the economic significance of the product and the level of technological capability. Without the facts, it may have been easy to conclude that the role of *gari* and *fufu* as main meals was the driving force behind the development of technological capability, in other words, that the rate of technical change depends on the economic significance of the product or industry. However, the results of this study have shown the reverse — at the initial stage of development, the level of economic significance attained depends on the rate of technical change. *Gari* was, until the start of this decade, a simple snack, eaten when it was soaked with sugar and water. Similarly, it was only recently that most people started eating *fufu* as a staple meal. As the technical changes took place in cassava processing, cassava products were produced in larger quantities at lower cost and, hence, became popular substitutes for rice.

Even though sporadic scarcity of rice forced Sierra Leone to look for a substitute staple, that substitute turned out to be *gari* and *fufu* and not *tui* because there was a level (albeit low) of technological capability required to enhance the production level of *tui*.

It is quite likely that if *tui* processors were to introduce innovations to overcome the grinding operation, which has been the main technical constraint, then *tui* could compete with *fufu* and rice. For instance, grinding could be done with machines, and if the operator was unable to afford it, he or she could contract out that activity to mill owners.

Recommendations

The purpose of this section is not to recommend policy but to identify some areas where policy efforts could be concentrated to develop the technological capability of the informal food-processing sector. If the sector is to play a major role in the industrial development strategy of Sierra Leone, there must be policies with the objective of increasing the productivity, growth, and income of these processors. This undoubtedly will involve efforts to improve the present low technological capability.

More use of machines

Most processors would like greater mechanization of their operations so as to reduce the demands on human energy and increase production rates and income. The cost and scarcity of smaller machines to suit their level of operation were considered obstacles. A policy package could make such machines available in the processing operation, either by funding the development of small-scale machines or by advising on the reorganization of the operation to enable some activities to be carried out mechanically on a contract basis.

Changes in products

The short shelf life of the products, especially rice products, is a constraint that affects the production rate. An intermediate product (rice flour) could overcome this problem. However, the promotion of this product will not be easy. There is a need to introduce new products into the market or find new uses for existing ones. For instance, the use of cassava flour as a nonperishable substitute for *fufu* should be encouraged, as was done for *gari* as a substitute for rice.

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CHAPTER 7

Technology Transfer and the Acquisition of Managerial Capability in Tanzania: Analysis and Policy Implications

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Introduction

The idea of international technology-transfer projects (ITTPs) has become a cornerstone of industrial and entrepreneurial development in Tanzania. Such projects have been implemented through the Small Industries Development Organization (SIDO), a parastatal established to develop small-scale industries (SIs) in Tanzania. SIDO's role has been (1) to identify the technological gaps affecting the growth of certain industries; and (2) to seek foreign firms willing to establish a similar or slightly modified enterprise in Tanzania and to act as a guarantor for the project. This mode of transferring technology has been widely studied (OECD 1981; Ranisk 1984; Alange 1987), and the evidence suggests that the transfer of capacity to produce specific items in the recipient country was emphasized. But the issues associated with how the transferred production capacity would be effectively used, maintained, and developed (where necessary) seemed to attract less attention.

A few earlier studies (Vitelli 1979; Bell 1984) examined the extent to which managerial capabilities are acquired through ITTPs. Some of the results lacked convincing empirical evidence because of the research methods used. For example, Vitelli used an indirect method for analyzing licence statistics. The method produced data that bore no direct relation to the subject of the study. Our study of reports on technology transfers and our visits to SIs involved in ITTPs convinced us that transferring the hardware or the capacity to produce specific items has its own problems and is definitely inadequate. Using the transferred capacity to make the system work according to technical specifications and to produce the necessary items to meet the identified needs and wants at a profit is a basic function.

Our study of the literature and our visits to the SIs showed that ITTPs definitely played a significant role in developing technical and managerial capabilities. Yet, there seems to be no effective method of measuring acquired managerial capability. The approach taken by Vitelli (1979) proved woefully inadequate. The methods used by Alange (1987) indicated what was or was not learned. In the light of these inadequacies, we set out to examine the extent to which ITTPs facilitate the development and use of managerial capabilities.

Concepts and methodology

Definition of managerial capability

Managerial capability is a management quality essential to running new or established industries. Managerial capability is a person's ability to perform specific and general management functions; of these functions, we chose to study production, marketing,

financial management and control, and leadership. The ability to expertly perform each of these management functions depends on the use of

- the stock of knowledge the manager has;
- the skills the manager has acquired;
- the experience the manager has accumulated in similar endeavours; and
- the type of training the manager has had (for the task to be performed).

Managerial capability is defined as the knowledge, skills, experience, and training a manager has to perform management functions.

Definition and measurement of capability factor

We measured each capability factor — knowledge, skills, experience, and training — by awarding points to empirically measurable variables:

- knowledge — measured by academic qualifications, which varied from a certificate to a degree;
- skills — measured by actual performance of a task, quality of the end product, and possession of a professional award;
- experience — measured by the number of years a person has been exposed to similar management situations;
- training — measured by time spent in training on the job or outside it.

Furthermore, each capability factor was perceived as having two time-related aspects. One of these aspects was what the manager was before joining the Small-Scale Industrial Programme (SIP). The pre-SIP period t_0 was taken as the 10 years preceding the time an entrepreneur was selected for the SI project. The post-SIP period t_1 starts from the point of selection and continues to 1988. This is roughly 10 years with few variations, depending on when an SI was started. Thus, by weighting pre-SIP by the factor $w_0 = 0.4$ and post-SIP by the factor $w_1 = 0.6$ and summing them up, we obtain the value of a capability factor. For example, the knowledge component is measured as

$$\begin{aligned} K_t &= w_0 K_0 + w_1 K_1 \\ &= 0.4 K_0 + 0.6 K_1 \end{aligned} \quad [1]$$

where K_t = stock of knowledge at the present time, t . By computing the scores for each of the capability factors and summing them, we can express the capability value for performing each management function as follows:

$$C_f = K_{it} + S_{it} + E_{it} + T_{it} \quad [2]$$

where C_f is the functional capability; K_t is the score for knowledge; S_t is the score for skills; E_t is the score for experience; T_t is the score for training; t is time; and i is the capability factor, that is, $i = 1, 2, 3$, or 4 (knowledge, skill, experience, or training).

The managerial capability of a management team or, therefore, of a given SI is obtained from the following formula:

$$C_{Sj} = K_{ijt} + S_{ijt} + T_{ijt} \quad [3]$$

where C_{Sj} is the managerial capability of a management team or of a given SI; j is the selected management function, that is, $j = 1, 2, 3$, or 4 (leadership, production, financial management and control, or marketing); and the rest of the variables have the same meanings as in eq. [2].

Field survey and application of the measurement model

Three industrial estates managed by SIDO in Dar es Salaam, Moshi, and Arusha were visited. In each estate, five SIs were randomly selected. The SIs in Moshi and Arusha industrial estates participated in an ITTP sponsored by Swedish industrial concerns. The SIs selected from Dar es Salaam industrial estates had access to different kinds of technological assistance from Indian enterprises. These SIs manufactured various products, ranging from metalware to paper and rubber products. In each SI, the following functions of the management team were identified:

- function 1 — general manager, managing director, or the manager who provided leadership;
- function 2 — production manager or director;
- function 3 — financial controller or chief accountant; and
- function 4 — marketing or sales manager.

In Dar es Salaam industrial estate, the five management teams did not fit the list above. In three of the five SIs the team members performed both functions 1 and 2, functions 1 and 3, or functions 3 and 4. In the analysis, they were treated as individual persons performing different management functions, though a single measurement value was used.

Members of the management teams of the 15 SIs were interviewed about their management functions. We obtained data and information on other aspects of the SIs by reviewing the literature and interviewing knowledgeable persons at SIDO headquarters and the Ministry of Industries and Trade. The interviews and data processing were carried out between September and December 1989.

Discussion of the findings

This section assesses the qualitative impact of ITTPs on capability development and the performance of the management teams of the enterprises studied.

Leadership capability

Leadership capability is the ability of the management team to direct the affairs of the enterprise. This requires an entrepreneurial vision that would always place the team leader a step ahead of the team members. Leaders are normally high achievers, risk takers, and original thinkers (innovative, creative, and perceptive) (Meredith et al. 1982). These qualities motivate the team members and other employees of the SI to work effectively. The importance of leadership capability cannot be overestimated, as prosperous organizations like IPP Ltd (Tanzania) and Afrocooling System Ltd (Tanzania) have shown.

In this study, we studied the issue of leadership by conducting in-depth interviews with the managing directors and general managers, most of whom were the entrepreneurs selected and trained by SIDO to start the SIs. The selected entrepreneurs had different levels of knowledge and experience and fairly good skills in leading groups of people to achieve organizational goals. Depending on the different levels of SI need, the duration of training these managers received abroad or in Tanzania also varied. The achievements of the SIs are an indicator of the strength of this leadership. The specific achievements we measured were the following:

- leadership — measured by the ability to think ahead, the ability to analyze present trends, the ability to forecast future trends, and the ability to direct the development of the SI;

- production — measured by the extent to which technical capability was assimilated (expressed by the number of new products added and their quality and quantity);
- financial management and control — measured by the ability to forecast sales and cash flows, the ability to identify new investment opportunities, and the ability to mobilize financial resources from local financial institutions; and
- marketing — measured by the extent to which new products were added to the original set of products assembled or manufactured and the extent to which products were marketed abroad (i.e., export drive).

There was evidence of high levels of leadership traits in all the SIs studied, especially in Arusha and Moshi. The only exception seemed to be Endelea (Dar es Salaam), which had the lowest score, about 5.5. Northern Electrical Manufacturers Ltd (NEM) scored the highest, about 12.5.

Fabricated and Wire Products Manufacturing Ltd is an example of an SI that had the ability to identify new investment opportunities. In a bid to acquire new technology, it sent its managing director to Sweden for training in new investment policies and ventures.

Nearly all the SIs had added at least one new product to the original list of products they had assembled or manufactured. NEM had a desire to market the SI's products abroad, so it sent the managing director and production director to Sweden for training in export marketing and new product lines.

Production capability

Selected SI entrepreneurs had different levels of knowledge, skills, experience, and training — some of them had been associated with other industries as either owners or employees. The lowest pre-SIP production-capability scores, 2.46 and 2.88, were obtained by Handmade Paper Ltd and Endelea Sheet Metal Company Ltd (both in Dar es Salaam). In a second group, the production-capability scores were slightly better: 3.29 for Tanza Saws Ltd (in Dar es Salaam), 3.29 for Tanzanian Locks and Metal Products Co. Ltd (in Moshi), and 3.88 for AMOCO (in Moshi).

A third group of SIs (three from Arusha, two from Dar es Salaam, and two from Moshi) scored still higher: from 4.18, obtained by Northern Packages Ltd, to 4.88, obtained by Arusha Hot-Dip Galvanizing Company (AGACO). A fourth group of SIs (two from Arusha and one from Moshi) scored on average >5 production-capability points.

The results show that production capabilities differed from one enterprise to the next. This is very much expected because of differences in the technical complexities and in the extent to which operators adapted them to their own capabilities or to the environment (e.g., the opportunity to use different raw materials or to manufacture other products). The results also showed that SIs in the Moshi and Dar es Salaam industrial estates reflected these levels of technical capabilities.

Financial-management and control capability

The management personnel responsible for financial management and control take charge of all the financial and accounting matters of the enterprise. This involves planning its financial requirements and methods for raising and investing funds to achieve the enterprise's objectives. Control measures involve planned levels of profit, cash flows, and financial ratios (assets turnover, current ratio, and return on equity). These personnel also examine the financial performance of the enterprise and prepare

relevant performance reports.

In the SIs studied, we noted that few financial positions were occupied by people with accounting or finance qualifications with an academic or professional degree and considerable experience. NEM and AGACO, though, employed highly qualified (academically and professionally) personnel. The pre-SIP financial-management-capability score of AGACO was 7.08; that of NEM was 6.84, the second highest.

Other SIs employed personnel that were not as highly qualified and had little on-the-job training. In this group, the pre-SIP scores ranged from as low as 2.47, obtained by Endelea (Dar es Salaam), to 7.08, obtained by AGACO (Arusha). Among the three industrial estates, the scores levels were lowest in Dar es Salaam, after Arusha and Moshi. All the SI accounts showed high administrative and overhead costs. This factor seriously undermined the liquidity positions of most of them, especially GIFCO (an ITTP in Arusha), Handmade Paper Ltd (Dar es Salaam), and Kilimanjaro Electroplates Ltd (Moshi). The accounts of these SIs showed losses during the 1980s.

Marketing capability

The products from the SIs were intended to replace those previously imported, so the markets for these products were assumed to exist. However, marketing personnel needed to have some capability to

- recognize his or her role in making the SI a success;
- identify the existing and new markets for the products and services;
- ascertain how such markets were being serviced previously;
- know what other environmental factors need to be considered; and
- develop suitable strategies to match the products and services with the specific market.

The marketing function contributes immensely to the SI's profitability by maximizing sales and minimizing marketing costs. For sales to be maximized, there must be a good marketing program, which, among other things, considers such policy parameters as the quality of the product, its quantity, its price, the location where it will be displayed for sale, and its promotion. The marketing or sales manager needs to manipulate these parameters to achieve a strategic fit between the enterprise and the target market that is very likely to attract maximum sales.

The pre-SIP marketing-capability scores varied between 2.47, obtained by Endelea Sheet Metal Co. Ltd (Dar es Salaam), and 6.48, obtained by AGACO (Arusha). The scores divide the 15 SIs into roughly three groups. One group included SIs from the Dar es Salaam industrial estate, which on average scored <3 capability points. Another group of SIs, from the Arusha industrial estate, scored ≥5 capability points.

From the sales statistics, we observed that the trend has been moving upward but differs from one SI to another. In 1988, for example, the sales value ranged between about 180 000 TZS (in 1995, 580 Tanzanian shillings [TZS] = 1 United States dollar [USD]) for Handmade Paper Ltd (Dar es Salaam) to about 56 000 000 TZS for NEM, which scored about 5.5. These sales figures also reflect the extent to which management was involved in developing and using capable marketing personnel. NEM employed skilled and knowledgeable marketing personnel. The director of marketing holds a diploma in business administration (marketing option) and has a long working experience (15 years) in marketing. There is an export manager with the same qualifications but less experience in the marketing field. Both

the managing director and the marketing director have had training (in Sweden) in marketing and export marketing. The marketing manager uses the marketing-mix variables to considerable advantage.

The other SIs have different arrangements for applying their marketing capabilities. AGACO has no marketing department; the accounts department is responsible for sales and all marketing activities.

Most SIs in Dar es Salaam depend on both solicited and unsolicited orders. Made-to-order selling practices tended to limit the use of dynamic marketing strategies to expand existing markets and product assortment. These selling practices also limited the exploitation of the potential production and technical capabilities of the enterprise. It was not possible to ascertain the effect of low application of marketing capability on the efficiency of production techniques because different SIs use different measurement units, such as pieces, units, metres, and pounds. But the extent of product mix, which was wider among SIs in Arusha than among those in Moshi and least among the SIs in Dar es Salaam, gave us a good impression of the use of production techniques and technical capabilities. The same indicator also could explain the importance that different management teams attach to the role of marketing capability in enhancing the efficiency of technical capabilities.

Successful use of the marketing capability has tended to move sales higher from one year to the next. For example, AGACO (in Arusha) increased its sales from nearly 3.55 million TZS in 1983 to 12.9 million TZS in 1988; in the same period, NEM (in Arusha) increased its sales from 36.2 million to 56 million TZS. The SIs in Moshi showed an improved sales record, as well. Tanzanian Locks and Metal Products Co. Ltd increased its sales from nearly 2 million TZS in 1983 to an estimated value of more than 11 million TZS in 1988. Handmade Paper Ltd (in Dar es Salaam) increased its sales from less than 120 000 TZS in 1983 to about 300 000 TZS in 1984. Unfortunately, it could not sustain the momentum, and its sales dropped to an estimated value of less than 180 000 TZS by 1988.

Managerial capability

The study approach enabled us to examine the structural components of, and the relationships among, the factors forming a capability trait. These capabilities have been proven necessary for the management of established as well as new enterprises. Managerial capability factors are a person's knowledge, skills, experience, and training. These capability factors complement each other, eliminate deficiencies, and improve the overall level of a person's or management team's capabilities. Ideally, a person is expected to have a complete set of high-level capability traits. But is this actually possible?

Our studies (Mapima 1986, 1987) have shown that management personnel may have different levels (high, medium, or low) of each of the four capability traits (factors). These could be carried over in performing the different management functions, which in turn could affect the efficiencies of the management teams that run the SIs. Lack of *esprit de corps* among management personnel in some of the SIs (in Dar es Salaam, especially) accounted for different levels of performance. Since individuals have different levels of capability, it becomes obvious for the entrepreneur, who is also the general manager or managing director, in most cases, to build up management teams that serve to make up for individual deficiencies. Research findings on new industry start-ups (Utterback 1982; Alange 1987) revealed the importance of having groups of management personnel with complementary abilities to increase the likelihood of success. These results are not unexpected because the theory and practice of enterprise management emphasize a complementary mix of

different capabilities. It has been SIDO's policy to select a team of SI entrepreneurs with complementary capabilities, although technical knowledge and experience have been emphasized as selection criteria (Alange 1987).

SIP's contribution to the development of managerial capability

The literature contains different approaches to assessing the impact of ITTPs on capability development. In this section, to highlight the impact of the SIP on the development of managerial capabilities in SIs, we compare our findings with the results of Alange's (1987) study.

Results of the present study

The present study estimated the values of managerial capabilities brought into a project (pre-SIP) and those acquired through it (post-SIP). The study showed that four different modes of capability acquisition were prevalent:

- Some managers received formal training in Tanzania and Sweden, where they were exposed to a capability-building process, which emphasized the acquisition of knowledge and techniques.
- Most managers acquired the specific skills and knowledge they needed for solving problems, making decisions, or accomplishing specific tasks (e.g., for manufacturing, accounting, pricing, and maintenance) through learning by doing at the work place.
- Some managers consulted knowledgeable and experienced persons to obtain information or advice. Another way of acquiring information or advice was to consult documents (e.g., manuals, contracts, and technical brochures) about production processes, marketing techniques, and maintenance practices.
- Most SIs hired personnel with the requisite knowledge, skills, and experience to train other employees in the SI and perform specific managerial functions.

For the 15 SIs, we determined the total capability stock by adding together the pre-SIP and post-SIP capability scores. The maximum possible combined score was 80 for the four managerial functions. The level of capability stock in each SI was rated as *very high* (70–80), *high* (55–69), *medium* (40–54), *low* (26–39), or *very low* (25 or less).

With this classification, 60% of the 15 SIs had a medium rating, about 26% had a low rating, 6.7% had a very low rating, and a further 6.7% had a high rating. In six industries analyzed, the combined capability stocks varied from a low level of 38.8 (48.5%) at Tanzanian Cyclebells Manufacturing Ltd (in Dar es Salaam) to a high level of 68.9 (86.1%) at NEM (in Arusha).

The main sources of capability acquisition were local industrial and entrepreneurial activities. SIDO played a great role in upgrading the capabilities of the SIs. Quite a number of them, such as Arush Metal Industries, Fabricated and Wire Products Manufacturing Ltd, and NEM, had considerable experience and capabilities in supervisory, accounting, and technical areas.

Like Alange (1987), we also observed that the SIP had made substantial contributions through its training programs in both phase I and phase II (at different times), its initial supervision, and its continued contacts with the SIs. The SIP's contributions were mostly felt in the build-up of production and administrative capability. In specific cases, the program helped develop other capabilities, such as

entrepreneurial and accounting capabilities in Mwalongo and Partners and export-marketing in NEM.

To ascertain the contributions of the SIP to the build-up of individual industrial capability, we evaluated in relative terms the shares of the cooperating industry. The SIP contributed only 40% to NEM's total capability, the lowest in the cases studied. Its entrepreneurs had higher pre-SIP knowledge, experience, and skills than other SI entrepreneurs and were, therefore, better placed to benefit from the training and advice provided through the SIP. The highest contribution, 62.4%, was observed at Mwalongo and Partners.

Alange (1987) examined four different types of capabilities: production, innovation, administration, and entrepreneurship. Table 1 indicates that the entrepreneurs had different backgrounds and capabilities before joining the SIP. The table shows that NEM had a comparatively capable management team. During the SIP period the management teams acquired various capabilities, which started with production in phase I.

Table 1. Contribution of the Small-Scale Industrial Programme (SIP) to capability acquisition.

Small-scale industry ^a	Pre-SIP capabilities	Capabilities contributed by SIP			Missing capability
		Phase I	Phase IIA	Phase IIB	
AMI	PIA	P	PIA	PIA	E
FAWIPMA	PAE	P	PIAE	PIA	
NEM	PIAE	P	PIAE	PIE	
TANLOCKS	PAE	P	PA	PA	I

Source: Alange (1987, pp. 140–144).

Notes: P, production; I, innovation; A, administration; E, entrepreneurship.

^a AMI, Arusha Metal Industries; FAWIPMA, Fabricated and Wire Products Manufacturing Ltd; NEM, Northern Electrical Manufactures Ltd; TANLOCKS, Tanzania Locks and Metal Products Co. Ltd.

The most important point to note is that phase II contributed more dynamic capabilities, in most cases, than phase I. To give this aspect more credibility, Alange (1987) computed other values (Table 2), where an SI's pre-SIP stock of managerial capability was given points based on a continuum of 0–100, and the SIP's relative contribution was given a score from 0 (no contribution) to 1.0 (total contribution). The last column in Table 2 illustrates the order of magnitude of SIP's contributions to managerial capabilities. Both methods of assessment indicated that the SIP made considerable contributions to the capabilities of the entrepreneurs.

Policy implications and conclusion

There is no doubt that the ITTPs transfer technical, managerial, and other capabilities. However, in examining the Tanzanian cases, we had to develop a model that, as the results indicate, made it convenient to measure managerial capability in terms of knowledge and skills. By applying the model to SI cases, we observed that levels of capability vary among individuals in a given SI management team and across different enterprises. The successful application of acquired managerial capabilities would be better achieved through management teams, where members complement each others' abilities.

Table 2. Numerical values for the contribution of the Small-Scale Industrial Programme (SIP) to capability acquisition.

Small-scale industry ^a	Stock of capabilities (x)	SIP contribution (y)	Value of SIP contribution (x × y)
AMI	Medium (60)	Considerable (0.7)	42 (70%)
FAWIPMA	Medium (60)	Considerable (0.7)	42 (70%)
NEM	Very high (100)	Limited (0.4)	40 (67%)
TANLOCKS	Low (40)	Considerable (0.7)	28 (47%)

Source: Alange (1987, p. 144).

^a AMI, Arusha Metal Industries; FAWIPMA, Fabricated and Wire Products Manufacturing Ltd; NEM, Northern Electrical Manufactures Ltd; TANLOCKS, Tanzania Locks and Metal Products Co. Ltd.

Our results indicate that the SIP enabled the SI entrepreneurs to acquire additional capabilities in the managerial functions: production, marketing, financial management and control, and leadership. The SIP focused primarily on developing production capability. Production capability includes technical know-how, skills, and knowledge of machinery, equipment, and processes. Capabilities in the other managerial functions were either acquired tangentially or through hiring qualified personnel to meet the capability needs of the management teams.

The results have several implications for policy:

1. Managerial capability is an essential prerequisite for determining the choice and acquisition of technology. Thus, it is correct for SIDO to define enterprise size in terms of the control and management capabilities of Tanzanians. The importance of this fact should be recognized by those formulating policies on technology development, acquisition, and transfer.
2. Policy makers may have to emphasize the importance of including training in all technology deals. The essence of transfer is embodied in the acquisition of the knowledge and skills needed to operate or redesign acquired hardware. Without training and skills development, the transfer of technology may not be effective.
3. The training component should always address specific knowledge and skill deficiencies, which should be identified before a deal is drawn up.
4. The relevance of any technology acquisition or transfer should be appraised, *inter alia*, on the basis of the transfer project's contribution to managerial capability.

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CHAPTER 8

Formulating Technology Policy in Africa: New Directions

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Introduction

In 1980, the “Lagos Plan of Action” (LPA) took note of the appalling state of most African economies and attributed this to a lack of industrial development. The LPA further identified science and technology (S&T) as critical elements in economic and industrial development. It has been many years since African countries adopted the LPA as a broad framework for economic and industrial development. Africa’s Development Decade is soon coming to an end, but Africa remains the least developed continent in the world, despite its abundant resources.

This paper will discuss the technology policy for national economic and industrial development. It will argue that the central factor in Africa’s underdevelopment is its failure to formulate and implement the strategic technology policies needed for economic and industrial development. Most development strategies adopted by African countries do not nurture the potential of local technological capacity to sustain both economic and industrial development.

Background

Past and present perceptions of economic and industrial development in most African countries have tended to marginalize or totally ignore the critical role of technology policy. In this section, we shall look at how such notions as national industrial development and technology policy have been perceived or ignored by African countries.

National economic development

Before the demise of colonial empires, most African economies were seen as mere extensions of the economies of the major industrial colonial powers. As a result, the planning of economic development was left to the colonial powers. In the capitalist system, these African economies played specific roles, mostly producing tropical agricultural crops and mineral products for the markets of the colonial powers. Technologies for producing these products were designed by commercial interests and mining companies, which controlled a strategic position in the circuits of production.

However, at independence, African countries attained discretionary power to plan their own economies. During the early decades of independence, modernization became the dominant development paradigm. Put briefly, the modernization theory saw underdevelopment as being largely due to the low levels of capital formation, resulting in a small, modern (monetized) sector and a large subsistence sector. Economic development was seen as the gradual expansion of the modern sector. This was to be achieved through primary production, which would expand to the point where industrial production became the dominant sector in the economy. Indicators

of this form of development were measured in terms of growing per capita income and increasing levels of per capita consumption of industrial products, such as steel and cement.

This type of economic development implied levels of planning to reallocate factors of production. It also implied the belief that the barrier to economic development was largely due to the archaic structures of the developing countries. Thus, the process of economic development was to instil modern norms and attitudes not only in the marketplace but also in social, cultural, and political spheres.

However, this perception of development was challenged by those who saw the central problem as the persisting structural relationships between developing countries and the developed countries. These writers developed their own corpus of literature, which became known as the dependency school. This school of thought rejected the view that economic development meant being more like the West. Furthermore, it was argued that as long as these structural relationships continued, becoming more like the West would become more and more difficult. These writers saw no value in economic growth that was not accompanied by equity. According to their vision, economic development rested in the capacity of developing countries to disengage themselves from the West and strike out on their own.

The current perception of economic development has largely been inspired by the past failures of most Third World countries to escape from the poverty syndrome. The poorest countries (most of which are in Africa) have for the past decade been showing negative economic growth rates, experiencing balance-of-payments deficits, and accumulating huge debts with multilateral and private financial institutions. These circumstances have fuelled a new orthodoxy, which holds that economic development in these countries is only possible if market controls are removed and market forces are given a free hand in the economy. The removal of structural rigidities would thereby lead to efficient allocation of resources.

Industrial development

For each of these perceptions of economic development, there is a different industrial development strategy. However, all agree that industry is a critical factor in economic development. For the modernization school, industrial development is seen as the critical factor, which could usher in a state of mass consumption and break down the vestiges of traditional life and the subsistence economy. Import-substituting industrial development is the preferred model. In this model, developing countries are urged to locally manufacture goods: first, by importing capital equipment and semiprocessed materials; second, by substituting locally produced inputs for imported ones; and third, by locally manufacturing the capital goods. Unfortunately, this type of industrial development has not taken place in the manner envisaged. Instead, the efforts to realize import-substituting industrial development stopped at the assembly stage. As a result, there was continuing reliance on externally generated inputs and technical services. This gave credence to attacks from the dependency school on the efficiency of this path of development.

The industrial development strategy of the dependency school is concerned more with the development of industries that use locally generated raw materials and that meet local mass-consumption needs. There is a great emphasis on the need to integrate industrial and agricultural activities, to establish small-scale and labour-intensive industries, and to rationally use already existing industrial capacities. However, despite the brave attempts to implement this form of industrial development strategy in a number of African countries, not much has been achieved in industrial growth or economic development.

The more current view of industrial development places great emphasis on export-led growth. This industrial development strategy is inspired by the notion of comparative advantage; it is suggested that the comparative advantage of the poor countries lies in the cheap labour and raw materials available in these countries. Consequently, the industries that are being encouraged are those that exploit these cheap resources to maximize the country's comparative advantage in the international market. This approach to industrial development has resulted in an inordinate emphasis on the export market, at the expense of the domestic market. As a result, it is not uncommon to find critical shortages of domestic goods in the countries taking this approach. Also associated with this approach is a high rate of inflation induced by international prices putting excessive pressure on domestic prices.

Technology policy

The failure to achieve higher levels of industrial development in most African countries, despite the different industrial development strategies adopted, has largely to do with the lack of appreciation of the role technology plays in economic and industrial development. This is largely due to the fact that mainstream economics, which has had a major influence on economic and industrial development theories and models, treats technical and institutional change as factors largely exogenous to industrial and economic development. Consequently, there has been no serious attempt to formulate and implement technology policies as integral parts of the development process.

In general terms, a policy is an official statement with a specific purpose, a set of objectives, defined goals and outcomes, and a set of criteria for choosing among competing alternatives. However, what distinguishes a policy statement from mere wishful thinking is the fact that a policy statement is backed by a policy instrument. A policy instrument is made up of three components: a legal device, an organizational framework, and an operational mechanism. The legal device (act, decree, or statute) gives a policy its normative force. The organizational framework (state structure or ministry) ensures the implementation of a policy after it has been adopted. The operational mechanism (government department or directorate) oversees the day-to-day implementation of a policy. Furthermore, policies take two forms: explicit and implicit. An explicit policy aims at inducing a direct effect to achieve a specific goal, whereas an implicit policy is aimed at another area of activity but has residual effects.

Mlawa (this volume) has pointed out that explicit technology policies have three primary objectives: the management of international technology transfer; the execution and management of technical change; and the acquisition of technological and managerial capability. Implicit technology policies, on the other hand, include all those aimed at inducing the general development of economic, cultural, ecological, and demographic activities in society, with residual effects on the technology transfer process, the management of technical change, and the nurturing of local technological capacity.

Technology and industrial development

Although it is true to say that mainstream economic theory treats technology, especially technical change, as a residual or exogenous factor, the history of industrial development cries out very loudly about the interrelationship between technology policy and industrial development. Students of the industrial revolution have observed that although the industrial revolution was a continuous process, beginning around 1800, four stages can be discerned. Each stage had its key industries (technology) and

geographical location.

The first industrial revolution (1780–1840) was based in the United Kingdom, and its key achievements were the steam engine, the textile industry, and mechanical engineering. The second industrial revolution (1840–1900) was based in Europe (England, France, and Germany), and its key achievements were railways and the steel industry. The third industrial revolution (1900–1950) was based in the United States, and its key achievements were the electric engine and industries manufacturing heavy chemicals, motor cars, and consumer durables. The current phase, the fourth industrial revolution (1950–2000), is based in the Pacific Basin (Japan and California), and its key industries are synthetics and organic (petroleum) chemicals.

What is important to note here is that during the third and fourth industrial revolutions, we saw the integration of S&T in the key industries, as well as growing centralization and concentration of the industrial capital and its institutions: the multinational corporations. Consequently, it is legitimate to say that S&T and industrial and economic development became fused in one socioeconomic process.

Technology policy in industrialized countries

Although there was apparently a lack of explicit technology policies in industrialized capitalist countries during the early phases of industrial development, many implicit technology policies were adopted as part of the restructuring of preindustrial society. One illustration of this is the adoption of various educational policies that had a direct bearing on industrial and economic development.

In the United Kingdom, the introduction of a stratified educational system, based on the public and comprehensive schools, ensured the stability of the class system for the development of British industry. The public schools, with their emphasis on leadership and classics, were meant to train those who would become captains of industry, and the comprehensive school system was designed to produce industrial workers.

In the United States, the adoption of a liberal education was instrumental in producing a modern industrial labour force, whereas the technical colleges in Germany, which had very strong links with industry, were instrumental in preparing a labour force suited for the development of scientific industries. Other technology-related policies — including such practices as the control of the movement of skilled personnel; the advocacy of trade liberalization or trade barriers, depending on the relative power in the marketplace; and the various state support schemes for innovators and inventors — helped to foster conditions conducive to industrial and economic development.

However, it was in the late-industrializing nations, such as the former Soviet Union and Japan, that more explicit technology policies were advocated as an integral part of industrial and economic development. For example, in the former Soviet Union, the economic-planning instrument (the 5 year plan) is specifically designed so that economic and industrial development planning can respond to new technical innovations. This is done through the technology plan, which comprises the following components:

- scientific research and experimental-design work;
- introduction of S&T achievements into the national economy;
- enhancement of material and technological aspects of scientific work to ensure that such advances increase mechanization and automation of production;
- financing of S&T research;

- capital investment in the development of S&T; and
- training of S&T personnel.

It could be argued that all industrialized countries, whether they be market or planned economies, have both explicit and implicit technology policies aimed at enhancing their industrial development process.

Technology policy in newly industrialized countries

The newly industrialized countries, such as South Korea and Brazil, have, despite being market economies, also adopted explicit technology policies directed at (1) managing technology transfer, (2) managing technological change, and (3) developing local technological capacity. Because of the international division of labour, these policies have tended to be directed at critical issues.

The management of international technology transfer

The policies for managing international technology transfer deal with issues connected with the search for, and selection of, the most appropriate technical system, as well as the negotiation of the best terms for the relocation of imported technical systems.

The management of technical change

The policies for managing technical change attempt to ensure that once the technical system is relocated, the host country, industry, or firm is able to assimilate and adopt the technical system. Furthermore, the policies also see to it that imported technical systems are easily replicated (diffused) in the national economy and that, in the long run, it is easy to make innovations based on such technology.

Development of local technological capacity

The policies for developing local technological capacity are intended to develop human resources, an S&T infrastructure, and a dynamic industrial infrastructure.

The types of policy are interrelated and cannot be tackled sequentially or piecemeal. However, it is also important to note that it is through state mediation that such policies are formulated and implemented.

Technology policy in African countries

It was only after independence that people in African countries began to talk about the importance of technology development in their plans for national economic development. A number of countries, such as Egypt and Kenya, have formulated explicit national technology policies. It is also true that most African countries have made statements declaring the importance of technology in their development efforts. However, these statements do not amount to national technology policies.

Even in those countries that have adopted explicit technology policies, one finds that such policies are not implemented. This is largely due to

- poor understanding of the relationship between technology and economic and industrial development;
- unrealistic understanding of the nature of the dynamic industries and their technological requirements;
- dependent economies and structural imbalances; and
- a serious absence of strategic indigenous programs of action for overcoming underdevelopment.

This poor showing is due to unresolved technological problems in the areas that form the basis for any realistic national technology policy.

Areas forming the basis for technology policy

To facilitate economic and industrial development, technology policy must take into account three critical areas: human resources, S&T infrastructure, and industrial infrastructure. African countries should formulate policies that will nurture these critical areas.

Human resources

The development of human resources is one the most important preconditions for economic and industrial development. This statement is borne out by the fact that some of the small, natural resource-poor European countries are among the most industrially developed countries in the world (many resource-rich African countries, on the other hand, remain among the least developed nations in the world). The development of human resources requires a modern education system and industrial and management training. A modern education system consists of primary, secondary, and tertiary education and technical, vocational, and professional training. A good modern education provides training in scientific and technological thinking. National policies should ensure that people get a modern education.

Industrial training includes all those less formalized training programs and schemes, such as apprenticeship, on-the-job training, in-service courses, and learning by doing. Industrial training, in general, aims at either equipping the employee with the skills needed for a job (training) or giving the employee a chance to acquire skills in a given industry. This training enhances the local capacity to assimilate, adapt, and diffuse imported technologies.

Management training includes formal and informal training aimed at producing a cadre of professional planners and decision-makers at the enterprise and the national levels. However, because management training combines formal and informal training, it has not been viewed as a discipline requiring serious attention: you either have managerial capabilities, or you don't.

Consequently, there has not been any systematic program for training managers. For example, a study carried out to assess the quality of managers in the parastatal sector in Zambia revealed that many Zambian managers did not have the necessary qualifications or experience to run their companies. It also showed that most Zambian managers did not see any need to learn the basic principles of the industry they were appointed to run.

The training of managers and planners is seriously needed. More important, this cadre is central to the management of technology transfer.

The scientific and technological infrastructure

One of the main distinguishing features of the industrialization process is the application of S&T to production. The advent of the industrial revolution was, in fact, a product of this marriage. A community of scientists and engineers is a direct result of the educational system, the efficacy of which is greatly enhanced by an institutional framework. This institutional framework often takes the form of a national academy of science or a national council for scientific research (NCSR). Most academies of science serve as centres of excellence, undertaking fundamental (basic) scientific research and acting as honorary organizations for scientists. In some countries, the responsibilities associated with planning an S&T policy are left to the NCSR. The

functions of the NCSR may also include basic scientific research. Although most African countries have NCSRs (largely in name only), very few have national academies of science.

Applied research, aimed at immediate industrial use, is often carried out in research and development (R&D) establishments. These establishments are owned by governments, intergovernmental organizations, or private corporations. In addition, some laboratories and pilot plants are owned by universities and NCSRs. Although Africa has agricultural research centres and quality-control laboratories, it is ill equipped in applied research.

The translation of S&T information into operating technical systems is usually accomplished by consulting engineering firms. This work is critical to the implementation of industrial projects, and it is a vital element in the scientific and industrial infrastructure, as it plays a central role in the transfer of technology and the management of technical change. The few consulting engineering firms one finds in most African countries are mainly subsidiaries or offices of international consulting firms.

Lastly, information systems are important in the dissemination of S&T innovations; information systems are a vital element in any S&T infrastructure, including general and technical libraries, documentation centres, and various marketing outlets for books and journals. The main functions of such information systems are to collect and make available information on S&T developments from outside the country and to record and store information on S&T developments and innovations made in the country, thus providing a crucial resource to industrial managers, as well as the consulting firms.

The industrial infrastructure

A dynamic industrial infrastructure comprises numerous strategic industries in the national economy, including basic metals, chemicals, metal-working, and engineering. The basic-metals industry is often divided into two parts: the ferrous metals (iron and steel) and the nonferrous metals, such as copper, lead, zinc, tin, and nickel. Generally speaking, the basic-metals industry involves mining, metallurgy, rolling, extrusion, and drawing and produces intermediate goods, which are inputs to the metal-working industry.

The chemical industry produces a wide range of intermediate products, which become inputs to an equally wide range of industrial processes. Bernal once observed that the chemical industry is second only to the electrical industry in being transformed by science in this century. By manipulating the molecular structure of materials, the chemical industry is able to produce a greater number of materials in greater purity than found in nature. The chemical industry is strategic because it supplies intermediate goods for the other industries; it is difficult to think of any industrial process that does not use products from the chemical industry.

The metal-working industry is broadly divided into three basic parts: metal forming (forging and foundry), metal cutting (milling and machining), and sheet-metal working (fabrication). This industry is strategic in the production of capital goods and spare parts for industrial plants and equipment.

The engineering industry comprises a number of elements, which together provide the industrial infrastructure with machine-building and technical services. These elements include engineering design and development, tool engineering and production, production engineering, materials engineering, and maintenance engineering. Although these categories are self-explanatory, it is important to note that, together, they translate S&T innovations and developments into new, more

efficient and more economical machines, plants, and equipment. This industry has the capacity to design, adapt, and manufacture the components of new technical systems, as well as repair, modify, and rehabilitate existing industrial plants and equipment. Thus, the engineering industry forms the central pillar of an industrial economy. Unfortunately, it is also an industry that is noticeably absent from most developing countries.

Formulating and implementing a national technology policy

Developing countries have not adopted the technology policies crucial to economic and industrial development. There is need to formulate national technology policies, to put technology at the centre of development planning. We need to establish institutions to formulate and implement these policies and nurture a national S&T capacity. Such institutions would implement the various technology policies suggested in Chapter 5 of the LPA and be responsible for

- planning S&T inputs to other sectors of the economy;
- planning and developing human resources;
- planning and developing a national S&T infrastructure;
- planning and strengthening a dynamic industrial infrastructure; and
- coordinating national and international factors affecting S&T.

Those who are formulating technology policy ought not to confine themselves to planning for research; they should also plan for the S&T requirements of the other sectors of the economy. The principal sectors are food and agriculture, natural resources, industry, energy, transportation and communications, health and sanitation, housing and urban development, and the environment. The institution charged with planning technological inputs to other sectors of the economy would have to work very closely with other ministries and the national planning office to ensure that most, if not all, the technological requirements are taken into consideration and that they are in line with an overall national development policy. A separate unit in the national planning office should be established to deal with these issues.

The development of human resources is also a very crucial component in the development of a national technological capacity. Policy planners should take an inventory of S&T personnel to identify the areas that have a critical shortage and to suggest training programs to offset these shortages. Furthermore, there may be a need to revise and develop school curricula to strengthen the teaching of science and industrial arts. The development of human resources includes the development and strengthening of industrial and managerial training programs, as well as the training of S&T teachers. A directorate for the development of human resources ought to be created to manage these critical tasks.

Developing a national S&T infrastructure comprises three tasks: (1) nurturing a community of scientists and engineers, (2) strengthening the country's R&D capability, and (3) establishing local engineering consultancies. A community of scientists and engineers could be nurtured by a national academy of S&T, which would act as a centre of excellence and stimulate domestic S&T activity. Strengthening a domestic R&D capability would include the establishment of applied-research units in various industries, government departments, and other organizations. As well, the NCSR could be charged with the coordination of these activities. An engineering consultancy capability may provide the link between products of the S&T infrastructure and industry.

A dynamic industrial infrastructure would largely supplement the sectoral policies relating to industrial development. However, many strategic industries contribute not only to industrial growth but also to S&T. Also needed are low-cost technologies — not simple or primitive technologies — especially suited to development of rural areas. Specific policies aimed at strengthening the industrial infrastructure should be administered by a department of the ministry of industry.

Lastly, a national technology centre could have both national and international functions. On the national front, the centre would concern itself more with the dissemination of technological information among the different sectors of the economy and institutions and the mobilization of funds to support domestic S&T activities. On the international front, the centre could be charged with ensuring scientific and technical cooperation, coordinating technological policies at regional and subregional levels, and managing and monitoring of technology transfer.

Critics of such institutions may say that they are a typical bureaucratic response, a futile but classic reflex action of throwing money at vexing yet intractable problems. There is no denying that governments are often in the habit of doing just that. However, the recommendations of this study would not require huge government subventions; such institutions could be financed by an independent industrial development fund supported by all the business houses in a country. This could be achieved by collecting a small percentage of sales from all industrial establishments in the country. The fund would not only raise finances for promoting and planning technological development but also help to create in the S&T community a vested interest in the success of industry — the piper would no longer play just any tune, but the one requested by the people who foot the bill.

Conclusion

It should be emphasized that these reflections are not intended as a comprehensive national technology policy package. What has been attempted is an outline of a national technology policy that may create the conditions for economic and industrial development. Policies do require an institutional framework. Without those institutions, any planning or policy will remain a pipe dream, however elaborate or well intentioned.

CHAPTER 9

Exploring the Potentials of Water Mills in the Grain-Milling Industry in Ethiopia

Dejene Aredo

Introduction

Technology transfer in Ethiopia has meant the importation of largely labour-saving innovations to replace obsolete equipment. Water mills, which used to be the most widespread rural technology, lost their importance when diesel mills entered the rural areas after the Italian occupation of Ethiopia (1936–1941). In large urban centres, water mills were wholly replaced by electric mills. Today, water mills are restricted to virtually inaccessible rural areas. Neglected by policy makers and rural-development practitioners, the technology of water milling survived for decades without access to spare parts or components from the modern sector. Government policy in the 1950s and 1960s encouraged the spread of diesel engine mills by providing cheap, imported fuel. Today, however, water mills are showing some signs of revival in rural areas, following the rise in the prices of fuel and spare parts for diesel mills. It is not yet known how this type of technology has survived the period of massive importation; its immense potential has remained hidden from researchers and rural-development practitioners.

The demand for improved water mills will likely increase when diesel mills become too expensive for the rural poor, whose real per capita income has been declining in recent years. The water mill's social value is expected to rise when imported fuels become more expensive.

The purpose of this study is to explore the hidden potentials of a microenterprise by identifying and analyzing the complementary roles of water mills and modern mills, with a view to instigating further research in the rural, hydro-based grain-processing industry. The specific objectives of the study were (1) to characterize the grain-milling industry in Ethiopia; (2) to identify and explain the relative advantages of water mills; (3) to identify and explain the major constraints on the expansion of water mills; and (4) to propose that further research be done on alternative designs for water mills for the consideration of promoters of rural technology in Ethiopia.

The data in this study were obtained mainly in northern Shewa. The region was appropriate for this study because the earliest mills are still found there, as well as many partly abandoned water mills. I captured a general picture of water mills by undertaking a survey of 12 *woredas* (subdistricts) in northern Shewa. A detailed study of the mills focused on two villages. In one of the two villages, Gedilge, a household survey ($n = 21$) characterized the users and nonusers of the mills. The interviewees were all women. Other sources of information included mill owners, local officials from the Ministry of Agriculture, leaders of peasant associations, and village elders. A mill in the other village, Chaka, was selected to illustrate the mechanics of milling.

Theoretical perspectives

Bagachwa (1991) succinctly reviewed the approaches to technology choice. These were the neoclassical approach, the fixed-factor-proportions approach, and the appropriate-technology approach. The neoclassical approach is based on the model of pure and perfect competition. For developing countries, this implies (1) the adoption of the labour-intensive techniques of production, arising from the assumption that labour is the most important resource in these countries; and (2) the correction of distortions in market prices.

The fixed-factor-proportions approach, which is based on the Leontief–Harrod–Dommar assumption of constant-input coefficients, questions the plausibility of the neoclassical assumption of a near-infinite range of available technologies. This approach rules out the possibility of factor substitution. It draws much of its support from the observation that almost all technological innovations take place in developed countries, where the direction of technological change is toward labour-saving innovations. It is assumed that newer capital-intensive technologies supersede older ones as they become obsolete and unproductive (Romijn and De Wilde 1991, p. 103):

Once modern western technologies are brought into traditional society, they manage to superimpose themselves and compete successfully with local production processes to such an extent that the latter find it difficult to survive.

As a result, developing countries may not have efficient technology alternatives, other than those with the high capital–labour ratios found in developed countries. The efficient-factor combination is considered fixed in the proportions found in developed countries (Eckaus 1955; White 1978; Bagachwa 1991). This type of technology choice creates a state of dependence in which factor proportions in developing countries are determined by patterns of resource endowments in developed countries.

The appropriate-technology approach combines aspects of both the neoclassical and fixed-factor-proportions approaches. The centrepiece of this approach is the assumption that (1) there is a lack of technology tailored to or adapted to the conditions of developing countries and (2) there is a need to develop technologies consistent with the patterns of resource endowment in these countries. An appropriate technology can, in general, be characterized as follows:

1. Appropriate technology should be technically efficient, not wasteful. It should be economically efficient, making the best use of available resources. It should be inexpensive and small scale so that poor people can afford it, leading to a more equitable distribution of incomes and assets.
2. Appropriate technology should be socially and culturally compatible, enhance the quality of life, be satisfying (creativity of work), involve machines that are subordinate to people, use communal rather than individual goods and services, foster social participation, and facilitate deconcentration of power.
3. Appropriate technology should be environmentally sound. It should preferably use renewable rather than nonrenewable energy and raw materials. It should produce durable goods that can be recycled or reused, cause minimal pollution and wastes, and blend into local ecosystems. It should be compatible with the rational, sustained use of the environment.

Hydropower provides a developing economy with opportunities to develop appropriate technologies. It has been noted that “one of the first things a country can do is to assess its opportunities for developing alternative energy sources. In hydropower, the hydrologic studies are basic to the entire process” (NRECA 1980, p. 23).

Hydropower in developing countries (NRECA 1980) has nine distinguishing characteristics: sustainability, dependence on local resources, cost effectiveness, durability, flexibility, simplicity, ability to fit into existing systems, accessibility to isolated rural communities, and ability to meet multiple purposes.

The sustainability of hydropower arises from the fact that it uses a renewable source of energy — water. It is essentially nonpolluting. It is environmentally sound and acceptable. Hydropower makes maximum use of local resources and, thus, compared with thermal-power, is usually much more appropriate for conditions in many developing countries, which face shortages of the foreign exchange required to import fuel oil. Hydropower is largely cost effective and is, to some extent, insulated from inflation. No fuel is required and heat is not involved, so operating costs are low. Approximately 650 kW·h production by a hydropower plant will reduce the requirement for oil (or its fuel equivalent) by 1 bbl (1 bbl = about 0.16 m³). Because of this and the durability of the facilities, a hydropower installation is to some extent inflation proof. Because no heat is involved, the equipment has a long life, and malfunctioning is uncommon. Dams and control works can perform for decades, and limited maintenance is required. Hydropower's reliability and flexibility of operation, including fast start-up and shutdown times in response to rapid changes in demand, makes it an especially valuable part of a large power system of a developing country. The relative simplicity of a small-scale, hydro-based enterprise makes energy instantly available. Small-scale hydropower fits nicely into the energy balance of a country. It can contribute to interregional equity by meeting the needs of isolated rural communities. It can be made available in small installations and with relative ease in remote areas of developing countries. A small-scale hydropower facility can generate enough power for grain milling, sorghum dehushing, and village-level electrification. Hydropower, of course, presupposes the availability of water. Therefore, it is difficult to reach every part of a country with small-scale facilities.

The total energy of Ethiopia is largely obtained from traditional biomass fuels. It is estimated that biomass fuels account for 95% of the total energy consumption, with only 5% coming from modern energy sources. Deforestation is so pervasive that today less than 4% of the total land area of the country is covered by natural forests, compared with 40% just a century ago.

Ethiopia's potential for hydroelectric power is considerable. The gross hydro-energy potential is estimated at 650 TW a⁻¹, which is roughly 8% of Africa's potential. However, the installed capacity of the five major hydroelectric plants is only about 360 MW a⁻¹. Ethiopia's per capita electricity consumption, at about 25 kW a⁻¹, is among the lowest in the world.

Large-scale use of imported fuel has been precluded by the ever growing shortages of foreign exchange. Today, fuel accounts for about one fifth of the value of total import merchandise. Therefore, it is high time to explore the economic potential of small-scale hydropower facilities in rural industrialization. A study conducted by Tebicke and Gebre-Mariam (1990) clearly indicates that where the resource is available near the locality, small-scale hydroelectricity offers considerable advantages over both the grid-extension and diesel-electric sources. Small-scale hydroelectricity sources offer considerable scope for indigenous technical capacity, contributing to lower investment and supply costs, especially in foreign exchange. The same cannot be expected from the alternatives because of the high level of technical sophistication of the diesel and grid equipment components (Tebicke and Gebre-Mariam 1990).

The grain-milling industry in Ethiopia

In Ethiopia, on-farm consumption accounts for as much as 80% of the total output of grain. Quite a substantial proportion of rural households still hand-grind grains, using a stone grinder, or pound the grain into flour, using a pound and pestle. However, in northern Shewa, grain mills are widely used. An important characteristic of the food-processing industry in Ethiopia is the scarcity of commercial milling. Custom milling, which is done by private or cooperative mills in exchange for payment of milling fees, is still the dominant form of food processing in the country. An Ethiopian woman rarely buys flour from shops or mills.

Four alternative types of technology are available in the food-processing industry: hand grinding (or pounding), water mills, diesel-engine-powered mills, and electric-motor-powered mills. Flour for the bakeries is produced largely by state-owned mills. The state gets the grain from imports or from the agricultural sector. In the past, state-owned mills obtained grain through a parastatal, the Agricultural Marketing Corporation. Many rural households are net purchasers of food. Urban dwellers occasionally buy bread (made from wheat) from bakeries. Otherwise, they buy grain from the market and pay to have it ground into flour. In recent years, the private sector and the market system have played an increasing role in the distribution and processing of food grains.

In Ethiopia, industry plays a limited role in the economy. In 1993, the share of manufacturing output in the gross domestic product was only 11%; that of small-scale industry was 4% (Mulat 1994).

Commercial milling is little practiced. Most of the flour required by households is processed by women using the traditional stone grinder, which is backbreaking and time consuming, or by small-scale custom mills. A foreign traveller, observing the grinding of grain in traditional Ethiopia, described it like this:

Women spent much time, and effort . . . in grinding. This was often carried out on hand-mills which consisted of a large fat stone of cellular lava, two feet long and one foot broad, raised upon a rude pedestal of stones and mud, about one foot and half from the ground. The rough surface of this stone sloped gradually forwards into a basin-like cavity, into which the flour fell as it was ground. A second stone, which weighed about three pounds, would be grasped in the hand of a grinding-woman who would move it up and down the inclined stone, thereby crushing the grain and gradually converting it into coarse flour.

Commercial milling is limited to 17 state-owned, large-scale mills (CSA 1992), which produce flour for the urban bakeries. These mills produce mainly wheat flour. One survey reported that 88% of the grain used by state mills was wheat, and the rest was maize (CSA 1992).

Agricultural processing in Ethiopia, which has forward-production linkages, is done in small-scale establishments for two reasons: (1) crops are bulky and heavy and are often perishable, and transport costs can be greatly reduced if agricultural processing is done close to the source of supply; and (2) the highly dispersed pattern of settlement requires dispersed milling establishments. Grain milling is the most widespread power-driven small-scale industry in Ethiopia, in both urban and rural areas. A survey of 11 towns in the country reported that grain mills accounted for 55% of all small-scale industrial enterprises (wood works accounted for 9%) (HSSIDA 1979). In a similar survey, conducted later, this was found to be 64% (HSSIDA 1980). In predominantly rural areas or remote places, grain mills may account for 100% of power-driven enterprises. On the other hand, this proportion falls with the size of urban centres. For example, one survey reported that in Addis Ababa, the largest city in Ethiopia, the proportion of grain mills in the total number of

establishments was only 34%, compared with 55% for all the towns (HSSIDA 1979).

The number of people employed at grain mills is considerable, though the worker–mill ratio is quite small. A survey of 963 small-scale industrial establishments in Ethiopia reported that grain mills provided jobs for 1823 people; all the establishments, including mills, employed 9695 people. In other words, employment in grain mills accounted for 19% of the total employment in industry (HSSIDA 1979). In another survey, grain mills accounted for 51% of the total employment in privately owned small-scale industries (HSSIDA 1985). But this proportion tends to fall with growth in urbanization. For example, in Addis Ababa, where there are many other industries, grain mills accounted for only 9% of the total employment in private industries (Ministry of Industry 1992).

A recent comprehensive survey of small-scale industries in Addis Ababa provided the following information about private grain mills: the average worker–mill ratio was 2.9 (1–12 paid workers); the average capital per mill was 19 826 birr; and the capital per worker was 6771 birr (in 1995, 6.3 Ethiopian birr = 1 United States dollar [USD]). Cooperative mills, however, were found to be quite large: the worker–mill ratio was 14; the average capital per mill was 154 518 birr; and the capital per worker was 11 109 birr. But cooperative mills, most of which are likely owned by urban dwellers and their associations, accounted for only 2.4% of the total number of mills in Addis Ababa (Region 14 Administration 1994).

The number of workers per mill is quite small compared with that in other small-scale industries, as evident from many surveys. In one survey, the average number of workers per mill was 3.4, compared with 10 per establishment for all types of industries (HSSIDA 1979). Another survey suggested that employment in the milling industry averaged 3.3 persons, compared with 6.3 persons per establishment for all types of enterprises (Ministry of Industry 1992). On the other hand, this ratio has been found to be high for commercial mills, which are largely state owned. A survey of enterprises employing more than 10 workers reported that there were 222 people per establishment (CSA 1992).

Wages in the grain-milling industry are small. One survey reported that 86% of the workers employed in the milling industry earned less than 100 birr per month, whereas in the food industry, as a whole, 72% of the workers earned less than 100 birr per month (HSSIDA 1985).

Women's rate of participation in the milling industry is lower than that of men. One survey reported that women accounted for 20% of the total employment in the industry (Ministry of Industry 1992). Also, it appears that women earn less than men. A survey of large-scale mills indicated that women's wages were 82% of men's (CSA 1992).

The contribution of grain mills to the gross value of output of the small-scale industries is quite small, compared with their relative size within the small-scale industrial sector. According to one survey, grain mills accounted for only 6% of the value of the total output of small-scale industries but for 55% of the total number of establishments in the industry (HSSIDA 1979). In another survey, the value of the services provided annually by grain mills amounted to an average of 19 665 birr per mill (Ministry of Industry 1992). The gross value added in the milling industry is also low, compared with that of other small-scale industries. For example, one survey reported that the gross value added in this industry was only 20% of that of coffee- and grain-clearing enterprises (HSSIDA 1979).

Operating surplus is the difference between value added in national account concept at factor cost and total wages, salaries, and benefits (Ministry of Agriculture 1992). The operating surplus of the milling industry was estimated at 48% of that of

the food and beverage industry (Ministry of Industry 1992). In other words, profit per establishment is very likely to be lower in the milling industry than in other types of small-scale industry.

Small grain mills are privately owned. Public ownership is restricted to large-scale commercial mills. This is an area where the private sector played a very important role during the socialization drive of the military regime. In a survey of 11 towns in the country, it was estimated that 86% of the milling establishments were owned by individuals; 10%, by partners; and 4%, by cooperatives (HSSIDA 1979). In another survey, it was estimated that 82% of them were owned by individuals; 8%, by partners; 5%, by cooperatives; and 5%, by training institutions, etc. (HSSIDA 1980). Among cooperatives, peasant service cooperatives play a very important role. Funds for the establishment of grain mills come mainly from the informal sector. Owners of mills make little use of the banking system because banks are not available in rural areas, where 85% of the population lives. In addition, the banks require borrowers to present their books of account to get credit for expansion or new investment; however, 79% of the small-scale industries in 1978/79 did not keep books of accounts. Most of the funds for the milling industry come from the informal financial sector. One survey reported that 97% of the total investment funds come from the owners of the mills (HSSIDA 1980).

Grain mills seem to need small investments. In one survey, grain mills, representing 64% of small-scale establishments, accounted for only 21% of the value of fixed assets (HSSIDA 1980). Working capital requirements are also small. According to one survey, the ratio of working capital to fixed assets in the privately owned industries was 0.12 for the milling industry and 0.35 for the food and beverage industry (Ministry of Industry 1992).

The cost of running a mill is much lower than the cost of running other small-scale industrial enterprises. According to one survey, "industrial" and "nonindustrial" costs of running an average mill were 13 069 birr and 28 975 birr for the whole of the food industry (HSSIDA 1985). Industrial costs, in particular, were found to be very small. *Industrial costs* included cost of energy, water consumption, repair and maintenance, rent, wages and salaries, benefits, and raw materials consumed. *Nonindustrial costs* included postage, telecommunications, and advertisements. The same survey reported that industrial costs per establishment were only one third of that for the food industry as a whole. In contrast, nonindustrial costs were higher for grain mills than for the food industry, amounting to an average of 5014 birr for the grain industry and 4723 birr for the food industry (HSSIDA 1985). The high non-industrial costs of running grain mills could be largely attributed to government policy, which makes the mills pay high taxes. The various types of taxes the mills paid in 1984/85 amounted to 84% of their total nonindustrial costs (HSSIDA). (It is, however, possible that mill owners, like other taxpayers, deliberately overstate the amount of tax they pay when they are interviewed.) The major cost component in the grain mill industry is fuel. According to one survey, about 49% of the total industrial costs of milling establishments is for electricity and diesel fuels (HSSIDA 1985). In urban areas, electricity is used as a major source of power for grain mills. A survey of private industries in Addis Ababa indicated that expenditures on electricity accounted for 71% of the total industrial costs of milling, with diesel fuels accounting for 5% (Ministry of Industry 1992). In large urban centres, diesel fuel is little used in grain milling. Electricity consumption also increases with the size of the enterprise. One report indicated that 55% of the total expenditure of the large mills was for electricity, 23% was for wood and charcoal, and 22% was for other fuels (CSA 1992).

On the other hand, diesel fuel is an important source of power for mills operating in rural areas where electricity is not available. However, the cost of fuel has been steadily rising since the 1970s. Large mills try to overcome this problem by switching to electric power. Nevertheless, the proportion of the total industrial cost of large mills given to energy steadily increased from 5.6% in 1977 to 8.7% in 1981 (CSA 1992).

The milling industry encounters a lot of problems (Mulat 1994), with the result that enterprises operate much below capacity. One survey indicated that grain mills operate at about 40% below capacity (HSSIDA 1980). According to a detailed study of mills in three areas in Ethiopia, actual capacity as a proportion of theoretical capacity was 46% (Lirenso and Aredo 1988). The major problems encountered by the industry can be classified as supply-side problems or demand-side problems. The socialist-oriented military regime, which ruled Ethiopia from 1974 to 1991, discouraged the expansion of small-scale industries. Private mills encountered shortages of spare parts and components. The demand for milling was constrained by shortages of grain and by limitations in household incomes.

A closer picture of the milling industry can be captured by considering the distribution of different types of mills in northern Shewa. In a survey of 122 "peasants' associations," it was found that the average size was about 185 households. A peasants' association was usually established in an area of 800 ha. A group of three to seven peasants' associations formed a service cooperative, often with its own grain mill. However, many of these mills were destroyed at the downfall of the military regime in 1991. There were no peasants' associations without at least one grain mill. The most common type of mill was the diesel-engine mill (1.4 diesel mills per peasants' association), which accounted for 66% of the mills covered by the survey. But most of these mills were installed in small towns and market places, areas accessible by vehicles. Next to diesel mills, water mills were the dominant type of technology, accounting for 29% of the mills. The corresponding proportion in southwestern Ethiopia was 25% (ONCCP 1980). However, the distribution of water mills among *woredas* was uneven, depending on the availability of water and accessibility. Most of the water mills were found in two relatively inaccessible *woredas*, Hagere-Mariam and Mafound. Of the 23 water mills found in Mafound *woreda*, 15 belonged to a single peasants' association, Gedilgie. The average distance from a water mill to the main town was estimated to be a 3 h walk. Electric mills, which accounted for only 5% of the establishments, were limited to areas located near highways. Further details of the milling technology in Ethiopia are given in Aredo (1987), Lirenso and Aredo (1988, 1989), and Aredo and Abebe (1991).

The advantages of water mills

The origins of water mills in Ethiopia can be traced to the mid-19th century, when King Sahle-Selassie of Shewa installed a mill along the Airara River, with the assistance of foreigners. However, its use was prohibited by the clergy of the local religion, who considered the innovation the work of a demon. Water mills had their heyday in the first half of this century, when water mills were the most widespread power-driven industry in Ethiopia. They were also one of the important sources of tax revenue. One testimony to the past importance of water mills is the exceedingly large numbers of abandoned mills in many locations in central Ethiopia. For example, at the village of Gedilge, some 15 km from the town of Debre Sina, six partly abandoned mills were found at a single site along a stream. Today, only one of them functions for commercial purposes.

The importance of water mills declined with the introduction of diesel mills after World War II. Their importance further declined as hydroelectric power stations made electric mills possible in urban areas. However, water mills are far from a dying industry. Recent years have seen their revival in some inaccessible areas. This is, perhaps, because of the sharp increases in the price of diesel fuel and spare parts for diesel engines and also an increase in electricity tariff rates.

Table 1 compares the production capacity, costs, income, number of workers, import dependence, profitability, capacity utilization, and working time of the three types of flour mills (i.e., water mills, diesel mills, and electric mills). Water mills have the lowest capacity; they produce about 9 quintals of flour in a day; diesel and electric mills produce 25 and 45 quintals, respectively. This is based on the assumption that the mills operate at full capacity. Water mills operate relatively slowly. However, the waiting time at a water mill is usually nil because customers tend to leave the grain with the mill owners and collect the flour at a convenient time. Strong personal relations exist between customers and mill owners. In the case of modern mills (diesel and electric), users often come from distant places or from urban centres, where the density of population limits personal relations with owners. The travel time saved by users of water mills is considerable. In the study area, the average number of daily visitors to water mills was 9, whereas that to diesel mills and electric mills was 60 and 210, respectively.

Table 1. Comparative performances of three types of mills.

Variable	Water mills	Diesel mills	Electric mills
Throughput (quintals/day) ^a	9	25	45
Book value of equipment (birr) ^b	1 500	20 000	35 000
Average number of clients (persons/day)	9	60	210
Service charge (birr/quintal)	2	4	5
Daily income (birr/working day)	20	120	178
Number of mill operators	2	3	3
Working hours (h/day)	6	10	12
Waiting time at mill site (min)	Nil	60	60
Running cost (birr/year) ^c	120	12 400	10 371
The degree of capital use (%) ^d	60	28	56
Rate of return (%) ^e	23	16	37
Ratio of net income to gross income	94	20	56
Import component (%) ^f	Nil	79	20

^a Throughput is the quantity of grain that would be processed into flour daily if the mill were operating at full capacity. The working day is assumed to be 8 h.

^b Book values are estimated for different years. The water mills were purchased more than 60 years ago, whereas the diesel- and electric-engine mills were installed very recently.

^c Running costs are recurrent costs, such as wages, taxes, and costs of fuel, electricity, and lubricants.

^d The degree of capital use was estimated by dividing the average amount of flour actually processed by the potential output (throughput) for each type of mill.

^e The rate of return was estimated by dividing net income by the value of fixed capital. In the case of water mills, current value of a mill was taken. The value of the shelter was excluded from the estimate of fixed capital.

^f The import component is the ratio of the value of imported materials to the total recurrent expenditure incurred in a year.

Water mills cater to the needs of the very poor rural households, as evident from the very low service charges these mills demand. In the study area, owners of

water mills charged about 2 birr per quintal for processing grain into flour, whereas owners of diesel mills and electric mills charged about 4 and 5 birr per quintal, respectively. The slow speed of water mills could be offset by the low service charge. Moreover, water mills can service inaccessible regions.

Investment outlays on water mills can be within the reach of the better-off peasant farmers. Table 1 shows that the book value of water mills is very low. Moreover, water mills present an investment opportunity in rural areas, in contrast to modern mills, which tend to be in urban centres. The cost of installing a new water mill is much lower than the cost of installing a modern mill. In one of the study villages, 300 birr was required to install a water mill. On the other hand, to install a diesel mill in the same area would require about 1100 birr. Another advantage of water mills is their very long life span. Most of the currently operational water mills are 60 or more years old. The recurrent cost of maintaining them is very low. The annual recurrent expenditure for water mills averages 120 birr, whereas that for diesel mills and electric mills averages 12 400 and 10 371 birr, respectively. Diesel mills, in particular, are very costly to maintain.

A big advantage of water mills is their greater ability to rely on local resources, making use of almost no direct imports. On the other hand, diesel mills heavily depend on imported fuel and other imported inputs. According to the case studies, the ratio of the value of imported inputs to the total annual recurrent expenditure was nil for water mills. But in the case of diesel mills, imported inputs accounted for 79% of the total recurrent expenditure. This is because of the high cost of imported fuel. Water mills also have high social value because of their use of local materials.

Simple ratios suggest that water mills are profitable. For example, the rate of return to fixed capital for water mills was estimated at 23%, whereas it was 16% for diesel mills and 37% for electric mills. However, the net income from operating a water mill is too small to attract urban-based investors.

Capacity underutilization is common for all types of mills. Diesel mills, in particular, operate much below capacity, mainly as a result of frequent breakdowns and shortages of fuel and spare parts. This study found that diesel mills operate, on average, at 28% of full capacity. Water mills, although they face relatively low demand, perform better (about 60% of full capacity) because they depend on local materials for their spare parts and because their parts and components are much more durable. The shaft, for example, lasts for about 38 years. Its current price is only about 150 birr. The grinder (which is made of a special type of stone) costs about 60 birr and may last up to 6 years.

A water mill can be an important source of income for the farmer. The typical Ethiopian farmer is subsistence oriented and has little cash for purchasing modern inputs and consumer goods or for meeting other types of outlay. A daily income of 20 birr from operating water mills (see Table 1) is vital for the Ethiopian peasant. Income generated by small-scale rural enterprises, such as water mills, can contribute to increased demand for products from the agricultural and other sectors.

Water mills can create off-the-farm employment opportunities for some farm households. In the study area, an average of two people were needed to operate a water mill. In the case of a diesel mill or an electric mill, on average, three people were needed. Fixed schedules are rarely used by owners of water mills because of the often irregular demand they face. The mill owner is assisted by family members or neighbours when there is a peak in the demand for flour. Cash payments are rarely offered to assistants in a society where farm households are little integrated into the market. Modern mills, on the other hand, often pay cash to mill operators.

Water mills are almost invariably located near streams, rivers, or springs because, obviously, they require water as a source of power. Today, they are largely restricted to inaccessible areas. An additional factor in the location of water mills is population density: a reasonable population density is needed to make a mill financially feasible.

The opportunity cost of the land used for a water mill is small. The site is often unsuitable for cultivation or for grazing because of the terrain, which is often very steep. The actual area used as a mill site measures about 50 m². The water discharged from the mill is often used for small-scale irrigation. The area around the mill is typically woody and luxuriant.

The relative advantages of water mills can also be analyzed from the point of view of the customers canvassed in the household survey. The major reasons for using water mills (in order of importance) are (1) personal relations with the mill owner, (2) proximity, and (3) low service charges. Users and mill owners are often neighbours or relatives with strong personal and social ties. Owner–customer relations sometimes involve reciprocity and similar nonfinancial dealings. A woman may frequent a particular water mill simply because she feels that it is her obligation to do so. She may not want to harm the feelings of the owner, who may process her grain for free when she runs short of money.

The catchment area of a water mill is often restricted to its neighbourhood. The lack of transportation to distant places may preclude the use of modern mills, which are located in towns or market places. Poorer households cannot afford the pack animals they would need to transport the grain to town.

Water mills are also attractive to poorer households because the service charges demanded by owners of water mills are lower than those demanded by the owners of the modern mills. It is likely that the demand for cheaper milling technology will increase as the decline in real per capita income in rural Ethiopia continues. Several studies have suggested that modern mills operate much below capacity because of the rural people's shortages of cash (Aredo 1987; Lirenso and Aredo 1988; Aredo and Abebe 1991).

In addition to the regular users, other people visit water mills only occasionally, mainly when a diesel or electric mill is malfunctioning because of a breakdown or shortage of power, especially fuel. The demand for water mills peaks when a diesel or electric mill stops work. In this way, water mills complement modern mills. Water mills are more reliable and flexible than modern mills.

Modern mills are preferred for their high speed. About 42% of the sample households reported that they had frequented electric mills for this reason. People often combine their visits to modern mills with other tasks they are undertaking. About 21% of the women visited mills on their way to the market.

How do we characterize the regular users of water mills? According to the household survey, people who frequent water mills are younger than those who frequent electric or diesel mills. The average age of those who frequent water mills (of the household head) was 37, whereas that of the users of electric and diesel mills was 41. The number of people in the households that used the water mills averaged five, and that of the households that used the electric and diesel mills averaged six. The average size of land holdings per household of the frequent users of water mills was 0.68 ha, and that of the frequent users of modern mills was 0.95 ha. Clients of water mills live a few minutes' walk from the mill site. In general, it seems that regular users of water mills are poorer and younger households, residing near the mill.

Water mills, however, have their disadvantages:

1. They are very slow to operate. The long waiting time may discourage

households from using water mills. One way of overcoming this problem is to leave the grain with the mill owner and collect the flour at a convenient time. There is mutual trust between mill owners and clients.

2. They are subject to water problems. During the rainy seasons, their sites could be flooded, which may cause work interruptions. In the extreme case, the entire structure could be destroyed and carried away by floods, which happened to a mill in the village of Chaka recently. During dry seasons, on the other hand, there could be too little water to run the mill. It is also at this time that people demand more water for irrigation. Conflict between mill - owners and neighbours is not unheard of. In short, irregular supply of water is a major technical problem faced by mill owners. A topic for further research is, therefore, a way to ensure regular supplies of water for grain processing, as well for irrigation. So far, there has been no attempt to address this problem. In fact, there are cases where detrimental measures were taken; for example, water in the village of Gedilge was diverted to the town of Debre Sina by a small dam in the very place where there were many water mills.
3. They operate very little on cloudy days, especially in the rainy seasons, because there is not enough heat from the sun to dry the grain brought for milling. Water mills process only dry grains.
4. Their wide is precluded by the fact that their location depends on the availability of water. However, they could be promoted in the southern part of Ethiopia, where there are numerous streams, rivers, and springs.

The relative advantages of the three types of mills are summarized in Table 2. Water mills rank first for all the desirable characteristics of an appropriate technology, except for waiting time, product quality, and location flexibility. One major weakness of a water mill is that it is location specific: its uses are restricted to places where water power is available. Electric mills, admittedly, are restricted to places where electric power is available, but diesel mills can be established anywhere there is sufficient population density and reasonable transportation facilities. Of all the characteristics listed in the table, the highest weight should be attached to reliance on local resources.

Table 2. Ranking of milling technologies according to their relative advantages.

Advantage	Water mills	Diesel mills	Electric mills
Dependence on local resources	1	3	2
Fit with local farming system	1	2	2
Capacity utilization	1	3	2
Location flexibility	3	1	2
Customer waiting time	2	1	1
Accessibility to the poor	1	3	2
Contribution to interregional equity	1	2	2
Product quality	2	1	1
Working conditions	1	3	2
Contribution to environmental protection	1	2	2

Water mills fit into the local farming system by (1) making water available for small-scale irrigation, (2) using the spare labour of the farmer, (3) making use of the skill of local artisans (such as blacksmiths, who repair and improvise components), and (4) making use of materials available within the locality. The lower capacity of

water mills is in harmony with the capacity of the local economy, which has characteristically low-level output and limited cash income. Modern mills operate with high excess capacity because of shortages of grain and the limited ability of customers to pay service charges. But modern mills require less waiting time at the mill site. Water mills are accessible to poorer households and to people living in remote areas. Although consumers prefer the texture of the flour from modern mills, there are those who say that these mills “burn” the flour, meaning, perhaps, that the strong heat released by these mills tends to shorten the shelf life of the flour. Working conditions at water mills are appreciated because of the cool, noiseless, fresh environment. Also, water mills contribute to environmental protection, using a renewable source of energy and recycling water for irrigation.

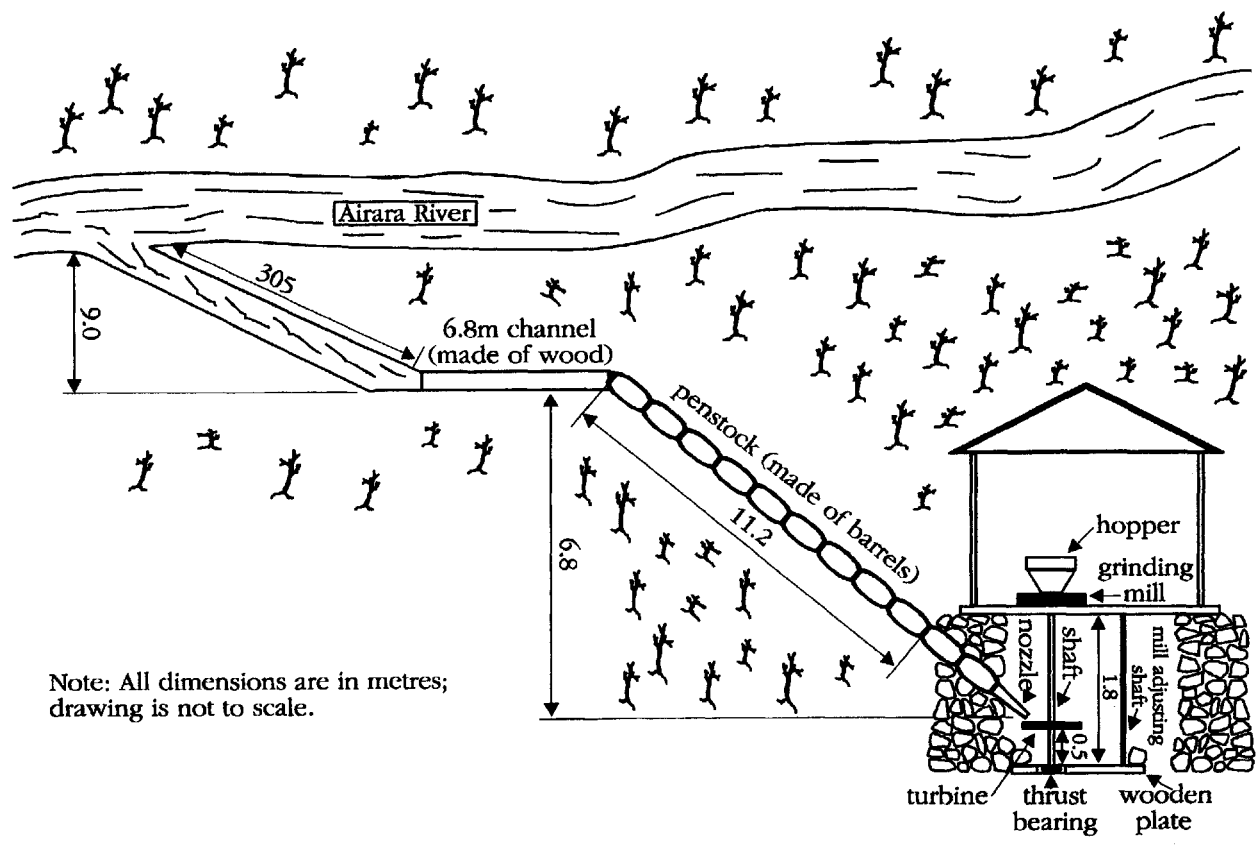
Water mills could, therefore, complement modern mills if their designs were improved and policy makers appreciated their importance. They could be of immense use in relatively inaccessible areas with sufficient hydropower.

The case of Chaka

The village of Chaka is located in one of the most inaccessible regions of Ankober *woreda*, some 42 km from Debre Birhan, the capital city of northern Shewa. After less than an hour’s drive from Debre Birhan to the town of Gorebella, one has to walk (and sometimes crawl and roll down) along a steep gorge and then cross the Airara River to reach the village of Chaka. The people of Chaka grow wheat, barley, horse beans, and other crops. There are about 400 households in the village. Numerous streams flow from the chains of mountains overlooking the Airara Valley.

It was along these streams that water mills were established many years ago, within a few kilometres of each other. The village of Chaka, itself, is located a few kilometres away from the historic town of Ankober, the seat of kings of Shewa. Minilik II moved his capital city from Ankober to Addis Ababa. Some of these mills were established by foreign residents (Greeks and Armenians). For example, the oldest mill (and yet the most powerful one in the village) was installed by a certain Mr George, some 75 years ago. In those days, hand grinding (using a stone grinder) was the most effective technique for processing grain, and slave labour was available. Households sought milling services at the water mill only on important occasions, such as a wedding, an annual holiday, or a grand feast, when a lot of flour was needed to prepare the food. Payment for milling services was made in kind (e.g., eggs and grain). Gradually, water mills gained in popularity among the local people. At peak times, mills operated 24 h a day. Customers waited in line for as long as 8 h at mill sites. However, those water mills gradually lost their market to the diesel mill that was established in the nearby town of Gorebella. Foreign residents switched to other activities as water mills became relatively unprofitable. Mr George, the owner of the oldest mill in Chaka, sold his mill to a local farmer and left the area. But the mill is still operational (Fig. 1).

The mill was bought for a few hundred birr by the present owner, Mr H, who was a part-time mill operator for the original owner. Mr H. established a workshop and undertakes all the repairs and maintenance of the equipment. He has made a number of innovations, including manufacturing from local materials the iron block on which the shaft is mounted (see Fig. 1). The only skill he doesn’t possess for his business is the skill of manufacturing the grinders, for which he pays 600 birr every 4–6 years. The two grinders are made of a special type of stone by local crafts people. As a by-product of his milling business, his services as a blacksmith are provided to



Note: All dimensions are in metres; drawing is not to scale.

Figure 1. Water mill in the village of Chaka.

the village people. Both his workshop and his house are located near the Airara River. Up the hill, he grows barley, wheat, horse beans, and other crops, and he grows vegetables, enset, and hopper, using the water discharged from the mill. He gets a substantial income from the sale of these products, and he has planted eucalyptus trees along the river. From his old mill, he earns about 1800 birr annually. He demands a service charge of 1–1.50 birr per 50 kg of grain. Sometimes, he provides free milling services to close relatives and neighbours. These people often help him a great deal when he has difficulties. One of his relatives helps him with mill operations. Mr H says that his business has been constrained by a lack of market and some technical problems, such as shortages of bolts and barrels for the mill. His mill does not function from June to September, as this is the time when the sky is cloudy and it is difficult to get sun-dried grain for processing. Some of the reasons why he lost his market to diesel mills were that (1) his mill was slow to operate, (2) the bran was not ground into powder, and (3) better-off households considered his mill an “inferior” form of technology and the diesel mill a status symbol. On the other hand, his mill has many loyal clients, especially neighbours and relatives. Peak demand for his mill coincides with the frequent interruptions in the operation of the diesel mill in Gorebella. He knows each one of his regular customers and has close personal relationships with them. Many of them are poor, so he rarely uses the scale for weighing grain brought for milling. Weight is determined roughly: he just looks at the amount of grain. He will start the mill no matter what the size of the load of grain or the number of customers. A loyal customer is not turned back simply because there is not enough business that day. He may interrupt farm work to start mill operations.

The working principles of a typical water mill in Ethiopia are as follows (see Fig. 1). The water jet, coming through the nozzle, causes the turbine to rotate, which drives the grain mill. The grain enters the mill through the hopper, and the flour is delivered at the flour exit. The quality of the flour can be adjusted by varying the clearance between the grinding stones.

The maximum output of the turbine, shown in Fig. 1, can be estimated at about 6.3 HP (4.7 kW). If he installed a more efficient turbine, then an output of 15–20 HP (11–15 kW) could be obtained.

Water mills tend to have mechanical problems, which could be avoided through simple improvements. Mr H. identified these problems:

- Grain dust may damage the bearings. Therefore, the bearings should be properly sealed. The same applies to other bearings exposed to grain dust.
- Millstones need special care: They must be replaced or re-dressed after a certain period. To increase the life of the millstones, the mill speed should be kept at or below the normal operating speed and the millstones should be adjusted properly. Production and re-dressing of the millstones should be done locally to reduce costs.
- Solid bodies, like leaves and stones, may get into the penstock and the turbine. Although leaves and smaller floating bodies can flush easily through the turbine without creating any problems, stones damage the vanes of the turbine rotor and the penstock. To avoid this, a suitable forebay should be set up at the end of the open channel, before the intake of the penstock, and a trash rack should be placed at the inlet to the penstock.
- Although not a mechanical problem, flooding of the mill house may occur during rainy seasons. The location of the mill should be selected to avoid the danger of flooding. A spillway should be constructed at the end of the

water-entrance channel. In case of heavy rains, the excess water will flow through the overflow ditch and have no access to the mill house.

- The thrust bearing wears out quickly. The thrust bearing consists of a metal block fixed to a thick wooden plate; the end of the turbine shaft has a rounded or a sharpened edge and is mounted on this metal block. The problem occurs if the metal block is made of forged steel. To increase the life span of the bearing, bronze or cast iron plates should be used. These materials can be obtained locally. Another way to solve the problem would be to modify the design of the bearing.

When a properly designed turbine is used, there are no major difficulties during operation. Some modern turbines were installed by the Evangelical Church of Ethiopia, and so far no major problems have been observed. The cross-flow turbine has proven especially durable.

There are several possibilities for developing modified designs of water mills, using local resources. In the Ethiopian context, there are three possibilities: (1) improving the common water mills that already exist, (2) developing new water-propelled mills, and (3) making other improvements. The multipurpose mill is another possibility.

Conclusions

This study attempted to throw light on a neglected postharvest technology and the role it could play in responding to the rising costs of imported diesel fuel and the growing shortages of cash incomes in rural areas. The strengths of water mills are that they make use of locally available materials and are accessible to poor households in remote and inaccessible areas. Water mills provide a striking but a rare case of a foreign technology that has been almost fully "indigenized" in rural Ethiopia. The technology fits nicely into the local farming system.

By exploring the economic and technical feasibility of water mills in selected rural areas, this study has suggested the possibility of raising the efficiency of the water mill by about 20–25% and tripling its horsepower through design improvements, using local materials. Researchers and promoters of rural technologies can develop the alternative designs proposed in this study. An engineering study, in particular, is highly recommended to further investigate and develop alternative designs and the other proposals of this study.

Policy-makers and rural-development practitioners may appreciate the immense potential of hydropower-based technology, water mills in particular. The Science and Technology Commission and the Rural Technology Promotion Department of the Ministry of Agriculture may encourage the expansion of improved water mills in selected areas. Appropriate policy instruments should be designed to encourage the expansion of water mills in areas where water is available. Some of the measures that could be taken are (1) removing the taxes imposed on water mills, (2) establishing a water-mills promotion project within the Rural Technology Promotion Department of the Ministry of Agriculture, and (3) commissioning feasibility studies.

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PART III

Technical Change, Innovation, and Diffusion

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CHAPTER 10

Technological Change and the Textiles Industry in Tanzania

H.M. Mlawa

Introduction

A number of studies in this book have underscored the role of technological change in sustainable industrial developments. This study examines the relation of technological change to productivity in the manufacturing industry in Tanzania. The cotton textiles sector (Mlawa 1983) provides the basis for this case study.

Textile manufacturing

The manufacture of cotton textiles involves three main processes: spinning, weaving, and processing. The analysis in this study is limited to the first two.

The technology used in the mills is simple. Raw cotton, often compressed in bales, is mixed and blended, goes through various processes, (spinning, blowing, carding, drawing, roving, etc.), and emerges as yarn. The yarn is transmitted to the loom shed (weaving shed), where further processing produces grey cloth (unprocessed cloth). The grey cloth then goes to the processing shed for desizing, bleaching, dyeing, printing, and so on. The processed cloth is finally cut into suitable sizes and packed for sale. A crew of line operatives and helpers, supported by maintenance personnel and supervisory staff, forms the core of the labour in each of these steps.

The analysis in this paper is based on five spinning sheds and four weaving sheds. All the spinning sheds produce a uniform product (coarse yarns, mostly of count 20s), and all the weaving sheds produce a uniform product (standard plain weaves). These plants were established in the mid-1960s, and all are publicly owned.

Performance measures

Proxy measures of performance (indicators of performance) were computed to reflect levels of x efficiency (operating performance) of the sheds. This computation was based on a set of data the Production Statistics departments in the mills recorded and used to measure production performance in the sheds. On the basis of these data, the following set of physical performance measures were computed. (The tight measures reflect the efficiency when the mills were actually running, thus minimizing the effects of exogenous variables, such as power failures and material shortages, on operating efficiency.)

Labour productivity

Labour productivity was measured as physical output (kilograms, for spinning; metres, for weaving) per person-hour. However, two performance indicators were used: (1) labour productivity based on actual person-hour inputs and (2) labour productivity based on potential person-hour inputs.

Capacity utilization

Capacity utilization is indicated by the ratio of machine-hours (i.e., spindle-hours or loom-hours) to the total stock of installed equipment (i.e., spindles or looms). In the case of spinning, the stock of equipment in the mills did not change during the period of the study. Change in the number of spindle-hours was, therefore, used to measure capacity utilization in the spinning sheds.

The situation was different in weaving: capital stock in Kiltex-Dar and Kiltex-Arusha remained constant during the 1973–1979 period, but additional looms were installed in Urafiki sheds 1 and 2. The technical characteristics of these additional looms were identical to those of the original equipment, so the number of new looms was simply added to the number of the old looms to indicate the size of the capital stock. Change in the ratio of loom-hours to looms installed was, therefore, used to measure change in capacity utilization in the weaving sheds.

Machine productivity

Machine productivity reflects the efficiency of machine operation. For spinning, it was measured as spindle productivity: the volume of output (kilograms) per spindle-hour. For weaving, it was measured as loom productivity: output (metres) per loom-hour.

Changes in output and labour productivity

Spinning

Table 1 summarizes the output change in the individual spinning sheds and in the sheds as a group over the 1973–1979 period and shows two main features of the output growth: (1) within individual sheds, growth was mixed (ranging from 2.44% annually in Urafiki shed 2 to 4.96% annually in Kiltex-Dar); and (2) the overall the rate of growth in the group was modest (0.01% annually).

Table 1. Change in output in the spinning sheds (1973–1979).

	Output (1000 kg)		Annual change (%)
	1973	1979	
Urafiki-1	3 218.0	3 693.6	2.11
Urafiki-2	1 651.0	1 933.2	2.44
Mwatex	2 891.4	2 778.7	-0.56
Kiltex-Dar	1 728.1	1 128.3	-4.96
Kiltex-Arusha	897.2	860.0	-0.59
Group	10 385.7	10 393.8	0.21

Source: The Production Statistics departments of the mills studied.

Table 2 shows (1) the level of person-hour inputs (actual and potential) in 1973 and 1979; (2) the levels of labour productivity for both years; and (3) the average annual rate of change in person-hour inputs and in labour productivity. The table shows that actual person-hour inputs for the group increased by 6.4% annually. The potential person-hour inputs increased at a faster rate during the period. The change in labour productivity (based on actual person-hour inputs) was marked — productivity fell in all the sheds by about 4–9% annually. The rate of productivity decline was higher on the basis of potential person-hour inputs.

Table 2. Change in actual and potential person-hour inputs and labour productivity in the spinning sheds (1973-1979).

	Person-hours (thousands)		Annual change (%)	Productivity (kg person-hour ⁻¹)		Annual change (%)
	1973	1979		1973	1979	
<i>Actual person-hour inputs and labour productivity</i>						
Urafiki-1	1952.1	2817.3	6.3	1.65	1.31	-3.7
Urafiki-2	930.5	1509.7	8.4	1.77	1.28	-5.3
Mwatex	1488.9	2528.4	9.2	1.94	1.10	-9.0
Kiltex-Dar	1006.9	909.7	-1.7	1.72	1.24	-5.3
Kiltex Arusha	548.9	824.4	7.0	1.63	1.04	-7.2
Group	5927.4	8589.5	6.4	1.74	1.19	-6.0
<i>Potential person-hour inputs and labour productivity</i>						
Urafiki-1	2054.3	3299.3	8.2	1.70	1.12	-5.5
Urafiki-2	989.8	1728.1	9.7	1.67	1.12	-6.4
Mwatex	1628.3	2857.0	9.8	1.78	0.97	-9.6
Kiltex-Dar	1097.2	1051.9	-0.7	1.07	1.07	-6.3
Kiltex-Arusha	600.1	914.4	7.3	1.50	0.94	-7.5
Group	6369.7	9850.7	7.5	1.63	1.05	-7.1

Source: The Production Statistics departments of the mills studied.

Weaving

Table 3 summarizes the output change in the individual weaving sheds and in the sheds as a group over the 1973-1979 period. It shows that the group rate of growth of grey-cloth output was greater (i.e., 2.1% annually) than that of yarn (0.01% annually).

Table 3. Change in grey-cloth output in the weaving sheds (1973-1979).

	Output (1000 m)		Annual change (%)
	1973	1979	
Urafiki-1	13 767.1	16 354.4	2.9
Urafiki-2	7 748.3	11 456.3	6.7
Kiltex-Dar	10 533.2	6 132.4	-8.6
Kiltex-Arusha	4 394.2	7 264.0	8.7
Group	36 442.8	41 207.1	2.1

Source: The Production Statistics departments of the mills.

Labour-productivity measures were based on both actual and potential person-hour inputs. Table 4 shows (1) the levels of these inputs in 1973 and 1979; (2) the levels of labour productivity in both years; and (3) the average annual rate of change in person-hour inputs and in labour productivity.

Actual person-hour inputs for the group as a whole increased at an average rate of about 9% annually. Among the individual sheds, the rates of increase varied widely. The rates of increase in person-hour inputs were roughly associated with rates of growth in grey-cloth output, but in all cases the growth in person-hour inputs was

much greater. Consequently, the level of labour productivity for the individual sheds fell (albeit at different rates) during the 7 year period.

Table 4. Change in actual and potential person-hour inputs and labour productivity in the weaving sheds (1973–1979).

	Person-hours (thousands)		Annual change (%)	Productivity (m person-hour ⁻¹)		Annual change (%)
	1973	1979		1973	1979	
<i>Actual person-hour inputs and labour productivity</i>						
Urafiki-1	6 468.1	8 972.3	5.6	2.13	1.13	-2.6
Urafiki-2	3 842.7	7 440.2	11.6	2.02	1.54	-4.4
Kiltex-Dar	4 271.8	5 216.5	3.4	2.47	1.18	-11.6
Kiltex-Arusha	1 844.3	6 059.3	21.9	2.38	1.20	-10.8
Group	16 426.9	27 688.3	9.1	2.20	1.49	-6.4
<i>Potential person-hour inputs and labour productivity</i>						
Urafiki-1	6 885.4	10 315.0	7.0	2.00	1.59	-3.8
Urafiki-2	4 070.3	8 962.2	14.1	1.90	1.28	-6.4
Kiltex-Dar	4 271.8	6 082.6	4.9	2.31	1.01	-12.9
Kiltex-Arusha	1 961.3	6 723.4	22.8	2.24	1.08	-11.5
Group	17 474.1	32 083.2	10.7	2.09	1.28	-7.0

Source: The Production Statistics departments of the mills studied.

Changes in capacity utilization and machine efficiency

Spinning

Table 5 shows (1) the number of spindle-hours (our measure of capacity utilization) in the mills in 1973 and 1979; (2) the average annual rate of change in spindle-hours; and (3) the average annual rate of change in output for the same period, for comparison. The table shows that in all but one of the mills, spindle-hours increased during the study period; for the group as a whole, they increased by about 3% annually.

Table 5. Change in spindle-hours worked in the spinning sheds (1973–1979).

	Spindle-hours worked (<i>n</i>)		Annual change in spindle-hours (%)	Annual change in output (%)
	1973	1979		
Urafiki-1	265.47	374.90	5.9	2.11
Urafiki-1	125.44	186.52	6.8	2.44
Mwatex	235.85	250.37	1.0	-0.56
Kiltex-Dar	140.23	115.65	-3.2	-4.96
Kiltex-Arusha	76.42	79.56	0.7	-0.59
Group	843.41	1007.00	3.0	0.01

Source: The Production Statistics departments of the mills studied.

As might be expected, differences in the rate of change in capacity utilization among individual mills were associated with differences in the rate of change in output. For the group as a whole, spindle-hours increased at a much faster rate (3.0%

annually) than output (0.01% annually). Clearly, then, output per spindle-hour was not rising; in fact, it was falling (Table 6).

Table 6. Change in spindle productivity in the spinning sheds (1973-1979)

	Productivity (kg spindle-hour ⁻¹)		Annual change (%)
	1973	1979	
Urafiki-1	0.0121	0.0098	-3.5
Urafiki-2	0.0121	0.0104	-2.5
Mwatex	0.0123	0.0111	-1.6
Kiltex-Dar	0.0123	0.0097	-3.9
Kiltex-Arusha	0.0117	0.0108	-1.4
Group	0.0123	0.0103	-2.9

Source: The Production Statistics departments of the mills studied.

Evidently, although management increased the person-hour inputs in order to expand capacity utilization, this move did not raise the productivity of the running machinery. Indeed, machine productivity was not even held constant as capacity utilization increased. Because output during the period of study was more or less constant for the group as a whole, increasing capacity utilization (expanding by about 3.0% annually) was required simply to compensate for decreasing machine efficiency (falling by about 2.9% annually).

Weaving

Table 7 shows (1) the number of hours the looms in the weaving sheds were running in 1973 and 1979; (2) the change in the ratio of loom-hours to looms installed (our measure of capacity utilization); and (3) the average annual rate of change in grey-cloth output during that period.

Table 7. Change in the ratio of loom-hours operated to number of looms installed in the loom sheds (1973-1979).

	Loom-hours		Change in ratio of loom-hours to looms (%)	Annual change in grey-cloth production (%)
	1973	1979		
Urafiki-1	14 922	18 675	3.8	2.9
Urafiki-2	11 279	13 976	3.6	6.7
Kiltex-Dar	12 065	13 986	2.5	-8.6
Kiltex-Arusha	8 241	26 257	21.3	8.7
Group	46 507	17 203	6.1	2.1

Source: The Production Statistics departments of the mills studied.

In all the weaving sheds, individually and taken as a group, capacity utilization increased. Differences in the rate of change among individual mills were loosely associated with differences in the rate of change in output. Although capacity utilization was rising, output per loom-hour was not; in fact, it was rapidly decreasing (Table 8).

Table 8. Change in loom-hour productivity in the weaving sheds (1973–1979).

	Productivity (m loom-hour ⁻¹)		Annual change (%)
	1973	1979	
Urafiki-1	2.05	1.38	-6.4
Urafiki-2	2.08	1.42	-6.2
Kiltex-Dar	2.09	1.05	-10.8
Kiltex-Arusha	2.04	1.06	-10.3
Group	2.07	1.28	-7.7

Source: The Production Statistics departments of the mills studied.

Evidently, then, although some of the increase in capacity utilization resulted in an increase in output, a much larger proportion was simply required to offset rapidly falling loom-hour productivity.

Benchmark efficiency levels

These data provide a very clear overall picture: according to almost every indicator of production efficiency, performance was declining in most of the mill sheds during the period examined. In contrast to the mass of evidence about learning curves in industrial production and development in industrializing economies, these data, plotted against time (or cumulative total output), would show an array of “unlearning” curves. Evidently, then, this infant industry was rapidly unlearning during this 7 year period.

This path of development in one of the country’s leading manufacturing sectors should perhaps be set in context. This analysis does not cover the initial start-up or running-in phase of production in the mills. By 1973, all the mills studied had been operating for at least 5 years, so the decline in productivity does not reflect a decline from design-level efficiencies that had been attained in the start-up phase.

It was possible to establish benchmark efficiency levels for the types of equipment installed in the mills. With the assistance of the staff of the Shirley Institute, based in Manchester in the United Kingdom, I estimated benchmark efficiency levels for two performance indicators (labour productivity and machine-hour productivity) as being 65% of the specified design-level efficiencies for the type of equipment used in Tanzania. The downward adjustment of 35% from the specified design-level efficiencies allows for start-up discrepancies and provides a reasonable norm for Tanzania.

Spinning

Because, in a broad sense, the technical characteristics of the spinning equipment were similar across the plants, I established identical benchmark levels for each piece of equipment:

- labour productivity = 4.55 kg person-hour⁻¹; and
- machine productivity = 0.035 kg per spindle-hour⁻¹.

Table 9 shows the productivity levels actually achieved in the Tanzanian spinning mills in 1973 and 1979 and compares them with the norms. In 1973, actual

efficiency levels were slightly more than a third of the benchmark levels. By 1979, the process of unlearning had reduced relative efficiency in the spinning sheds to only a little more than a quarter of the estimated benchmark levels.

Table 9. Actual productivity levels achieved in the spinning sheds compared with the benchmark productivity levels (1973–1979).

	Actual productivity levels		Ratio of actual to benchmark (%)	
	Labour (kg person-hour ⁻¹)	Spindles (kg spindle-hour ⁻¹)	Labour-hour	Spindle-hour
<i>1973</i>				
Urafiki-1	1.65	0.0121	36	35
Urafiki-2	1.77	0.0121	36	35
Mwatex	1.94	0.0123	43	35
Kiltex-Dar	1.72	0.0123	38	35
Kiltex-Arusha	1.63	0.0117	36	35
Group	1.75	0.0123	38	35
<i>1979</i>				
Urafiki-1	1.31	0.0098	29	28
Urafiki-2	1.28	0.0104	28	30
Mwatex	1.10	0.0111	24	32
Kiltex-Dar	1.24	0.0097	27	28
Kiltex-Arusha	1.04	0.0108	23	31
Group	1.21	0.0103	27	29

Weaving

The technical characteristics of the weaving equipment varied among the mills. The benchmark efficiency levels I established, therefore, also varied. Table 10 shows the productivity levels actually achieved in the Tanzanian weaving sheds in 1973 and 1979 and compares these with the norms.

In 1973, the actual efficiency levels in the weaving sheds were about a third of the benchmark levels (with the exception of Kiltex-Dar, where it was nearly half). By 1979, the process of unlearning had reduced relative efficiency to around 25% of the estimated benchmark levels, even in the case of Kiltex-Dar, and to only about 15% in the case of Kiltex-Arusha.

In effect, then, after some 10–15 years of cumulative production experience, the mills were producing as if they were still in the start-up or running-in phase of development. Production efficiencies were still far below design-level efficiencies. The cumulative production experience had not automatically generated the efficiency improvements needed to bring performance up to even the benchmark levels. In fact, performance was moving away from, not toward, those levels.

Evidently, increasing production experience and the passage of time were associated not with improving production efficiency, but with decreasing production efficiency.

Table 10. Actual productivity levels achieved in the weaving sheds compared with the benchmark productivity levels (1973–1979).

	Actual productivity levels		Benchmark productivity level		Ratio of actual to benchmark (%)	
	Labour (m person-hour ⁻¹)	Looms (m loom-hour ⁻¹)	Labour (m person-hour ⁻¹)	Looms (m loom-hour ⁻¹)	Labour-hour	Loom-hour
<i>1973</i>						
Urafiki-1	2.13	2.05	6.5	5.85	33	35
Urafiki-2	2.02	2.08	6.5	5.85	31	36
Kiltex-Dar	2.47	2.09	5.2	4.55	48	46
Kiltex-Arusha	2.38	2.04	7.8	6.50	31	31
<i>1979</i>						
Urafiki-1	1.13	1.38	6.5	5.85	28	24
Urafiki-2	1.54	1.42	6.5	5.85	24	25
Kiltex-Dar	1.18	1.05	5.2	4.55	23	23
Kiltex-Arusha	1.20	1.06	7.8	6.50	15	16

Conclusions

This paper examined the growth experience of Tanzania's textile industry during the period 1973–1979 and looked for evidence of productivity improvement resulting from technological change.

The main finding was that from 1973 to 1979, productivity (x efficiency) in this industry, far from improving, actually declined. Labour productivity and machine productivity, two of the performance measures used to indicate efficiency levels and trends, showed a persistent decline. Capacity utilization, on the other hand, increased in almost every mill.

This suggests a general deterioration in efficiency in use of the imported technology. Clearly, then, this industry shows no evidence of technological learning in the sense of endogenous execution and management of incremental technological changes or productivity improvement. Instead, the industry appears to have rapidly unlearned.

The above conclusions suggest that very limited assimilation, absorption, and mastery of imported technology took place in this sector of the importing economy during this period. It also suggests that there wasn't much effort in Tanzania to build up the technological and managerial skills, expertise, and related capabilities needed to improve productivity and efficiency in the industry.

Recommendations for further research and analysis

There is little systematic research on, or analysis of, technological change and industrial development in Tanzania. This observation implies two things:

1. Our knowledge about how technological change bears on the process of industrial development of Tanzania is very limited.
2. There are few empirical data on Tanzanian realities to inform future policies, plans, strategies, and management of technological change and industrial development.

However, it is possible to recommend further research to improve the analytic and empirical bases of our understanding. Such an understanding will benefit future policy and planning.

Systematic and in-depth studies

This study, like many others on technological change and industrial development in developing countries, is a general and preliminary one. There is an urgent need to design and carry out systematic and in-depth studies focusing on specific sectors, industries, or firms. The main objective should be to uncover the evolution of technological change in these sectors, industries, and firms. Such studies are likely to be particularly useful in a developing country like Tanzania.

Studies on the determinants of technological change

Most studies on technological change and industrial development in developing countries focus on the value characteristics (e.g., quality) of products, processes, and procedures. It would be useful to think of more specific and comprehensive productivity measures that would capture both the physical and the value characteristics of products, processes, and procedures.

Comparative studies

The vast majority of studies on technological change and productivity in developing countries (such as this study) are case studies of single sectors, or even firms, drawn from single countries. Such studies are extremely useful and informative, especially in describing technological change in these sectors and firms. However, such studies often are unhelpful in explaining causality. Nor are they helpful in prediction. Carefully designed comparative studies of firms from different sectors, countries, and historical periods would help our understanding of technological change and performance growth.

Studies linking technological change and technology transfer

The rate and direction of technological change and productivity performance in a given plant or sector depend on, among other things, the characteristics of the production techniques used. The production techniques used in many plants in Tanzania and similar developing countries are not locally supplied but imported through international technology transfer. A clear understanding of technological change and productivity improvement in a particular sector, industry, or firm presupposes some knowledge of how the technology in the plants was acquired in the first place.

Studies on technological change and productivity improvement should address linkages between technology transfer and technological change. Realistically, in technologically underdeveloped economies, technology transfer and technological change form a continuum, rather than a series of discrete, unrelated processes. It is important, therefore, that studies of technological change in such countries take into account this rather obvious point.

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CHAPTER 11

Diffusion of Precommercial Inventions from Government-Funded Research Institutions in Nigeria

Titus Adeboye

Background

Nigeria faces many problems. There is massive unemployment, partly as a result of retrenchment in government and business. The fluctuations in international oil prices mean that Nigeria has had its share of financial crises — not because of the size of its debt but because of the country's decreasing ability to repay it. There is a crisis that results from dependence on imports and dwindling reserves of foreign currency. With the massive underuse of present production capability, the national government has been pressed to seek ways of reducing waste by cutting down on imports, putting idle resources to productive use, eliminating or reducing the serious price distortions that plague Nigeria, and, indeed, restructuring the entire economy.

The crisis that has resulted from excessive reliance on imports seems to have worsened in the last few years. Nigeria not only imports the bulk of its manufacturing machinery but also depends on imports for

- most of the agricultural raw materials for manufacturing, such as oil seeds and sugar;
- all the intermediate inputs required in industry, such as chemicals, petrochemicals, dye stuffs, soft-drink concentrates, barley malt, and citrus-fruit concentrates; and
- all the components used in the assembly plants, which have mushroomed in the country.

The foreign-exchange crisis has seriously reduced the availability of these industrial inputs. Foreign-exchange licencing and quantitative restrictions have forced many factories to shut down, and those still operating carry unacceptable levels of excess capacity (a survey shows that capacity utilization in manufacturing was only 30% in 1985). In 1980, the manufacturing sector grew by 17.6%. This was its best year of growth — it was 9.5, 2.7, and 12.3% in 1981, 1982, and 1983, respectively.

Early in 1986, the Nigerian government announced that it would phase out imports of certain industrial raw materials, on the grounds that local substitutes had been developed. Prominent among these were wheat flour and barley malt for beer brewing. Maize and rice imports were banned. All import-dependent manufacturers now have to go to new second-tier foreign-exchange markets to acquire the inputs they need. Costs will likely escalate.

Through the years, however, the federal government, some state governments, the universities, the polytechnical institutes, and even private establishments have been funding research on the country's problems, and all have been developing technically feasible solutions. It is of great interest, therefore, to determine the extent to which

the manufacturers' problems (especially the problems with imported inputs) have been solved by these researchers and the extent to which their solutions have been adopted by the manufacturers. To what extent has this research offered better alternatives to traditional technologies?

Objective

The narrow objective of this investigation was to determine the extent to which "precommercial inventions" developed through Nigerian government-funded research have been adopted in Nigerian industry. By explaining the extent of this diffusion, we hope to reveal policy implications.

By *precommercial invention*, we mean a product or process that is patentable but has not yet reached that stage described in the economic literature as "innovation," that is, the stage at which it is commercialized. Precommercial inventions have been proven feasible. Our definition of *precommercial invention* does not apply to minor improvements because these are usually not patentable.

The manufacturing technologies examined were developed at three Nigerian research institutes: the Federal Institute of Industrial Research at Oshodi (FIRO), the Leather Research Institute of Nigeria (LERIN), and the Project Development Institute (PRODA).

Methods

The first step in the investigation was to examine the precommercial inventions and summarize the important ones. The study began with desk work. I examined the annual reports of the three institutes were examined, along with other published materials covering their activities, including periodicals, journals, briefs, workshop and seminar papers, technical information bulletins, and special research reports.

At this stage, I classified the inventions in two broad categories. The first category, "product invention," included introductions of new products, radical transformations of existing local products, indigenous substitutes for imported raw materials, and new uses for otherwise unused resources. The second category, "process invention," included new equipment and processes for performing existing manufacturing tasks and radical modifications of existing inventions.

The fieldwork consisted mainly of interviewing research personnel and the users or prospective users of the inventions. The objectives of the interviews were

- to examine the problems that the inventions solve, the cost of development, the technical problems encountered during development, the sources of solutions, the various disciplines involved, and the ways these factors have affected the rate of diffusion;
- to determine, for each invention, the years elapsed after the demonstration of its technical feasibility and the number of adoptions of the invention or the extent of diffusion, defined as growth in market share;
- to evaluate performance problems, raw-material availability, equipment, specifications, input-output efficiency, and utility-use efficiency in the experience of users and prospective users;
- to identify the bottlenecks to greater diffusion, such as product- or process-engineering, administrative, institutional, commercial, or other problems; and
- to discover policy implications for better rates of diffusion.

I measured diffusion at two stages: (1) I specified the inventions and the number of years since the demonstration of their technical feasibility. From research-institute responses, I obtained the number of businesses started on the basis of patents or agreements reached with the research institutes to use their technology. (2) Where no such business was started, I related diffusion to percentage of market share. The rate of diffusion of technology at this second stage was defined as the increase in any given product group.

As all three research institutes run programs to aid prospective commercial adopters of their technology, part of the diffusion process could be assumed to take the form of training courses. For accuracy, it is necessary to distinguish the following elements of diffusion:

- attendance at courses designed to train prospective investors or their staff in the use of the technology;
- purchase of a patent licence or process technology for commercial operation;
- purchase of equipment and other fixtures and devices, based on a research institute's design or licence; and
- emergence of a commercial-scale operation on the basis of a research institute's technology.

I was also interested in diffusion that occurred when research-institute personnel decided to start their own businesses using the technology they developed. This is known as technological entrepreneurship. I did not use questionnaires.

The institutes

The Federal Institute of Industrial Research at Oshodi

FIIRO was established in 1956 to conduct applied research in the area of manufacturing. At the time of this report, the institute's staff numbered 515. Of the 515 employees, about 125 had university degrees or the equivalent. Of these, 35 had graduate degrees. The disciplines include mechanical, chemical, civil, electrical, and industrial engineering, chemistry, physics, biochemistry, biology, food technology, and systems engineering. An experienced design engineer was recently hired by the institute.

FIIRO's functions are

- to conduct applied research on Nigerian raw materials to discover their potential industrial uses;
- to develop processes to most effectively convert these raw materials into finished products;
- to carry out pilot-scale trials of processes found to be technically feasible in the laboratory;
- to assess the feasibility of such processes on a commercial scale; and
- to develop import-substituting products and, thus, conserve foreign exchange for Nigeria.

FIIRO is the most developed of the three institutes. It has more graduate-level, more personnel research and development (R&D), a larger scope of activity, and better engineering facilities (the engineering capabilities of the three institutes are compared in Tables 1 and 2). Situated on about 5 ha of grounds at Oshodi, FIIRO has

Table 1. Metal-working facilities in FIIRO, LERIN, and PRODA.

Type of machine	Function	Number available		
		FIIRO	LERIN	PRODA
Welding equipment				
High-pressure oxy-acetylene	For welding metals and alloys	1	1	1
Electric-arc		1	—	1
Universal nibbling machine	For circular cutting, dishing, straight and rectangular cutting, round and square notching, louvre cutting, pipe beading	1	—	1
Hydraulic press (16 t, with bits, dies, punches, 10–20 mm)	For press-shop operations	1	—	—
Hydraulic guillotine shearing machine (3200 mm)	For shearing mild steel 13 mm thick and cutting stainless steel 9 mm thick	1	—	—
Universal punching, notching, cropping machine (18 mm shears)	For punching, notching, cropping, rod shearing	1	—	—
Plate-bending and -rolling machine	For forming drums up to 310 mm diameter	1	—	—
Mechanical press (with square die)	For producing angle iron of various sizes	11	—	—
Machine tools				
Heavy-duty centre lathe	For turning, cutting, boring, milling	1	1	—
Medium-duty lathe	For planing	1	1	1
Precision turn and screw-cutting lathe	For gear cutting, lapping, honing, etc.	1	1	1
Universal mill	—	1	—	1
Vertical type	—	1	—	1
Grinding machine	—	2	—	1
Other	For shaping, bench drilling, cylindrical boring, power hacksawing	6	—	2
Total		31	4	9

Notes: FIIRO, Federal Institute of Industrial Research at Oshodi; LERIN, Leather Research Institute of Nigeria; PRODA, Project Development Institute.

wide engineering capability, including design, detailed engineering, fabrication, installation, trouble shooting, and maintenance. FIIRO also interacts with many manufacturing subsectors through contracts for technical services, such as analysis of

materials, material testing, engineering, fabrication of parts, electroplating, training, and workshop courses and patent services for Nigerian inventors.

Table 2. Foundry and other fabrication capability at FIIRO, LERIN, and PRODA.

		Number available		
		FIIRO	LERIN	PRODA
Foundries	Melting 1 t iron	1	—	1
	Melting 250 kg brass and other nonferrous metals	1	—	1
	Lift-out type for ferrous and nonferrous metals	1	—	—
Heat treatment	Electrically heated salt bath, oil bath, air furnace	2	—	—
	Magnetic particle tester	1	—	—
	Hardness tester	1	—	—
Electroplating	Cadmium, copper, brighter nickel, bright chromium, and zinc plating	1	—	—
Total		8	—	2

Notes: FIIRO, Federal Institute of Industrial Research at Oshodi; LERIN, Leather Research Institute of Nigeria; PRODA, Project Development Institute.

The Leather Research Institute of Nigeria

LERIN started operations in 1964, under the United Nations Food and Agriculture Organization (FAO), at the request of the Government of Nigeria. The FAO project came to an end in June 1972. The institute then functioned as a division of the federal livestock department between 1972 and 1976. As part of the federal government's national science policy, the Ministry of Science and Technology was created. In 1980, LERIN came under it, along with other institutes.

LERIN had a total staff of 248 at the time of our survey. Of this number, 56 had graduate qualifications in the physical sciences and leather technology. There was one mechanical engineer.

LERIN was formally established by a decree in 1973. Its main objectives are

- to collaborate with the relevant government departments and organizations to provide raw materials, labour, leather, and standardization in production;
- to conduct basic and applied research in leather science and technology for Nigerian leather industry and its allied industries so that they can maximize the quality of their domestic and export products;
- to conduct periodic market surveys at home and abroad to gain market intelligence for use by the Nigerian leather industry and its allied industries;
- to investigate vegetable tanning materials and other auxiliary chemicals indigenous to Nigeria to develop a strong base for their supply to the leather industry;
- to build up a national information system on leather science and technol-

ogy; and

- to develop into a full-fledged regional centre for leather and leather products.

LERIN is organized around five divisions: administration, research and extension, training, production, and maintenance. It has 14 research programs: hides and skins improvement; collagen; tanning agents and mechanisms of tannage; leather auxiliary; tanning and finishing; foot wear and leather goods; quality control and standardization; leather trades engineering; slaughterhouse and tannery by-products; control and treatment of effluent; economics and marketing; technical training; research extension; and library, publications, and documentation.

LERIN has the weakest engineering base of the three institutes. Maintenance is constrained by lack of spare parts, and, at the time of our study, its few machine tools were unserviceable.

The Project Development Institute

PRODA is an industrial R&D organization established by the now defunct East-Central state government. It was taken over by the central government in 1976, and it came under the federal Ministry of Science and Technology in 1980. At the time of the study, PRODA employed 535 people. About 180 were graduates. PRODA was then developing its new 55 ha site at Enugu; several laboratories at the staff quarters were already built.

PRODA's main aim is to develop industrial projects using local raw materials and indigenous human resources, through laboratory and pilot-plant investigations. Its range of activities includes

- chemical and physical analyses of products, chemicals, drugs, and industrial raw materials;
- the manufacture of scientific equipment for educational and industrial establishments;
- geological investigations, including soil testing for engineering purposes, drilling for mineral deposits, water-well drilling, and hydrological investigations;
- ceramic research, including research on white ware (pottery), heavy clays, refractories, and physical and chemical characteristics of clays and raw materials for ceramics;
- engineering design, fabrication of miscellaneous machine parts, production of castings in aluminum and brass, and preinvestment surveys; and
- investigations of raw materials for pulp and paper.

I first examined the broad range of inventions developed at the three institutes and categorized them as product inventions or process inventions.

Table 3 shows that 21 of the 25 inventions from FIRO were product inventions, whereas only 4 were process inventions. FIRO, however, sees all inventions as products. On the other hand, all the inventions from LERIN were process inventions, which is how LERIN also sees them. Of PRODA's 30 inventions, 8 were product inventions and 22 were process inventions. It is clear that the bulk of the inventions were agricultural. Both FIRO and PRODA have done extensive R&D on cassava, which provides derivative staple foods. Five product and two process inventions from FIRO were developed from cassava, as were seven of PRODA's process inventions.

Measure of diffusion

To determine the diffusion of these inventions, I counted the number of users of each invention. Two types of diffusion must be distinguished. The first type relates to the outright purchase of the R&D institute's invention as a final product. The second type is the starting of production facilities on the basis of an institute's invention.

Only 7 of the 25 inventions from FIIRO (mechanized *gari*-making, portable alcohol, bottled palm wine, Nico cream, smoke curing of fish, sparkling wine, and soap making) have been diffused to outside manufacturers and, therefore, qualify as innovations. *Soy-ogi*, perhaps one of the oldest of FIIRO's inventions, has not been successfully commercialized by any outside group. FIIRO is discussing commercialization of this product with two large multinational companies. The first three inventions in Table 4, *soy-ogi*, *gari* flour, and *fufu*, are currently produced by FIIRO, itself, in pilot plants. They are, however, products that have been commercialized by the institute. The institute also produces and sells *gari* on a limited scale at its pilot plants.

The two most widely diffused inventions from FIIRO are palm-wine bottling and soap making, with 40 and 60 commercial clients, respectively. Calculations show that only these two inventions have significant shares of the market. FIIRO-technology users have the entire bottled palm-wine market in Nigeria. Despite the large numbers of users of FIIRO technology in soap making, their share of the laundry and bath-soap markets at the time of this report was about 5%.

Five of the 30 PRODA inventions have been diffused and, therefore, qualify as innovations. The most important of these relate to *gari* making. The laboratory equipment factory, set up at Enugu, was responsible for more than 40% of all science equipment distributed to schools by the federal government in 1986. Traffic lights are still produced by PRODA, but no factory has been started. The PRODA inventions were diffused by the direct sale of equipment and machinery.

To date, not too many patent licences have been taken out for the use of technologies developed by PRODA. Nonetheless, several licencing agreements have in fact been concluded, although the technologies have not yet been put into operation. Table 5 shows the licencing agreements made for FIIRO technologies.

However, despite these agreements and the extent of the diffusion that has already taken place, we have to conclude that most of the inventions from the research institutes remain unused. In particular, those that appear to address the important problem of dependence do not appear to have been diffused (Table 6).

Because of the ban on imported wheat and the proposal to phase out barley malt imports, one is surprised to find that neither sorghum malt nor the composite flour products have been adopted by the industries most affected. The importance of these questions is further underlined by Nigeria's import dependence (Table 7). Why were these inventions, which seem to directly address the country's import-dependence problem, not diffused?

Several studies on diffusion of new technologies have uncovered factors in diffusion. Where innovation was a direct response to an expressed need, especially a need expressed by the ultimate user of the product or process, diffusion is swift (Schmookler 1966). When R&D is contracted in response to a user's request, it is more likely to be diffused than inventions produced independently of an identified user (Freeman 1974). Inventions that demonstrate a clear advantage over existing alternatives are diffused more easily than those with no clear advantage (Rogers 1971). Usually the advantage results in higher profitability for a better product. Where

Table 3. Precommercial inventions in three Nigerian research institutes (1971–1986).

Institute	Product inventions	Process inventions
FIIRO	Cassava flour	Cassava peeling and grating
	Cassava starch	Detoxified cassava
	Gums, glues, adhesives from cassava starch	<i>Gari</i> -making machinery
	<i>Gari</i> and <i>gari</i> flour	Gluco
	<i>Fufu</i>	
	Maize flour	
	<i>Soy-ogi</i> baby food	
	Composite flour	
	Sorghum flour	
	Femos beer	
	Potable alcohol	
	Bottled palm wine	
	Pitto (local beer)	
	Table vinegar	
	Tomato puree, ketchup, powder	
	Peanut butter	
	Salad cream and mayonnaise	
	Full-fat soy grits and oil	
	Nico skin cream	
	Laundry soap and bath soap	
Smoked fish		
LERIN		Tanning agent from <i>Acacia nilotica</i> (<i>bagaruwa</i>) pods
		Tanning agent from <i>Anogeissus schimperi</i> (<i>marker</i>) leaves
		Tanning agent from <i>Parkia clappertoniana</i> (<i>dorowa</i>) husks
		Local lime upgrading for modern tanning
		Local fat liquors for leather
	Dehairing and bating agents from <i>Adenopus breviflorus</i> (<i>tagiri</i>)	

Table 3 (concluded).

Institute	Product inventions	Process inventions
PRODA	Laboratory equipment, wood-work products, glass products, thermometers	Cassava peeling machine
	Steam cooker	Cassava grating machine
	Air blower	Pulp-dewatering screw press
	Traffic lights	Depulping machine
	Multipurpose grinder	Gari-frying machine
	Foundry products (bearing bars, bearing housing, water valves, pulleys, metal ingots)	Gari-screening machine (rotary or shaker)
	Refractory bricks	Gari cyclone unit
	Industrial adhesive	Seed planter
		Maize sheller
		Palm-oil mill (with bunch stripper, palm-fruit cooker, digester, etc.)
		Kero-oil press
		Shelf dryer
		Solar dryer
		Solar hothouse
		Industrial blender
		Low-cost oven
		Bread oven
		Ceramic pottery equipment (blunger, vibrating sieve, spray booth, potter's wheel)
		Alcohol-distilling plant
		Water-distilling plant
		Industrial washing machine
		Sorghum malt

Notes: FIRO, Federal Institute of Industrial Research at Oshodi; LERIN, Leather Research Institute of Nigeria; PRODA, Project Development Institute.

prospective commercial clients perceive the effects of an invention as positive, they are more likely to adopt it (Agarwala 1972). The lower the risk involved in the new technology, the higher the chances of diffusion: inventions involving risk, real or

perceived, tend not to be diffused. On the other hand, the inventions that cater to existing values, needs, or habits tend to be diffused more widely. Finally, the type of innovation decision affects the rate of diffusion.

Table 4. Diffusion of inventions from three Nigerian research institutes.

Institute	Invention	Number of users
FIIRO	<i>Soy-ogi</i> baby food	1
	Mechanized <i>gari</i> flour production	1
	Mechanized <i>fufu</i> production	1
	Mechanized <i>gari</i> production	6
	Potable-alcohol production	4
	Palm-wine bottling	40
	Smoke curing of fish using FIIRO kiln	1
	Nico cream production	2
	Sparkling-wine production	1
	Soap making	60
PRODA	Automated <i>gari</i> -processing factory	4
	Village <i>gari</i> unit	2
	<i>Moi moi</i> factory	1
	Laundry and washing machine	2
	Traffic lights	2
LERIN	Laboratory equipment factory	1
	Nil	—

Notes: FIIRO, Federal Institute of Industrial Research at Oshodi; LERIN, Leather Research Institute of Nigeria; PRODA, Project Development Institute.

Table 5. Patent agreements based on FIIRO technology.

Invention	Patent fee (NGN)	Royalty due (% of sales)	Agreements ^a (n)
Nico skin cream	15 000	2	1
<i>Soy-ogi</i> baby food	30 000	2	2
Femos beer	100 000	2	1
Ginger powder, oleoresin, and concentrates	89 625	2	1
Tomato puree, ketchup, and powder	1 500	—	1
Refined kaolin and gypsum	7 500	2	1

Notes: FIIRO, Federal Institute of Industrial Research at Oshodi. In 1995, 78.5 Nigerian naira (NGN) = 1 United States dollar (USD).

^a In negotiation.

Table 6. Inventions relevant to import dependence.

Invention	Import	Industry affected
Sorghum malt	Barley malt	Beer (38 brewers)
Composite flour	Wheat flour	Baking (15 large users)
<i>Soy-ogi</i> baby food	Weaning baby foods	Food industry
Ginger powder, oleoresin, concentrates	Soft-drink concentrates	Soft drinks (41 bottlers)

Table 7. Imports by major sectors, Nigeria.

	Imports (million NGN)										
	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
Food and live animals	155	298	441	736	1 021	767	1 438	2 115	1 756	1 341	152
Beverages and tobacco	9	48	64	133	71	50	12	17	11	9	7
Crude materials	64	74	79	79	108	112	157	202	172	168	144
Mineral fuels	55	100	175	129	175	207	155	176	151	132	111
Oils and fats	4	9	25	47	73	52	115	123	129	97	85
Chemicals	191	333	397	498	648	540	914	1 256	1 013	963	852
Manufactured goods	523	1 008	1 136	1 565	1 850	1 524	1 982	2 641	2 165	1 928	1 242
Machinery and transportation equipment	612	1 562	2 445	3 387	3 588	3 792	3 650	5 407	4 653	3 666	3 257
Miscellaneous manufactured articles	114	278	372	510	665	415	645	953	711	582	418
Miscellaneous	11	12	15	9	14	14	29	29	11	18	11
Total	1 737	3 722	5 149	7 094	8 212	7 473	9 096	12 919	10 771	8 904	7 178

Notes: 1982 figures revised; 1983 and 1984 figures estimated. In 1995, 78.5 Nigerian naira (NGN) = 1 United States dollar (USD).

The question of what conditions led to diffusion of the inventions of the three Nigerian research institutes was approached first from the point of view of the researchers and then from the point of view of the users.

Respondents at the research institutes felt that the successful diffusion of palm wine and soap was due to the client's perception that these products were highly profitability and the fact that the institute was prepared to train entrepreneurs and supply the equipment and technology required to operate the new business. Moreover, fees were required, and the initial equipment costs were low, about 32 000 NGN (in 1995, 78.5 Nigerian naira [NGN] = 1 United States dollar [USD]) for soap and 30 000 NGN for palm wine.

Ten soap makers and eight palm-wine bottlers were interviewed, as well as five mechanized *gari* manufacturers. The most frequently given reasons for adoption of the institutes' technologies were their relative technical advantage, the low investment risk, and the absence of technical problems. Respondents said that their training made them very conversant with the technology involved in palm wine and soap; the only problem was the availability of raw materials. Low investment cost was also underscored by the recipients. The responses are summarized in Table 8.

Table 8. Critical factors leading to diffusion of research institute inventions.

Factor	FIIRO innovation	PRODA innovation
Demand pull	Nico cream	Laboratory equipment
Relative advantage (technology push)	Mechanized <i>gari</i> (3) Sparkling wine (1)	Automated <i>gari</i> process Village <i>gari</i> unit (1)
Perceived advantage	Palm-wine bottling (8) Soap making (6)	Washing machine (2)
Low risk (technical or economic)	Palm-wine bottling (10) Soap making (8) Potable alcohol (2)	
Compatibility with existing habits, methods	Smoke curing of fish (1)	

Notes: FIIRO, Federal Institute of Industrial Research at Oshodi; PRODA, Project Development Institute. Figures in parentheses represent number of respondents who gave the factor as the reason for adoption.

Explanation for nondiffusion

To explain the nondiffusion of the bulk of FIIRO's inventions, particularly those that would help the import-dependence problem, I will discuss the inventions in greater detail, particularly those most important for saving foreign exchange.

Sorghum malt and beer brewing — FIIRO

Traditionally, malt has been obtained from barley. The malt is produced by steeping the grain in water, allowing it to germinate, drying it in kilns, and grinding it into flour. Lager beers are normally brewed from barley malt. Nigeria was spending more than 140 million NGN on imports of barley malt, annually. But foreign-exchange constraints were putting pressure on barley imports. After several years of research, FIIRO developed malt from a variety of sorghum, which is a staple food in the whole of northern Nigeria and is widely grown. Short kaura sorghum was found to have very

good malting qualities. Although the development of sorghum malt was started in the early 1970s, it was only after the Brewing Industry Research Foundation, Nutfield, made malting and brewing equipment available to *FIIRO* in 1976 that the work made progress. Seven sorghum cultivars were malted, and the malts were combined to create one portion of sorghum-barley composite malt (i.e., at a ratio of 1 : 1) for the first trial production of the seven cultivars: YG5760, L-1412, FDI, FFBL, MDW, RZI, and SK5912. The malt worts and the beers were fully analyzed (Table 9). The lager beer was acceptable and had a shelf life of 26 weeks. Short kaura sorghum (SK5912) was chosen as a result of these tests. In 1984, commercial-scale brewing was done by a major brewer, who used SK5912 sorghum malt at two replacement levels: 25 and 50%. The two products were branded *Femos Special* and *Femos Extra*.

Table 9. Analysis of PRODA and FIIRO beers.

	PRODA Dawa	FIIRO beers	
		Femos Extra	Femos Special
Colour at 430 mm (SRM)	3.30	5.00	10.25
Specific gravity (20°C)	1.016 08	1.003 51	1.000 34
Apparent extract (%)	3.10	0.90	1.25
Real extract (%)	5.80	2.79	3.33
Alcohol (wt.%)	3.10	4.11	4.40
Alcohol (vol.%)	4.70	5.16	NA
Extract of original wort (° plateau)	13.00	10.81	11.86
Real degree of fermentation (%)	55.50	74.00	71.92
Apparent degree of fermentation (%)	76.40	92.00	89.46
Total acidity (%)	0.44	NA	NA
pH	5.00	3.75	4.40

Notes: *FIIRO*, Federal Institute of Industrial Research at Oshodi; *PRODA*, Project Development Institute. SRM, standard reference material.

Eventually, higher sorghum-substitution levels of 60, 70, and 100% were achieved in *FIIRO* laboratories. For 100% sorghum malt, the false-bottom filtration system, with a press filter, was the only modification to the process equipment required.

After the initial success with both brands of *Femos* beer, the products were market tested in 1984. The criteria were taste, flavour, aroma, after-palate strength, aftereffect, clearness, and foaminess. The markets were Lagos, Jos, Makurdi, Port Harcourt, Aba, and Benin, the main beer-consuming centres of the country.

The pilot report was not accepted by the brewers, who argued that sorghum was different from barley malt in chemistry, taste, stability, and fat, tannin, and nitrogen contents. Only one major brewer showed any serious interest in sorghum or composite malt, even after acceptance tests for *Femos* had showed some of these arguments to be unfounded.

Interviews with personnel from the two leading beer brewers, Nigerian Breweries Ltd and Guinness Nigeria Ltd, revealed that their most serious reason for resisting sorghum malt was that any beer not made from barley malt cannot, technically speaking, be called a lager. They also asserted that sorghum malt does not contain husks, and, therefore, the enzymes required in the brewing process have to be sought separately. Also, the brewers resist making any major investment on the basis of laboratory results not replicated by commercial-scale production. Lastly, the

brewers see sorghum malting as an innovation still in its infancy, requiring several years of genetic engineering to replace barley as a malting medium.

From the point of view of the researchers at FIIRO, the real reason for industry resistance is the commitment of the different brewers to brewing specific brands of lager in the Nigerian market. In their view, an outright ban on the import of barley malt would force brewers to use local resources.

The brewers' perception of sorghum malt is different from that of the researchers. The brewers see it as experimental, with many problems still unsolved, such as those concerning cultivars, chemistry, requisite changes in equipment and tooling, and market testing of 100% sorghum malt beers and the effects of these on branding. Unlike the other diffused inventions, sorghum malt is not perceived as having passed through all the stages of development, from demonstration of technical feasibility to full commercialization, but a ban on barley malt imports would certainly hasten the process. It will not obviate the necessity for further work, as brewers still have the final consumer to deal with.

Composite flour — FIIRO

FIIRO introduced composite flour in response to the high demand for wheat flour in Nigeria and the country's inability to produce more than 5% of the requirements of the many large flour mills in the country. Composite flour is the name given to wheat flour that is diluted with other types of flour, such as those made from cassava, maize, and sorghum, which are more readily available in the country. Breads and confectionery are usually made from wheat flour, as wheat contains gluten, a good source of protein. The challenge in replacing wheat is finding a suitable substitute for the gluten.

After several experiments in which wheat flour was diluted with flours from maize, sorghum, and cassava, several baking tests and consumer-acceptance surveys were carried out. It was found that the composite flour most suitable for straight dough was 20% cassava starch, 5% soybean flour, and 75% wheat flour. For mechanical dough, the respective proportions were 25, 5 and 70%. Thus, the amount of wheat was still substantial, and the saving in foreign exchange was less than 25%.

Unfortunately, bakers have resisted the composite flour because it involves a major change in their baking habits. The majority of Nigerian bakers do not use the mechanized dough process. Composite flour, being weaker than wheat flour, is more susceptible to gluten damage with the process that most Nigerian bakers use. This risk probably explains the nondiffusion of this innovation.

The total elimination of wheat was recently achieved in laboratory trials for composite flour, but the new product is still experimental.

Certain conclusions can be drawn from the composite-flour project. The invention requires a major change in the baking habits of bakers and involves a high risk of loss. It is not surprising that this invention has remained largely undiffused. In the 0% wheat form, it is an invention with too many unresolved problems. It requires a change of taste by the consumer. As long as pure wheat flour is available, this invention is unlikely to be diffused, as no price advantage seems to accompany its use.

Soy-ogi — FIIRO

Soy-ogi was developed in response to the problems of low-income Nigerians feeding their infants on pap, a corn meal that is high in starch and low in protein. This has resulted in a high incidence of kwashiorkor, a disease that retards the mental and physical growth of children. On the other hand, the enriched, imported baby foods that are high in protein are not affordable to the poor. The FIIRO price for *soy-ogi* is about

60% of that of imported equivalents.

Soy-ogi was developed to be both affordable and high in protein, minerals, and vitamins. It is made from corn, soy beans, vitamins, and essential minerals. It was first introduced and test marketed in 1972–1973. Production has continued at FIIRO's pilot plant. Unfortunately, none of the big baby-food manufacturers in Nigeria has been licenced to produce it. Currently, discussions are on with Nestlé and Food Specialties to commercialize the product.

The nondiffusion of *soy-ogi* seems to be due to the initial problem encountered with toxicity after it was introduced. It had to be withdrawn from the market. This technical problem has since been resolved, but consumer resistance remains, likely because of the availability of inexpensive imported baby foods of known brands, marketed by highly efficient multinational companies.

Despite *soy-ogi*'s low cost and high nutritional value, it has remained largely a pilot project, produced and marketed by FIIRO.

Ginger powder, oleoresin, and concentrates — FIIRO

At the time this paper was written, there were 41 soft-drink-bottling factories operating in Nigeria, all using imported soft-drink concentrates. Although only five of these bottlers make ginger-based soft drinks, the market potential for this invention has been estimated at about 8 million NGN.

Ginger in its raw form has a taste and aroma that are appealing, but the ginger has to be processed to be edible. The purpose of processing ginger is, therefore, to extract its desirable properties and store these in concentrated form — as powder, oleoresin, or concentrates — to be reconstituted later. FIIRO has invented a process to do this.

The various extracts are obtained through cleaning, drying, milling, and extraction. Products that can be made from ginger include ginger ale, and ginger beer. However, all the concentrates used in the Nigerian industry are at present imported, despite Nigeria's being a leading and preferred producer of raw ginger and despite the FIIRO invention.

As well as having invented the product, FIIRO can fabricate most of the equipment for processing ginger-washing troughs, picking tables, and cold extractors. Mitchell-type trays, air dryers, apex hammer milling machines, and solvent strippers have to be imported.

I asked soft-drink bottlers why they had not adopted the FIIRO invention. They gave two main reasons. First, ginger drinks represent only about 5% of the soft-drink market, and many bottlers do not make them; those who do, produce them under licence. Second, they view the FIIRO invention with caution.

Perhaps the technical barrier to diffusion is that the bottlers would have to make new investments because their facilities are geared to production from concentrates. The most promising avenue of diffusion might be to erect legal barriers to the import of ginger in any form.

Tanning agents — LERIN

LERIN showed that *Acacia nilotica* (*bagaruwa*) pods make a technically feasible tanning agent. Trials yielded the following results: tannins, 60–65%; nontannins, 25–30%; moisture, 7–8%; insoluble matter, 2–3%; and Ph, 4.4. The institute's researchers were able to set up improved conditions for leaching and filtration and improved retention of active ingredients during storage.

Preliminary assessments showed that a commercial plant for producing tanning extracts would be crucial for the successful commercialization of this product. Another

prerequisite would be the availability of *A. nilotica* pods on a commercial scale. At present, they grow as wild plants, and for commercialization, it would be necessary to develop plantations. In other words, the project is still far from the commercialization stage.

The initial assumption was that the pod was widely available throughout northern Nigeria and that it was a wasted resource. However, even for the quantities required for a pilot plant, getting a regular supply would be a problem. Our initial inquiries showed that *bagaruwa* pods were sold commercially but not in quantities that could be relied on by a commercial producer of extracts. Availability is also seasonal. So far, two plantations have been developed, in Kaduna and Niger. However, they are not yet ready for harvesting. Storage is not a serious problem after the pods are dried in the sun or otherwise dehydrated.

Methods of producing extracts from the tannin have been developed on a pilot scale, but commercial-scale equipment for large-scale production could not be developed locally. A European firm is currently developing this equipment.

If extracts could be commercialized, then as much as 5 million NGN could be saved in foreign exchange, as a result of replacing imported tannins. The conclusion that seems clear is that critical conditions for commercialization of the *A. nilotica* invention are largely unmet.

Anogeissus schimperii (marker) leaves and *Parkia clappertoniana* (dorowa) husks are also feasible sources of tanning agents. The constraints to commercialization are LERIN's lack of design and fabrication capabilities for this. It is crucial to produce the tannins in extract form, rather than using the vegetables directly.

Research at LERIN on fat liquors for leather has concentrated on edible oils. Products from these edible oils are technically acceptable but uneconomic because of competition with human consumption. Groundnut oil was developed first but proved too expensive. Oil from the rubber tree has also been developed for use as a fat liquor in the tanning process. It is promising because it is not edible, but it has not been commercialized. Also, the mangrove tree has been shown to produce fat-liquor oil. It is a scientific success as a substitute for edible oils, but this development has also not been commercialized.

Work on a bating agent, *Adenopus breviflorus* (tagiri), is in a similar state. R&D is virtually complete, and industrial trials have been done.

Sorghum malt and beer brewing — PRODA

The PRODA sorghum malt project was undertaken in the 1970s, at about the same time as the FIRO efforts. Sorghum grain was steeped, drained, and malted. A three-stage decoction mashing method was used. Gelatinized maize starch and sucrose were used as adjuncts. Bottom-fermenting yeast (*Saccharomyces uvarum*) was used for fermentation, and the beer was decanted and lagered.

The malt obtained from initial experimental work gave these results: moisture, 5%; cold-water extract, 5.2%; hot-water extract, 22.8%; protein, 10.85%; nitrogen, 1.74%; extract (as is), 25.88%; extract (dry basis), 30.3%; apparent extract (° plateau), 4.65; diastasic power (° L), 10. The experimental beer was analyzed, as indicated in Table 9.

The PRODA beer was made from 100% sorghum and was branded Dawa. The construction of a small pilot plant to brew 1000 bottles of Dawa a day for taste tests was started in 1983 and completed in 1986. Also, a pilot malting plant, capable of malting 700 kg of sorghum grain, was built to carry out pilot malting for Premier Brewery Ltd. However, the project has remained essentially experimental. Interviews revealed the same kind of industry resistance that the FIRO beer project faced.

Alcohol distilling — PRODA

Because of Nigeria's substantial expenditure on imports of industrial ethanol and potable alcohol, PRODA developed an alcohol-distilling plant that could convert fermented raffia sap to ethanol; extract ethanol from molasses; and purify the local gin, *ogogoro*, into potable alcohol by reducing to a minimum the methanol, fusel oil, and aldehydes in it. The plant comprised rectifying towers, a deodorizing tower, boilers, a centrifugal pump, process-control facilities, etc. PRODA is able to deliver this plant in three sizes: 180 L day⁻¹ capacity (price, 40 000 NGN); 500 L day⁻¹ capacity (price, 72 475 NGN); and 1000 L day⁻¹ capacity (price, 90 000 NGN). Despite excellent test results, however, there have not been any orders for the plants. The PRODA plant is technologically superior to the local distillers' facilities, so it is surprising that it was not adopted.

The noncommercialization of this invention seems to be due to the relatively low cost of the traditional process and unawareness of the superiority of the PRODA process. One PRODA researcher also suggested that many traditional distillers distil very cheaply because they do not pay the high excise tariffs that they would have to pay if they adopted the large-scale, more efficient PRODA machinery. This was not verified for this study, as I did not interview the traditional distillers.

Palm-nut processing — PRODA

At the time of our investigations, Nigeria's oil-palm resources were estimated at 4×10^6 ha of scattered plantations and wild growth. Before the discovery of oil in commercial quantities in Nigeria, palm produce was the third major source of export earnings, after groundnut and cocoa. All the exported palm and kernel oils were extracted by traditional hand-operated mills, until the Dutch-designed Pioneer oil mills were imported in the 1950s. But these were found unsuitable by the small, peasant farmers, who formed the bulk of the oil processors. The mills broke down frequently, were plagued with lack of spare parts, and were inefficient and inappropriate for producing oil from the newer, high-yielding oil-palm varieties introduced to the plantations.

PRODA palm-oil mills were developed to replace the Pioneer oil mills in the rural communities. The PRODA mills comprised a bunch stripper, which spikes out the nuts from bunches; a palm-fruit cooker, capable of holding as much as 200 kg of loose palm nuts; a digester, which is a cylindrical container with a rotating shaft that mashes the oil pericarp; an oil press to extract the oil; a kernel-nut cracker, which cracks the dried palm kernels; and a screen.

If this invention were diffused, it could save Nigeria about 10 million NGN annually in imported machinery. It seems that the invention was not commercialized for many reasons. PRODA did not have the resources to fabricate the various components of the mill; it had the specifications only for the components and the prototypes. The only unit available for sale was the kernel-nut cracker. The large plantations seem to prefer imported machinery, and the peasants continue to use traditional methods.

Bread oven — PRODA

There were more than 10 000 bakeries in Nigeria in 1984. Most were using either mud ovens or imported gas or electric ovens. The small-scale bakeries relied predominantly on imported ovens. The PRODA researchers set out to design an inexpensive oven with even heat distribution and efficient heat use. They built and tested prototypes. The present oven has four decks; each deck measures 2.1 m × 1.22 m × 0.23 m and has

its own inlet pipe from the heating unit. The heat is supplied to the oven by a 320 000 Btu h⁻¹ oil burner (1 British thermal unit [BTU] = 1.05 kJ). The oven bakes bread evenly, without burning. It takes about 20 min to bake 300 loaves, 450 g each. PRODA saw its bread-oven invention as a welcome relief for bakers, as it was inexpensive and efficient and made from local raw materials.

The bread oven is said to be in commercial use in many parts of Nigeria. However, I was not able to visit any of the bakers who have purchased the ovens from PRODA. The invention was not yet commercialized in the sense of being produced by an established, commercial-scale factory; this was for technical and financial reasons.

Noncommercialization: A summary

This paper has just discussed some key inventions that were not commercialized, so it seems useful at this point to summarize the reasons for the noncommercialization of these inventions.

The process of technological innovation has the following stages:

1. Idea generation
2. Recognition of a need that requires a technical solution
3. Research leading to invention or demonstration of technical feasibility
4. Development of a product or process: raw materials; a prototype; design, fabrication, and erection of equipment; product or process debugging and modification; test marketing; and product or process promotion
5. Commercialization: design, fabrication, erection, installation, commissioning, and operation of a commercial-scale plant

The conditions for success are different for each of these stages. The competence required at each stage is also different. The least expensive of the stages is idea generation. Costs escalate as one moves along to later stages. The literature on innovation is replete with evidence that the first three stages are the cheapest and represent only a small fraction of the total cost. Usually, the last two stages — product development and commercialization — represent 60–90% of the total cost of innovation. All the stages are required.

However, very few organizations have the capacity to provide all the ingredients of innovation in-house. For instance, the largest and most versatile R&D organization in the world is Bell Laboratories in the United States, and some of the greatest technological breakthroughs came from it. But most of the development work and the eventual commercialization were done by outside firms, and some of these came into being merely to exploit the inventions.

Only a small fraction of inventions end up as successfully commercialized innovations. Several studies show that the proportion is between 5 and 25%. The pruning usually takes place in the development stage.

We reviewed a total of 61 inventions from the three institutes (see Table 3). Of these, 13 were commercialized, meaning that new production facilities were started on the basis of these innovations. This is 21% of the total number of inventions. This is consistent with previous findings.

Furthermore, we have seen that the best equipped of the three institutes also had the highest frequency of diffusion of its innovations. However, even FIRO, with its extensive design and fabrication capabilities, was ill-equipped to bring all of its inventions to the commercialization stage. In fact, evidence shows that to do that would be inefficient and probably a misallocation of resources. Most inventions do

not survive the development process, and this is borne out by the cases discussed in this research. The development problems ranged from perceived technical risk to market resistance, along with the sheer absence of development capability.

Also, commercialization was closely linked to the process of selection of research programs. R&D programs are based on the broad mandates tied to the legal instruments used to establish the research institutes. Within these mandates, individuals seem to concentrate their research according to their personal interests. There seems a complete absence of government R&D contracts like those that stimulated Bell Laboratories. It seems that each of the three institutes conducted R&D according to what it perceived was needed, and this probably explains the duplication of projects in the two most developed institutes (for instance, the *gari* innovations at both FIIRO and PRODA). Chances are that if more R&D programs with clear mandates and budgets were given to the institutes, better coupling would be achieved.

Finally, all three institutes seemed to be starved of the funds to keep even present programs alive. The best-funded programs apparently had enough money to pay salaries and purchase some basic consumables, according to the interviews I held with the researchers; however, the issue should be investigated more concretely.

Policy implications

The policy implications that come out of this research must be qualified. First, the study did not concentrate on the dynamics of the innovation process. It would have been enriched had I observed the various stages of the innovation process at each of the institutes, including the generation of innovative ideas; the collaboration of research teams to solve particular problems; the various constraints and hurdles; the various actors in the process; and the rivalries, intrigues, and infighting that often characterize R&D organizations. Second, for this research I made no attempt to assess the cost of each invention and the cost of running each of the institutes. I collected data only on budget and plan allocations, which may have little bearing on the actual expenditures. I therefore avoided assessing the direct or indirect benefits of their activities. These were not the aims of the research, but data on these could have enriched the study.

The policy implications of this study are the following:

1. Government-funded research should be drastically rationalized. The research programs at the institutes need to be evaluated to achieve the following ends:
 - eliminating duplication, by merging similar programs and assigning each duplicated program to a single institute (this may require some exchange or transfer of personnel in the case of important programs);
 - pooling the institutes' meagre resources, which are fragmented by duplicated projects (funds come from the Ministry of Science and Technology; therefore, it should be easy to effect this pooling with minimum disruption);
 - discontinuing projects and programs when other institutions have similar inventions (examples of these are the ceramic projects at FIIRO and the sorghum-malt project at PRODA); and
 - cancelling programs and projects that are carried forward from year to year without adequate resources, unless these programs and projects are seen to be related to national needs.
2. The government should not fund R&D activities until it identifies specific social, economic, technical, and other kinds of problems that need R&D

solutions. The next step should be to develop research programs with specific objectives and, after dialogue with R&D institutes, to evolve means for achieving the desired results. Funds should then be tied to specific research programs. R&D institutes should be made to sink or swim on the basis of the number of feasible need-oriented research programs they can attract and what they can do with the programs. This means putting an end to blanket funding for institutes.

3. The R&D personnel be rewarded on the basis of the ultimate utility of the solutions they devise, rather than for their inventiveness or the number of feasible technical solutions they can devise for problems.
4. The government and the institutes should stop trying to commercialize inventions in-house; they dissipate their meagre resources when they set themselves up as manufacturing outfits, trying to market their inventions. The best of these institutes lacks the range of capabilities needed for successful marketing. However, the Nigerian entrepreneur will require substantial technical input from the R&D institutes to commercialize the inventions. The commercialization role of R&D institutes should be limited to the following:
 - running training programs for entrepreneurs wishing to commercialize the institute's inventions (FIRO already runs several courses, such as those on soap making, gum-arabic production, palm-wine bottling, potable-alcohol distilling, and peanut-butter making);
 - acting as technical consultants, paid by entrepreneurs to provide detailed designs, specifications manuals, and other technical services;
 - encouraging their inventive personnel to branch out on their own and develop their own production facilities; and
 - solving (for fees) the various developmental problems encountered in commercialization.
5. The R&D institutes should use restraint in presenting their inventions to the public and policy-makers; they can otherwise give the misleading impression that the demonstration of technical feasibility in itself constitutes a sufficient condition for commercialization. Nondiffusion tends to be seen, then, as deliberate resistance to the use of the invention, rather than a result of attempting to make commercialization precede development. When inventions are mistaken for innovations, the required investment in further development is not made, and commercialization is further delayed.
6. The climate for the commercialization of inventions in Nigeria should be substantially improved to achieve better diffusion. For this, several steps need to be taken:
 - The need to commercialize the inventions has to be created in, or forced on, the nation, which is a fact borne out by the rushed introduction of many brands of sorghum beer soon after the government announced that barley-malt imports would be banned. Once a need of this kind has been forced on the nation, the need must be sustained for a long time for it to be worthwhile for investors to commit resources.
 - Government policies that deter self-reliance must be scrapped to bring about the commercialization of useful inventions. These policies include the liberalization of imports; the blanket interest rates for all classes of investment; indiscriminate withdrawal of subsidies for agricultural inputs,

which may badly affect local raw materials; and the deregulation of interest rates. The deregulation of interest rates penalizes delayed returns, and, because R&D projects involve various delays, they are the hardest hit by interest-rate deregulation.

7. A specialized institution should be developed to provide nursery beds for R&D institutes' inventions. This institution should be funded and made independent to enable it to
 - collect as many promising inventions as possible;
 - evaluate each of them and determine the ones with sufficient promise;
 - select and fund the development of promising inventions;
 - send the successfully developed and commercially feasible designs to willing entrepreneurs (the new entrepreneurship-development program of the federal Ministry of Labour should be tied to these activities); and
 - underwrite the losses from developed inventions that prove commercially unfeasible.
8. The R&D institutes should be allowed to sell their services to the private sector and thus become more relevant to the needs of the country. The institutes should be allowed to compete for research projects initiated in the private sector. For this to be effective, the government needs to provide the private sector with an incentive to use R&D services. A climate of liberal imports does not provide this incentive. The incentive should take the form of special tax rebates or outright matching of funds for private-sector users of indigenous R&D institutes.

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CHAPTER 12

Technological Capability in Oil Refining in Sierra Leone

Augustine J. Smith

Introduction

This article investigates the accumulation of technological capability within a petroleum refining company in a Third World country, Sierra Leone. However, technology transfer, technological capability, and technical change are all important because they directly affect development.

One view advocates technology transfer through free operation of transnational corporations (TNCs) in developing countries. The foreign capital brought by the TNC would generate more capital, entrepreneurship, tax revenue, foreign exchange, employment, and output (Lewis 1958). However, several recent studies showed that foreign-exchange crises are more common. The transfer of technology is not automatic. The recipient country must work hard to acquire it.

As a result of a successful transfer, technological capabilities may be built up within a country. These capabilities are apparent when its nationals can effect technical change. It is important to understand the contextual factors affecting the accumulation of technological capability in each country and in each region. This article concerns the study of such processes in Sierra Leone.

Science and technology policy in Sierra Leone

Like most other developing countries, Sierra Leone undertook industrial development without an explicit science and technology (S&T) policy. Developing countries once felt that substituting imports with direct foreign investment was an appropriate industrialization policy that would eventually lead to an automatic transfer of capital, management skills, and technical knowledge. Such transfers never took place in Sierra Leone. It is now widely accepted that effective transfer of technology requires a deliberate S&T policy in the recipient country to ensure that various technologies are compared; the appropriate one is selected for transfer; and the effectiveness of the transfer, assimilation, and adaptation of the selected technology is monitored. In Sierra Leone, the realization of the importance of such policies led to the recent establishment of the National Commission of Science and Technology. One immediate task of this body will be to coordinate the S&T ventures in the country. At present, various ministers regulate different aspects of industry, which is inefficient because there is little consultation among them.

The Sierra Leone Petroleum Refining Company

The Sierra Leone oil refinery was opened in 1970 as a joint venture between the Government of Sierra Leone (GOSL) and the subsidiaries of several transnational oil companies: BP, Mobil, Texaco, Shell, and Agip. The refinery is owned and operated by the Sierra Leone Petroleum Refining Company (SLPRC), in which GOSL has a

50% interest; the remaining 50% is held in various amounts by the subsidiaries. BP provides technical advice to SLPRC.

Although the Ministry of Trade and Industry has overall responsibility for SLPRC, the board chairman is the minister of Finance and contracts are ratified by the Ministry of Justice. The three ministries — Trade and Industry, Finance, and Justice — have their own mandates, and there is little consultation.

Although the refinery is capable of processing 450 000 t of crude oil per year, it processes only 220 000 t. The refined products include premium motor spirit (PMS), dual-purpose kerosene (DPK), aviation turbine kerosene (ATK), automotive gas oil (AGO), fuel oil (FO), bunker fuel oil (BFO), lead-free naphtha (LFN), liquid petroleum gas (LPG), marine diesel oil (MDO), and special distillate (SD).

The refinery has 138 established positions, all held by Sierra Leoneans. There seems to be some evidence of the accumulation of production capability within the refinery. The purpose of this study was to examine these indigenous capabilities and the ways they have developed.

Objectives of the Study

The main objectives of the study were to examine the technological capabilities of SLPRC staff and determine the extent to which these capabilities resulted from the transfer of technology from the oil TNCs. The constraints affecting the relationship between the TNCs and Sierra Leone were also examined to determine which aspects of this complex relationship resulted in the apparent success of the oil refinery. The specific objectives were to determine the following:

- the nature and extent of technological capabilities within the Sierra Leone oil refinery by identifying static and dynamic capabilities;
- the mechanisms for accumulating these capabilities within the firm;
- the extent to which increasing technological capabilities of the Sierra Leonean staff are reflected in increased innovation and technical change; and
- the internal and external constraints on the firm, such as government policies, TNC control, and management contracts.

Methodology

This is a case study of the accumulation of technological capability in Sierra Leone. SLPRC was selected for the study after a success story was told at a workshop on West African S&T policy held in Monrovia, Liberia, in 1982. The story is this: A boiler at the refinery broke down, and the management wanted to hire an expatriate boiler expert. However, the national maintenance engineering team decided to repair the boiler using facilities at the local railway workshop. Evidently, the repaired boiler performed better than it had before. This story clearly indicated that there was some local technological capability at SLPRC; hence, the company was selected for study.

Data acquisition

Data were collected on three aspects of the refinery: history, technological characteristics, and performance. The method of data acquisition was similar to that of Farrell (1979), but this study placed more emphasis on quantitative data collection and analysis. The research team used a combination of direct observation, interviews, archival research, and a questionnaire.

The research team visited the refinery site to observe the plant and its

personnel. Taking part in the preliminary exercise, I observed the 1983 annual plant overhaul, which proved to be a valuable learning experience. Information was collected on the refining process, the various components of the plant, and the functional organization of the personnel. From the initial visits, an interview list was drawn up to include all senior personnel, as well as representatives from the four groups of workers. Transcripts of the interviews were included in the first draft of the report (Smith 1984), and information from that report is used throughout this paper.

The research team also studied files, reports (e.g., Jones and Purves 1982; Koroma 1982), memoranda, newspaper articles, statistics, and other sources of information about the refinery. The main sources of data were the Ministry of Trade and Industry, which has overall responsibility for SLPRC; the Ministry of Development and Economic Planning, which collects periodic industrial statistics; the Bank of Sierra Leone, which deals with all the foreign-exchange transactions in Sierra Leone; and the Central Statistics Office and the Statistics Division of Sierra Leone Ports Authority, both of which collect import-export trade statistics.

The research team then studied the company's annual and monthly engineering reports to identify technical changes at the refinery, their causes, and their consequences. Senior and long-serving staff members were interviewed about their recollections of technical changes, and a detailed questionnaire was distributed to management and senior employees. Government representatives on the SLPRC board were interviewed about government policy regarding the refinery and the board's efforts to ensure implementation of the board's policies on oil refining.

Ten interviews were held with leaders of the national oil corporation PDVSA in Caracas, Venezuela, to find out about their efforts to ensure the transfer and assimilation of dynamic technology. In Venezuela, the oil industry, including the exploration, production, transportation, refining, and petrochemical sectors, was nationalized 10 years ago.

Interviews were also held in London with officers of BP and Shell connected with the refinery in Sierra Leone, as well as with board members. At BP, questions posed at the interviews focused on the methods for selecting general managers, technical advisers, and contractors for SLPRC, as well as on BP's attitude toward the technical services agreement and the skills and technological capabilities at SLPRC. At Shell, the major topics were (1) the relationship between the oil company directors and GOSL directors; and (2) the SLPRC problems with the debt for crude oil. The London interviews were far less fruitful than those in Venezuela. The people interviewed spoke only in general terms; no specific information about SLPRC could be obtained.

About the data collected

The reasons for collecting particular kinds of data provide an overall picture of the methodology. The archival data on the history of the refinery were collected in an effort to determine the extent to which SLPRC's preinvestment and investment decisions led to learning opportunities during the operating phase. The choice of technology and the refinery's management arrangement were also studied.

The principal and technical services agreements were studied to determine the extent to which training of local personnel for senior technical and management positions was a factor in negotiations. Some restrictive clauses preventing effective transfer of technology were also identified.

The literature search was carried out to establish the basic technology required to convert crude oil to refined petroleum products. A breakdown of its required skills dictated by the search was compared with the company's breakdown of its required

skills. Personnel with essential roles, including engineers, accountants, technicians, and scientists, were interviewed to determine the nature of their duties and the ability of Sierra Leoneans to perform them.

The annual reports, audited and unaudited accounts, minutes of board meetings, and other documents relating to the refinery, as well as engineering reports (import-export data), were analyzed to determine the extent of technical change and the refinery's ability to solve its major problems without relying on outside expertise.

A brief history of the refinery

In 1962, Shell, London, offered to build and operate a refinery in Sierra Leone for 2.8–3.0 million SLL (in 1995, 595 Sierra Leone leones [SLL] = 1 United States dollar [USD]). However, Shell and GOSL could not reach an agreement, and negotiations broke down.

In 1964, Haifa Refineries Ltd (HRL), a government-owned Israeli company, offered to help GOSL build a refinery to be owned and operated by a limited liability company incorporated in Sierra Leone and managed by HRL. The offer included a cash loan of 800 000 SLL, or up to 25% of the construction cost, as down payment for equipment and machinery. HRL representatives came to Freetown in March 1965 for negotiations with GOSL, and it was agreed that the HRL loan would be repaid from the earnings of the refinery, with interest payments starting 6 months after completion and repayment of the principal starting 12 months after completion, and the construction would be financed by the supplier's credit. As a result of these negotiations, three agreements were signed. The premanagement agreement covered HRL's activities and responsibilities during the preinvestment and investment phases of the project. HRL was to issue international bids for machinery and equipment; accept tenders; check designs and flow sheets; supervise materials, equipment, and construction; check compliance with timetables; and monitor the bills, accounts, and suppliers. GOSL would help HRL by issuing entry and residence visas for HRL personnel and their families, exempting them from Sierra Leone taxes, allowing repatriation of their emolument in US dollars, allowing duty-free importation and exportation of all required apparatus, equipment, and furniture, and paying HRL a fee for its services. Any disputes would be settled at the International Court in The Hague, The Netherlands.

Under the management contract, HRL was to manage the refinery after it was completed. The refinery would be owned by a limited liability company incorporated in Sierra Leone, and the power of the managers was outlined. GOSL was to provide the site and land title, electrical power, fresh water, licences, and other requirements for the efficient running of the refinery. GOSL was also obliged to construct the Kissy Jetty and make it available to the refinery and to maintain essential harbour services, including adequate pilotage and customs facilities. The refinery was to be granted development company status and was to enjoy maximum benefits under the *Development Company Act*.

Under the loan agreement, HRL was to lend GOSL up to 1.2 million USD but not more than 25% of the total cost of construction. Repayment would be in 14 equal semiannual instalments, starting 12 months after the completion of the project. The loan carried an interest of 6% before the completion of construction and 7% after. The loan, which would be taken over by the refinery, was covered by promissory notes guaranteed by GOSL.

With these agreements signed, HRL invited bids from 12 international companies in May 1965. Four bids were submitted, but these were rejected because

of unacceptable financing. Nissho, a Japanese construction company, was invited to tender, using a design submitted by the Litwin Engineering Company. Nissho offered to construct the refinery at a cost of 5.46 million USD, and in April 1966 Nissho and GOSL signed a contract: 25% of the cost was provided by the loan agreement with HRL and 75% by Nissho, through a loan agreement. Nine promissory notes (annual payments) were issued and guaranteed by GOSL. The contract allowed for inspection and testing during manufacture. GOSL would provide labour, electricity, fuel, and water free of charge. The constructor was allowed to hire subcontractors without the prior consent of GOSL, and all equipment was to be purchased tax free.

HRL assured GOSL that the value of the refinery products would not at any time exceed the cost, insurance, and freight value of similar imported products, and GOSL would not at any time be expected to make funds available to "operate" the Nissho loan.

Construction started in November 1966, and by the end of February 1967, a progress report, prepared by HRL, indicated completion figures for process engineering (97%), civil engineering (85%), mechanical engineering (55%), electrical engineering (60%), and instrument engineering (80%). The civilian government was then deposed by the National Reformation Council (NRC), a military junta, and the NRC chairman personally took charge of the refinery project. After some investigation, the economic adviser to the NRC made the following recommendations:

1. The management fees for HRL should be changed from 2% of the turnover to a fixed 50 000 USD per annum, in addition to 10% of the profits after operation costs and depreciation.
2. HRL should raise 10 000 SLL of the estimated 16 000 SLL needed to train refinery operators.
3. HRL engineers should determine whether the Kissy Jetty would be operational for the next 2 or 3 years.
4. Registration of the refinery company should be deferred because construction was not yet finished.
5. An independent firm of engineers should be selected to carry out a feasibility study.

HRL raised 5000 SLL and GOSL raised 16 189 SLL to train 80 students locally, and 73 successfully completed a 6 month course at the Technical Institute; 12 of the 73 were selected for further training in Haifa, and the other 61 were to be employed at the refinery. Construction of the refinery was still incomplete, and unsuccessful attempts were made to place these students in other industries. As a result they were asked to wait, and the further training in Israel was deferred.

The HRL engineers confirmed that the Kissy Jetty would be operational for at least 2 more years, and in November 1967 the King-Wilkinson Company (K-W) was selected to carry out a feasibility study. The feasibility study, submitted in February 1968, highlighted several technical and financial shortcomings of the refinery project. Having no catalytic reformer, the refinery would have to regularly import expensive blending materials to raise the octane number of the gasoline it produced. GOSL needed to provide 850 000 USD for crude oil, chemicals, engineering, spare parts, and salaries before start-up, and the loan-repayment scheme, based on irrevocable letters of credit due on fixed dates, would be an unrealistic financial burden on the refinery and would require GOSL subsidization to maintain its liquidity.

The report suggested that the capital structure of the refinery be reexamined, with emphasis on the starting capital and the loan-repayment scheme; it also suggested

the formation of a refinery company jointly owned by GOSL (50%) and the oil-marketing companies operating in Sierra Leone (50%), rather than a company wholly owned by GOSL. The suggested equity capital of the new company would be 2 million USD. GOSL could insist on the right to subscribe later. The report also suggested that the promissory notes to HRL and Nissho be cancelled and replaced by a long-term loan of 5 million USD, repayable in 15 years.

In March 1968, GOSL decided to accept the option of a refinery jointly owned by GOSL and the oil companies, and HRL was informed of the policy change. HRL agreed with this policy and urged GOSL to speed up negotiations for the formation of the joint company prior to the completion of construction in September 1968. GOSL decided that two officials of the Ministry of Trade and Industry would go to London in May 1968 for negotiations with the oil companies.

On 26 April 1968, there was yet another change of government. The new civilian Minister of Trade and Industry was immediately involved with the refinery project. In May 1968, the minister suggested that the cabinet should adopt the K-W recommendations, without paying cash for its 50% share of the new company. Instead, GOSL's contribution would be limited to the government's expenditure thus far.

At this stage, the government's main concern was to relieve itself of the financial burden it had inherited from the former civilian government. As a result of the K-W report, the HRL's activities were under scrutiny, and the Cabinet formed a high-level ministerial committee to look into the project. A letter was sent to HRL in July 1968, informing it that GOSL would stop honouring promissory notes. The committee had discovered that, although HRL had recommended the appointment of Litwin International as a consultant (which was approved by GOSL), HRL later appointed itself as consultant and drew up and negotiated bids, even inviting Litwin to bid, without asking GOSL to revoke the Litwin appointment. This was a violation of the premanagement agreement. The committee recommended that GOSL seek legal advice and referred the matter to the attorney general.

The Ministry of Trade and Industry then drew up guidelines for the London negotiations with the oil companies:

- Equity capital of the new company should be 3 million USD (2.5 million SLL, according to the then current rate of exchange) to ensure liquidity.
- GOSL and the oil companies would each own 50%, and the chair would be appointed by GOSL.
- Payment of the GOSL contribution would be made through capitalization of the amount already spent, together with the value of the site and other items; the rest of the repayment should be through the royalties due to GOSL.
- The price of products would not exceed the CIF value of imported petroleum products.
- There would be an excise on refinery products; this would be equivalent to the existing import duty on similar imported products, so that there would be no loss of revenue.
- Liabilities, such as the promissory notes to HRL and Nissho, would be transferred to the refinery company.
- There would be a timetable for takeover of the refinery.

The ministry guidelines also stipulated

- how the refinery would be managed;

- how many Sierra Leoneans would be employed at all levels, especially the 73 students trained at the Technical Institute at GOSL expense; and
- the terms of the development certificate of the refinery company.

Construction was eventually completed at the end of 1968, and the plant was commissioned in January 1969 by BP Trading, London, which brought in a team of 42 expatriates under the terms of the technical services agreement signed in May 1969. The BP team was to start refinery operations and recruit and train Sierra Leoneans, who would eventually take over.

The imperfections in negotiations

GOSL did not undertake a feasibility study after HRL offered to build the refinery in Sierra Leone. GOSL relied completely on HRL's promises that the refined products would not cost more than imported ones, the refinery would be able to pay for itself, and GOSL would not have to spend any more money on it. Both HRL and the economic adviser seemed to have interests contrary to those of GOSL. The economic adviser knew that HRL was in contact with Shell as early as April 1967, with a view to withdrawing from arrangements with GOSL. The economic adviser also knew that K-W was an engineering firm working for Badger, a company known to HRL and formed just to evaluate the refinery project, and that HRL had on many occasions inflated prices and the cost of products to produce positive cash flows. The economic adviser did not share this information with GOSL. The request for K-W to conduct a feasibility study and the change in proposed HRL fees from 2% of total turnover to 10% of the profits were two very positive steps taken by GOSL.

The K-W study may have been financed and, therefore, influenced by Shell (London). In particular, the recommendation that the oil TNCs become partners with GOSL in forming the new refinery company was not necessarily the best one. A truly independent study would have recommended other possibilities, such as a long-term loan from the World Bank, to pay off the short-term loan commitments of GOSL and the start of a refinery wholly owned by GOSL.

GOSL did show an interest in training, although this was restricted to 80 operators who were sent on a 6 month course at the Sierra Leone Technical Institute. A similar training program for engineers and senior oil experts should have been instituted. During negotiations, there was some discussion about training Sierra Leoneans to take over the refinery; however, there was no money allocated for this, and there were no firm timetables established. Thus, training was left entirely in the hands of the oil TNCs.

Performance of SLPRC

Data on SLPRC's performance for 1971–1983 were drawn mainly from audited and unaudited company accounts and other tables obtained from the Bank of Sierra Leone and the Central Statistics Office. Most of the data were collected between 1982 and 1984.

Productivity

Productivity figures for various products from 1971 to 1983 (Table 1) indicate that there was product diversification over the years, an example of technical change to be discussed more fully. Production of RMS was discontinued in 1982. RMS, with a research octane number (RON) of 83, was discontinued because the company could no longer obtain foreign exchange from GOSL to import platformate. Production of

Table 1. Refinery output (1971–1983).

	Output (long tons)												
	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
PMS	24 916	27 816	29 901	30 489	34 490	33 246	33 020	39 536	42 942	35 720	36 854	26 421	34 085
RMS	10 333	9 055	10 760	12 187	7 502	6 114	4 455	4 956	4 884	5 284	530	—	—
DPK	16 056	17 836	18 282	19 425	19 870	23 706	25 215	24 653	28 633	27 151	27 446	19 203	24 990
AGO	55 489	50 722	51 477	49 564	52 668	50 295	54 129	55 624	68 096	66 871	70 952	45 024	56 788
IDO	13 069	14 306	12 978	12 332	10 235	971	—	—	—	—	—	—	—
FO	25 307	25 218	28 712	26 170	23 815	21 758	17 039	22 785	16 928	28 372	30 985	33 041	30 430
LFN	118	77	71	108	148	118	126	208	269	235	234	223	129
LPG	—	—	—	—	—	216	817	880	633	662	743	656	751
SD	—	—	—	—	—	—	12	42	30	21	22	15	10
ATK	15 414	16 844	14 609	17 828	12 991	13 936	17 393	14 232	17 512	16 280	16 340	10 294	15 185
BFO	104 922	130 522	96 434	53 032	36 280	37 625	44 111	37 592	36 744	22 518	26 244	10 516	10 243
BGO	—	1 278	—	—	2 976	404	1 856	9 047	8 612	6 238	14 700	4 064	15 822
MDO	—	—	—	—	—	2 919	4 635	5 875	2 940	6 217	2 407	2 443	1 966
LN	2 911	10 949	—	1 364	995	—	—	—	—	—	—	—	—
Total	268 535	304 623	262 334	222 499	201 970	191 308	202 808	215 430	227 423	213 646	227 457	151 900	190 399

Notes: AGO, automotive gas oil; ATK, aviation turbine kerosene; BFO, bunker fuel oil; BGO, bunker gas oil; DPK, dual-purpose kerosene; FO, fuel oil; IDO, industrial diesel oil; LFN, lead-free naphtha; LN, leaded naphtha; LPG, liquid petroleum gas; MDO, marine diesel oil; PMS, premium motor spirit; RMS, regular motor spirit; SD, special distillate. 1 long ton = 1.016 tonnes.

IDO and LN was discontinued because of a lack of demand. During the same period, some new products were introduced: bunker gas oil (BGO), in 1975; LPG, and MDO, in 1976; and SD, in 1977. These products were introduced to respond to increased demand.

PMS production increased from 1971 and peaked at 43 000 long tons (1 long ton = 1.016 t). It then fluctuated at an average of about 35 000 long tons. The lowest level, 26 000 long tons, in 1982, was caused by a general reduction in the supply of crude oil to SLPRC because of its accumulated debts. That year was marked by production shortages and the accompanying hoarding and by exorbitant prices on the illicit market.

Production of DPK and ATK has increased steadily over the years, peaking in 1979. Production of AGO, another product in high demand, remained practically constant throughout 1971–1983.

The production of these products — PMS, DPK, ATK, and AGO — for local consumption was the main task of SLPRC, and the production of each has either increased or remained constant. The production of other products, such as FO, BFO, BGO, and MDO, has decreased significantly in relation to the production of desired products. This reduction has been achieved with fairly constant crude-oil import levels.

Capacity utilization

The SLPRC plant was designed to produce 10 000 barrels per steam day (bpsd) (1 barrel = about 0.16 m³). However, the only time it ran at full capacity was during testing. Table 2 shows the capacity utilization for 1972–1976. The operations department insists that processing Nigerian tests at a throughput of 5000 bpsd is all that is needed to meet local demand. This means that staff members do not have to consider technical changes leading to capacity expansion.

Table 2. Capacity utilization at SLPRC (1972–1979).

Year	Crude blend	Crude oil (long tons)	Unit time utilization	Production average (bpsd) ^a
1972	75/25 Nig/Manjid	332 000	84.4	8000
1973	80/20 Nig/Manjid			
1974	70/30 Nig tees/Med	237 000	70.4	5400
1975	80/20 Nig tees/Med	1 833 000	70.4	5400
1976	80/20 Nig tees/Med	180 000	71.2	5200

Source: T.W. Russel (United Nations).

Note: 1 long ton = 1.016 tonnes.

^a Barrels per steam day; 1 barrel = about 0.15 m³.

In recent years, the supply of crude oil has been erratic, causing slowdowns in the operations department. The refinery has no control over batch arrival times, so whenever oil does become available, the operations department has to process at high throughput to alleviate shortages as quickly as possible. Even when this happens, rates are well below 10 000 bpsd.

Financial performance

From 1976 to 1983, total product sales increased continuously, from 60 million SLL to 112 million SLL, but the exchange rate changed from 0.83 SLL = 1 USD to

2.54 SLL = 1 USD. Although there were increases in sales costs (cost of crude oil and platformate) and operating costs, the company had a net profit before taxes until 1981 (Table 3). In 1982 and 1983, however, there were losses. These were mainly caused by interest payments on crude-oil debts, which are owed because of the lack of foreign exchange.

Table 3. Taxes and dividends paid by SLPRC (1975–1981).

Year	Declared profit (1000 SLL)		Dividend paid (1000 SLL)
	Before tax	After tax	
1975	1200	579	579
1976	1200	579	597
1977	1000	720	382
1978	1600	720	770
1979	1461	789	1483
1980	na	na	na
1981	2456	970	970

Note: In 1995, 595 Sierra Leone leones (SLL) = 1 United States dollar (USD).

Although the company enjoyed profits from the beginning, it did not start paying dividends until 1975. The tax record showed that no dividends were paid in 1982 and 1983, but they were paid again in 1984, following the appointment of the first Sierra Leonean general manager. Profit was the main reason for the formation of SLPRC, at least from the point of view of the oil companies.

To ensure the continued profitability of the company, the principal agreement detailed a pricing mechanism: at the end of each year, SLPRC would estimate the next year's revenue requirements and product realization at the current price. If there were any shortfalls, an advisory committee would be set up to recommend new prices to offset the shortfall and make the company profitable again. After approval by the board, the new prices would go into effect. With the exception of 1978, there has been at least one ex-refinery price increase each year (Table 4).

The price the consumer pays is determined by the ex-refinery price, the excise duty, and marketer's margin. Table 5 shows ex-terminal prices (ex-refinery price plus marketers' margin), together with excise duty and the actual prices paid by consumers for some major products.

In general, GOSL in the past tried to avoid large fuel price increases, only allowing them when they would not have an immediate, direct effect on the public. The national economy is sensitive to increasing fuel and food prices, which eventually lead to demand for higher wages, and so on. Some fuel price increases in recent years have led to rioting in many of the major cities. In some cases, fuel prices were subsidized in Sierra Leone (not the reduction of excise duty on PMS, RMS, and DPK, which occurred in 1976 and 1977).

In 1982, prices for petroleum products in Sierra Leone were among the lowest to be found in countries not producing oil. However, GOSL started negotiating with the International Monetary Fund (IMF). As a result, between July 1982 and July 1983, pump prices for PMS rose from 3.40 SLL IG⁻¹ to 5.00 SLL IG⁻¹ and thence to 6.75 SLL IG⁻¹ (1 Imperial gallon [IG] = about 4.54 L). Early in 1984, there was an-

Table 4. Inland petroleum product price trends (1969–1981).

Date	Price/Imperial gallon (SLL)						
	PMS	RMS	DPK	AGO	IDO	FO	LFN
10-01-69	10.6	8.6	7.5	9.1	8.1	6.6	3.1
01-05-72	13.6	11.6	10.5	13.1	11.1	10.6	5.0
01-02-73	21.6	21.6	10.5	17.1	15.1	14.6	5.0
01-12-73	38.6	38.6	22.5	31.1	29.1	28.6	5.0
01-02-74	46.6	44.6	33.5	41.1	39.1	38.6	5.0
03-01-75	56.6	54.6	34.5	43.1	41.1	39.6	20.0
09-12-75	62.6	60.0	39.5	48.1	46.1	43.6	45.0
25-05-76	72.6	70.6	49.5	48.1	46.1	43.6	45.0
01-02-77	87.6	85.6	64.5	48.1	—	43.6	45.0
01-04-79	98.6	96.6	75.5	89.1	—	49.6	na
01-03-80	153.6	50.6	104.5	83.1	—	61.6	na
01-02-81	48.6	—	104.5	199.1	—	147.6	na

Notes: AGO, automotive gas oil; DPK, dual-purpose kerosene; FO, fuel oil; IDO, industrial diesel oil; LFN, lead-free naphtha; PMS, premium motor spirit; RMS, regular motor spirit. 1 Imperial gallon = about 4.5 L. In 1995, 595 Sierra Leone leones (SLL) = 1 United States dollar (USD).

other price increase, this time to 8.00 SLL IG⁻¹. There were similar price increases for all other petroleum products.

In interviews, SLPRC management reported that in 1973, GOSL, instead of reviewing SLPRC's price-increase proposals with the intention of minimizing the increases, tended to maximize them. GOSL wanted to use the increases to reduce consumption and, thus, heavy import bills. A one-step price increase from 3.40 SLL IG⁻¹ to 8.00 SLL IG⁻¹ was contemplated in 1982, but the increment must have been politically unpalatable to the government.

The efficiency and performance of SLPRC did not directly affect the availability or price of petroleum products. Other factors, such as marketer's margins, excise duty, IMF, and the availability of crude oil, petroleum products, and foreign exchange seem to have had greater influence on the prices paid by consumers.

Effect of external factors

Foreign-exchange shortages mean not only a shortage of crude oil but also a reduction in spare-parts stocks, and the company has to wait longer for major replacement parts. These shortages have so far postponed general overhauls for up to a year, but they have not caused a total production stoppage. This illustrates the careful manner in which SLPRC carries out scheduled plant inspections during the annual overhauls. All major parts of the plant, such as pumps, vessels, and the crude oil – gas oil heat exchanger, were replaced in the 1982 general overhaul (ultrasonic measurements of pipe thicknesses, made the previous year, had revealed the rate of corrosion). The plant inspection team suggested that the exchanger need not be inspected again until 1989.

The inspection date is obviously made with 1 or 2 years to spare so that annual overhauls do not unduly hinder the operation of the plant. In other words, a systematic inspection program exists, and it minimizes the impact of foreign-exchange shortages on SLPRC operations. A plant inspector and coded welder are the only two

Table 5. Sierra Leone light petroleum product price trends.

Date	Cost/Imperial gallon (SLL)											
	PMS			RMS			Kerosene			AGO		
	Ex-terminal	Duty	Price	Ex-terminal	Duty	Price	Ex-terminal	Duty	Price	Ex-terminal	Duty	Price
01-04-72	36.50	31.00	67.50	32.50	31.00	63.50	27.50	12.00	39.00	26.50	24.00	50.50
01-06-73	44.50	28.00	72.50	40.50	28.00	68.50	29.50	14.00	43.50	30.00	24.00	54.00
08-12-73	63.50	21.00	84.50	59.50	21.00	80.50	41.50	10.00	51.50	46.50	19.00	65.50
01-02-74	72.00	28.00	100.00	68.00	28.00	96.00	53.00	14.00	67.00	57.00	24.00	81.00
30-01-75	82.00	28.00	110.00	78.00	36.00	106.00	54.00	14.00	68.00	59.00	24.00	83.00
27-06-75	82.00	36.00	118.00	78.00	36.00	114.00	54.00	14.00	68.00	59.00	32.00	91.00
09-12-75	89.00	36.00	125.00	85.00	31.00	121.00	60.00	14.00	74.00	65.00	32.00	97.00
25-05-76	99.00	31.00	130.00	95.00	31.00	126.00	70.00	9.00	79.00	65.00	32.00	97.00
01-01-77	14.00	31.00	145.00	110.00	31.00	141.00	85.00	9.00	94.00	65.00	32.00	97.00
28-01-77	14.00	40.00	154.00	110.00	40.00	150.00	85.00	9.00	100.00	65.00	32.00	97.00
01-07-77	20.00	31.00	151.00	116.00	31.00	147.00	91.00	9.00	101.00	71.00	32.00	103.00
19-02-79	125.00	31.00	156.00	121.00	31.00	152.00	92.00	9.00	—	76.00	32.00	108.00

Source: BP Sierra Leone Ltd.

Notes: Terminal prices are paid by oil company marketing affiliates; duty is paid to GOSL; and price is what the consumer actually pays. AGO, automotive gas oil; PMS, premium motor spirit; RMS, regular motor spirit. 1 imperial gallon = about 4.5 L. In 1995, 595 Sierra Leone leones (SLL) = 1 United States dollar (USD).

experts SLPRC now requests from BP for the refinery's regular overhauls. Coded welding and plant inspection are required for insurance purposes.

Other economic problems do not seem to have had much effect on SLPRC performance because the company does not directly market its products — all the products are sold directly to TNC subsidiaries. Such factors as overvaluation of the leone, the existence of a thriving black market for petroleum products, particularly during shortages, and the poor state of infrastructure, especially the road network, do not affect SLPRC's operations directly. The country has been experiencing electric-power shortages recently because of fuel shortages and machine breakdown, but this has not affected SLPRC because its generator switches on automatically within 30 of a power failure.

Technical change and technological capability at SLPRC

In this study, technical change is regarded as the ultimate manifestation of technological capability within a firm. We looked for evidence of incremental technical change in SLPRC; we also looked for any creation of an indigenous technology and tried to relate the performance of technical change to learning.

Technical change may affect output-volume, output-mix, output-quality, and throughput parameters. We attempted to evaluate the effects of technical change at SLPRC, and to determine the direction of change.

Change that results from a deliberate effort by personnel to make the plant more efficient or to stretch its capacity is indicative of some rudimentary research and development (R&D) capability. Such capability may eventually generate new and indigenous technologies.

In contrast, technical change that is externally motivated, such as that carried out in response to increased demand or falloff in product quality, does indicate a capability for running and maintaining a production plant. This type of capability is really the beginning of the last stages in a sequence: (1) transfer and acquisition of technology; (2) development of a technological capability, including capability for adopting foreign technology; and (3) generation of a local technology.

The research team observed that a host of technical changes are carried out at SLPRC rather routinely. Most are minor and are done in response to some minor bottlenecks encountered in maintenance. Monthly engineering reports from the maintenance engineer to the chief engineer describe all engineering duties undertaken during the month and detail many modifications and fabrications of small and major replacement parts. Many of these modifications and fabrications qualify as technical changes when performed for the first time. Routine technical change occurs continuously at SLPRC, especially within the engineering departments.

Major technical changes

Major technical changes are those that have wide personnel participation or measurable effects on refinery performance. Table 6 displays a list of major refinery assets. By 1972, SLPRC had acquired from GOSL the plant, land, and water tanks. The extension of the refinery clinic in 1973 was a scale-multiplying change. The technical changes started with the installation of the standby generator and included all items marked with a superscript *b* in Table 6. The following sections give examples of the major technical changes, grouped according to their objectives.

Table 6. Schedules of main assets of the refinery.

Assets	Year of purchase	Cost (SLL)	Exchange rate (USD / SLL)	Cost (USD)
Land	1969	16 500	1.2000	198 000
Water	1969	14 400	1.2000	17 280
Process plant ^a	1972	5 034 907	1.2000	6 041 888
Extension to clinic	1973	3 560	1.1980	4 265
Standby generator ^b	1974	144 640	1.9800	178 279
PPD scheme ^b	1974	3 338	1.1980	3 999
Tank-farm lighting ^b	1974	5 858	1.1980	7 018
Refinery power installation	1974	24 180	1.1980	28 968
Crude transfer pump ^b	1974	16 536	1.1980	19 810
Extension to laboratory	1975	3 225	1.1980	3 864
LPG production unit	1976	332 480	0.8190	272 600
Storekeeper's office	1976	330 684	0.8190	270 830
Fire station	1976	2 333	0.8190	1 911
Gate	1976	78 332	0.9457	74 079
Air-circulating system	1979	2 350	0.9295	2 148
Crude-blending manifold ^b	1974	6 527	1.1980	7 819

Notes: LPG, liquid petroleum gas; PPD, pour-point depressant. In 1995, 595 Sierra Leone leones (SLL) = 1 United States dollar (USD).

^a Includes distillation facilities with a capacity of 10 000 barrels per steam day (1 barrel = about 0.16 m³); merox unit for kerosene and naphtha; storage for crude oil and products; laboratory stores; and workshop buildings.

^b Major technical changes.

Objective: to introduce new products

In response to local demand for LPG, a feasibility study for an LPG production unit was carried out. The study indicated that the project was economically feasible, so the capital costs were approved by the directors. Installation of the LPG production unit was carried out by SLPRC staff, with the help and supervision of a BP expert, whose job was to ensure that all specifications, as well as BP safety standards and practices, were strictly followed.

The local food industries required white spirit, so SLPRC produced an SD that had similar properties, except for a different flash point. This product proved acceptable to industry and is now produced regularly.

Objective: to increase production and production capacity

Steam is required in the crude column for stripping volatile substances from kerosene and gasoline, and the Marshall boiler was installed to produce steam. The automatic boiler required soft water, so a permanent softener was also installed. These changes were made to increase productivity and improve the quality of kerosene and gasoline.

SLPRC usually receives power from the National Power Authority. From 1971 to 1973, there were frequent power failures (51 in 1971 and 28 in 1973), and each meant the plant had to shut down. To overcome this problem, staff installed a standby generator. BP supervised the installation and made sure that BP standards and safety practices were adhered to, but the bulk of the installation was done by local staff.

Objective: to improve product quality

Pipe works leading to Shell, Mobil, and Texaco installations were modified so that ATK could be pumped through a dedicated line; PMS, DPK, and gas oil are pumped through another line. Black oil goes through a third line, ensuring minimum contamination of products, especially of ATK, which must conform to strict international specifications.

Objective: to reduce unit costs

In the 1971–1974 period, the price of crude oil increased considerably, and SLPRC could not increase its prices fast enough to keep pace. A lower throughput was required, but local demand also had to be satisfied.

During this period, the demand for fuel oil was falling because large ships were no longer refueling in Sierra Leone. It was necessary to reduce fuel oil production by cutting deeper into the fuel oil fractions for gas oil. A larger gas oil – fuel oil ratio could be obtained from lighter tees, but lighter tees are more expensive because they contain a higher percentage of the more expensive products, such as kerosene and gasoline. Therefore, changing to lighter tees not only meant the production of more gas oil at the expense of fuel oil but also the production of more gasoline and kerosene at lower throughput.

The SLPRC, thus, set its equipment to process lighter Nigerian tees. It started with a 60 : 40 mixture of Nigerian light–medium, then went up to 70 : 30, 80 : 20, and 90 : 10; it now processes 100% Nigerian light crude. By going to lighter tees, SLPRC was able to satisfy the local market at lower throughput and, thereby, solve the dual problems of escalating crude-oil prices and changing domestic consumption patterns. The lower throughput apparently offset the higher cost of lighter tees.

This is, perhaps, SLPRC's single most important technical change, indicating that it has a technological capability in oil refining and that the capability is not static. It shows that the company can produce a strategic response to ensure its financial stability in the face of severe external factors. The evidence available to the research team indicated that the SLPRC staff planned and executed this change with no significant foreign input.

The use of lighter tees caused some technical problems. Lighter tees are waxy, and because a deeper cut is taken from the fuel oil, its pour point rises and must be depressed. Initially, the pour point of fuel oil was depressed by adding some kerosene and gas oil, but this meant a reduction in the gains made by going to lighter tees. It was, thus, uneconomical to use diluents to depress the pour point of fuel oil, and a new technique had to be used. The company finally settled for a pour-point depressant (PPD) — a chemical additive that affects only the pour point. With a PPD, the advantages of lighter tees were regained.

The change to lighter tees necessitated the use of blending equipment and vessels with accompanying pumps, valves, and flow meters, and these were installed by SLPRC staff, a saving on installation cost.

Objective: to improve safety and preventive maintenance practices

A gasoline tank developed leaks and had to be rebuilt. A novel approach was taken: the foundation and frame were left intact, and sheets of metal were removed piece by piece and replaced with new ones. This meant a great reduction in cost and was so innovative, at the time, that two engineers from a Nigerian refinery were invited to observe. The technique was developed by BP, but the repairs were carried out by local staff, with BP supervision to ensure proper safety practices.

The story of the Hockadate boiler repair, narrated at an International

Development Research Centre workshop on S&T in Monrovia in November 1982, is what led us to select SLPRC for a case study. The Hockadate boiler broke down, the steam-chamber cover developed a crack, and the boiler-feed water pump stopped. The maintenance engineer at the time was an expatriate, and he immediately suggested ordering the faulty parts from the United Kingdom. The Sierra Leonean mechanical engineer suggested that the repairs be done locally, at much lower cost and shorter boiler down time, and was told to carry out the repairs locally. The pump was completely stripped and rebuilt, and some pump parts and the steam chamber cover were fabricated at the national railway workshop. The repaired boiler has been trouble free for a long time, apparently, and works better than it did before the repairs.

After several years of use, cooling-water pipes corrode, narrowing the pipes and reducing water flow and cooling efficiency. The use of a corrosion-control chemical in cooling water makes the very costly replacement of pipes unnecessary and prolongs their life by preventing further corrosion. Ammonia and Kontol are now used regularly in heat exchangers, overhead condensers, and even the crude-oil column.

An impingement plate was inserted in the crude-oil column where the hot crude oil enters. This preventive maintenance was intended to prolong column life. Heater tubes are operated at high temperatures, and they carry crude oil, which can become acidic. The originals are gradually being replaced by tubes made from a more resistant alloy. This preventive maintenance will avoid costly accidents, such as tube breakage.

A major fire-fighting main was constructed around the processing area, tank farm, and administrative building. The system was later extended to the jetty, and unlimited water can now be brought from the sea via cement-lined pipes. Construction of the water main was suggested during a safety audit.

Cleaning leaded tanks requires expatriate specialists, which could be quite costly to SLPRC. Company procedures were devised that are quite safe and cost nothing beyond normal operating costs. Other technical changes to improve safety were

- Certification courses in first aid and safety were given to employees.
- A new safety manual was prepared by refinery staff, and an emergency procedure booklet is carried by each employee.
- A company car, which had been written off and was about to be sold, was converted into an ambulance.
- Vessels to be welded were filled with foam, which eliminated vapors completely.

Effect of technical change on product mix

Table 7 shows that there has been variation in the product mix. New products like LPG and SD were introduced in 1976 and 1977, respectively, in response to local demand. Production of RMS was terminated in 1982 because a severe foreign-exchange shortage prevented SLPRC from importing the platformate it needed to blend to produce PMS with an RON of 93. Production patterns were, therefore, to include tetraethyl lead in the blend; the yielded a product with an RON of 87. This is now marketed as a single product, PMS.

Production of MDO also started in 1976, and Sierra Leone stopped importing it the same year. Subsequently, only the occasional barrel was imported, as local demand was satisfied by SLPRC. The termination of IDO production coincided with

Table 7. Refinery products as percentages of annual total production (1971–1983).

	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
PMS	9.28	9.16	11.32	13.70	17.08	17.38	16.28	18.37	18.09	16.72	16.03	17.06	17.90
RMS	3.85	2.98	4.07	5.48	3.71	3.20	2.20	2.30	1.72	2.47	0.23	—	—
DPK	5.98	5.87	6.92	8.73	9.84	12.39	12.43	11.44	12.06	12.71	11.94	12.40	13.13
AGO	20.66	16.72	19.48	22.28	26.08	26.29	26.69	25.84	28.68	31.30	30.86	29.06	29.83
IDO	4.87	4.71	4.91	5.54	5.07	0.51	—	—	—	—	—	—	—
FO	5.42	8.38	10.87	11.73	11.79	11.37	8.40	10.59	7.13	13.28	13.48	21.31	15.98
LFN	0.04	0.03	0.03	0.05	0.07	0.06	0.06	0.10	0.11	0.11	0.10	0.14	0.07
LPG	—	—	—	—	—	0.11	0.40	0.41	0.28	0.31	0.32	0.42	0.39
SD	—	—	—	—	—	—	0.01	0.02	0.01	0.01	0.01	0.01	0.01
ATK	5.74	5.55	5.53	8.01	6.43	7.28	8.58	6.61	7.38	7.62	7.11	6.65	7.98
BFO	39.07	42.98	36.50	23.83	17.96	19.67	21.55	17.46	15.48	10.54	11.42	6.76	5.38
BGO	—	0.42	—	—	1.47	0.21	0.92	4.20	3.63	2.92	6.36	5.11	8.31
MDO	—	—	—	—	—	1.53	2.29	2.73	1.24	2.91	1.05	2.62	1.03
LN	1.08	3.16	—	0.61	0.94	—	—	—	—	—	—	—	—

Source: Sierra Leone Petroleum Refining Company end-of-year accounts.

Notes: AGO, automotive gas oil; ATK, aviation turbine kerosene; BFO, bunker fuel oil; BGO, bunker gas oil; DPK, dual-purpose kerosene; FO, fuel oil; IDO, industrial diesel oil; LFN, lead-free naphtha; LN, leaded naphtha; LPG, liquid petroleum gas; MDO, marine diesel oil; PMS, premium motor spirit; RMS, regular motor spirit; SD, special distillate.

the beginning of MSO production. These two products are really the same. The introduction of MSO is, therefore, not a technical change but a scale-multiplying change. The production of IDO was 5% in 1975, and the total production of diesel oil (IDO and MDO) dropped in 1976 to 2% of the total (see Table 7).

Effect of technical change on production capacity

The SLPRC distillation plant, designed to produce 10 000 bpsd, only operated at that rate during trial runs. It is now known that local demand can be completely satisfied with the plant running at half its rated capacity. This, plus the fact that the principal agreement requires SLPRC to produce only for the local market, shows that there have been no technical changes with capacity expansion as the primary objective.

Effect of technical change on product quality

SLPRC product quality has always been high. This is partly because of the laboratory's vigorous quality control. Sampling and analysis of products are done at regular intervals during processing, and reports are given to the operations superintendent, who makes adjustments and uses blending to correct any errors. With this continuous sampling, testing, and adjusting, product quality has remained high.

Because of its quality-control consciousness, SLPRC installed a dedicated line to pump ATK to the Shell, Mobil, and Texaco terminals. DPK, PMS, and gas oil go through another line, and fuel oil uses a third. Because ATK is used by jets at high altitudes, it must meet high standards, and SLPRC makes a special effort to keep the product as free of contamination as possible. ATK is used to refuel aircraft at Freetown International Airport.

Effect of technical change on unit cost

SLPRC introduced significant technical changes to cut the production cost, which has two components: the cost of raw materials and the cost of refining. Table 8 shows that the cost of raw materials increased almost 30-fold and the cost of refining increased more than 10-fold from 1971 to 1983. The increase in the cost of raw materials was obviously caused by several jumps in world oil prices, but the reason for the increase in refining cost is mainly the decline in the value of the leone. At the start of the period, the exchange rate was 1 SLL = 1.24 USD, but at the end of the period it was 1 SLL = 0.17 USD.

Although the unit cost of product by raw materials rose from 87% to 94%, the refining cost declined from 13% to about 6%. A series of remarkable technical changes contributed to this. The first two were the selection of lighter tees and the adjustment of the plant to produce more of the products in high local demand. Those changes, more than any other, ensured survival of the company after the crude-oil price hikes.

There were also price increases that ensured profitability. The decline in real value of the leone contributed only to the yearly increases in the actual cost of production. It did not cause the reduction in the percentage contribution of the cost of refining relative to the cost of production. This could only have resulted from the technical changes.

The impact of changing the type of crude oil on unit input cost is seen most directly in imports of feedstock relative to 1971 values (Table 9). Imports started to decrease in 1973, continued to drop until 1977, when they were 30% below the 1973 level, and continued to drop until 1977. The biggest drop in a single year was in 1973

Table 8. Raw-material and refining costs of products (1971–1983).

	Cost / long ton (SLL)			Proportion of total cost (%)	
	Materials	Refining	Total	Materials	Refining
1971	19.01	2.83	21.84	87.0	13.0
1972	21.30	3.04	24.34	87.5	12.5
1973	26.34	3.27	29.61	89.0	11.0
1974	87.58	5.54	93.12	94.1	5.9
1975	93.18	8.56	101.74	91.6	8.4
1976	124.99	10.39	135.38	92.3	7.7
1977	138.77	10.20	148.97	93.2	6.8
1978	131.74	11.73	143.47	91.8	8.2
1979	192.56	12.73	205.29	93.8	6.2
1980	325.78	17.83	343.61	93.8	5.2
1981	406.65	18.99	425.64	94.5	4.5
1982	413.30	28.21	441.51	93.6	6.7
1983	546.01	33.56	579.57	94.2	5.8

Source: Sierra Leone Petroleum Refining Company end-of-year accounts.

Notes: 1 long ton = 1.016 tonnes. In 1995, 595 Sierra Leone leones (SLL) = 1 United States dollar (USD).

and seems to have been a strategic response to the 1973/74 crude-oil price hikes, when the cost of crude oil quadrupled.

Effect of technical change on safety and preventive maintenance

Several technical changes were aimed at plant and personnel safety. In the long run, these changes will also reduce the cost of production, but the most direct consequences were a safer work environment and longer equipment life span. Thus, new fire mains make the refinery safer. Chemicals into pipes to prevent corrosion increase safety and make equipment last longer, eventually reducing maintenance costs.

This type of change is important because it is internally motivated. Although its effect is difficult to detect in end-of-year accounts, the fact that the plant and its utilities have been operating for such a long time proves that they have been protected and well maintained.

Preventive maintenance is important because it involves consistent monitoring. This includes gathering information, inspecting facilities and equipment, drawing conclusions about problems, and executing a planned program of repairs and modifications. The key aim is to anticipate machine performance and deterioration. This is, in fact, a modest type of R&D.

At SLPRC, the planning and coordination of maintenance are carried out by the development engineer, whose functions include planning a schedule for testing and inspecting various parts of plant. Parts that have deteriorated to dangerous levels are repaired; otherwise, the date is set for the next inspection of the part. Parts and components needed for preventive and regular maintenance are ordered well in advance so that down time during planned maintenance is kept at a minimum.

Contributions of various divisions to technical change

The engineering division is responsible for major modifications of the plant and buildings, installation of additional equipment, and alterations of equipment and machinery. It also plans preventive maintenance and ensures that proper spare parts and supplies for engineering projects are available.

Table 9. Barriers to institute–industry interactions (mean responses).

Impediments to interactions	University ^a (<i>n</i> = 12)	Industry ^a (<i>n</i> = 16)
The orientation of the institute's research toward basic research is a mismatch with industry's needs for new and improved products	2.53 (3)	2.53 (2)
The need for the institute to publish research results is in conflict with industry's needs for protection of its trade secrets	3.35 (7)	3.44 (9)
Research performed by institutes is generally more expensive than in-house research	3.65 (9)	3.44 (9)
The institute often does not understand what industry needs in the way of product-oriented research or industry's need to maximize profits as return on investment	3.29 (5)	2.39 (1)
Legal matters regarding the institute's research inhibit the commercialization of these innovations	3.77 (10)	3.59 (10)
National industrial property policies hamper relationships	3.82 (11)	4.06 (12)
National research institutes are unable to efficiently undertake industry-sponsored applied research	3.47 (8)	3.03 (5)
Collaborations could affect the normal research environment and processes	4.35 (12)	3.97 (11)
Industry is reluctant to support national research institutes in basic research	2.24 (1)	3.03 (5)
Industry lacks its own in-house research capabilities	3.06 (4)	2.83 (4)
Attitudinal factors create a generalized culture gap and lack of understanding	2.41 (2)	2.83 (3)
Distance is a factor — some activities depend on close proximity between collaborators	3.29 (5)	3.36 (8)

Source: Field survey, 1991/92.

Notes: *n*, number of respondents; numbers in parentheses refer to the ranking of the determinants by order of importance.

^a Significance conversion table:

≤1.49	Dominant
1.50–2.49	Very significant
2.50–3.49	Significant
3.50–4.49	Occasionally significant
≥4.50	Insignificant

The laboratory's role, both before and after a technical change, is very important. Before the change, it collects data to determine potential results; afterwards, it collects data to show that expected results were achieved. However, for every big project, such as the LPG plant, the laboratory's role has been limited to sampling and chemical analyses — computer simulations and process design are done elsewhere.

Usually, the laboratory is involved in controlling the chemical and physical parameters of products and in the quality control of crude oil. It participates in plant experiments designed to test new tees or newly installed machinery or merely to change the production pattern to meet changing demand. These duties mean the

laboratory section will always be directly involved in technical change.

The operations department sets plant parameters to obtain optimum yield from new tees. It also determines the best operating conditions for new equipment.

The production section does market-type R&D, which determines the production pattern adopted by the operations group.

The safety department has modernized safety practices and emergency procedures. The emphasis is on preventing disasters, but adequate preparations have been made for dealing with emergencies.

In many instances, technological guidance is provided by BP, under the technical services agreement. When major pieces of equipment are added to the plant, the design, basic engineering, and detailed engineering are contracted out by BP; however, installation is done by SLPRC. BP's supervision is invariably limited to ensuring SLPRC follows the design specifications and BP's safety standards.

When asked about the contributions of expatriates during various installations, junior staff at SLPRC said BP experts contributed little. These junior workers do not understand the significance of strict adherence to specifications. However, SLPRC management are obviously aware of this need because they continue to approve a relatively large expenditure for foreign contracts every year (Table 10).

Table 10. Foreign exchange needed (1975–1982).

Year	Foreign exchange needed (USD)	
	Technical services agreements	Foreign contracts
1975	13 500	356 021
1976	58 627	568 540
1977	63 025	305 364
1978	138 545	356 095
1979	128 442	850 343
1980	136 265	323 948
1981	662 642	2 861 192 ^a
1982	309 070	107 006

Source: Bank of Sierra Leone.

Notes: Does not include foreign exchange needed for feedstock.

USD, United States dollars.

^aThis figure includes some accumulated debts as well as forward payments for 1982.

The technical changes described earlier seem to have boosted staff confidence, for it is now easier for changes to be proposed, accepted, and implemented. This was indicated by the increased number of modifications and fabrications cited in the monthly engineering reports after 1979. Another indicator is that the engineering department is supervising construction of a new laboratory building on its own. Some experience was gained in 1982/83, when the department constructed the main fire building, under outside supervision.

Learning and technical change at SLPRC

In this section, I will attempt to link technical changes with the learning that developed the technological capabilities of SLPRC. Technical change can arise in response to sharply changed external circumstances. Examples include the technical changes made in response to accompanied oil price increases and shifts in demand for

products, such as LPG and GO. Such changes will be classified as exogenously based.

Technical changes can also be endogenously stimulated, being made in response to anticipated changes in value: there is no danger to company profits. The continued use of chemicals to reduce the corrosion of pipes carrying cooling water is an example.

Another type of technical change is endogenously motivated, arising because plant personnel want to increase efficiency. This category includes all preventive maintenance practices and improvements in operating procedures resulting from greater familiarity with equipment.

All major technical change involves learning. The change to lighter crude oil is an example of crisis-induced learning. Crude-oil prices were escalating, but the political climate would not permit unlimited increases in product prices. The company needed a strategic response to ensure its survival, so it adjusted the production systems to use lighter tees that would reduce the throughput while producing roughly the same amount of high-demand products and reducing the production of low-demand ones.

The first change was that from Manjid crude oil from Gabon to Nigerian bonny medium-light 30 : 70. With the success of the original change, the company found it easier to implement subsequent changes, indicating that there was some learning by doing.

The installation of the standby generator and the LPG plant are two other examples of learning. In both cases the electrical installations, in particular, were done entirely by local SLPRC staff. SLPRC inherited from the Japanese the Sierra Leonean electrical-wiring technician who had wired the process plant during the construction phase. The company also employed a Sierra Leonean electrical engineer who had some power-generation experience with the National Power Authority. These two employees know more about the plant's electrical layout than any expatriate contractor could possibly learn within the short duration of any installation. They are usually responsible for the electrical portion of major installations. By employing the electrician who had participated in the construction, SLPRC acquired knowledge about the wiring of the plant. Similarly, employment of the local, experienced electrical engineer was far more cost effective than employing a younger graduate and sending him to the power authority for the necessary experience.

Similar comments can be made about the mechanical engineering section: the senior welder had been an apprentice welder during the construction phase, and an experienced Sierra Leonean mechanical engineer was hired soon after start-up. The story of the Hockadate boiler indicates the high level of local mechanical engineering expertise during SLPRC's early days. These examples indicate learning from the construction phase, as well as through employment of experienced personnel.

Another example of learning by doing involves the engineering department's supervision of construction of the new laboratory building. SLPRC engineers had been involved in several building projects in the past, participating in the construction at some level, but not as project supervisors. Because of the experience gained from the previous projects, SLPRC can now supervise the construction of one of its own buildings.

The main evidence of learning at SLPRC, however, is in the many minor modifications and adaptations carried out by the maintenance department, changes that are endogenously generated. After many years of operating the plant, the engineers understand their equipment well enough to recognize modifications that will improve the overall performance of various parts of the plant. For these changes, no specific external technological inputs are required. The changes are planned and executed by

company personnel, usually in response to their desire to improve plant performance. They have the ability to respond to meet urgent exogenous demands, the ability to anticipate the emergence of pressures or opportunities, and the concern to generate and improve the plant via minor modifications.

Conclusions

In this final part, the major conclusions of this study are summarized, and policy implications are discussed. Evidently, some indigenous and dynamic technological capability in oil refining exists within SLPRC. In particular, the company has demonstrated the capacity to react to exogenous demands, to anticipate pressures and opportunities, and effect improvements.

SLPRC has developed several capabilities:

- maintaining and repairing the plant and machinery;
- making minor changes to the plant and machinery to improve performance or durability;
- making minor changes to processes;
- running the company safely and profitably; and
- training another team to run a refinery that is similar in complexity to the one run by SLPRC and up to two times the size.

These capabilities were established without GOSL's explicit intervention in matters of technology transfer. The employment strategy adopted by the refinery's technical advisers has certainly hastened the development of technological capability. SLPRC recruits Sierra Leoneans who are already qualified and have some relevant experience. By doing this, the technical advisers hope to avoid elaborate training schemes and to lower personnel cost, as a Sierra Leonean may be employed at a fraction of the cost of an equally trained and experienced expatriate. Because oil-refining technology is transferred quickly to well-trained Sierra Leoneans and because their training is usually in science, engineering, or economics, they can easily adopt and master the technology.

Although expatriate technical advisers ensure that specifications and accepted safety standards are followed during major technical changes, local workers always play a major role in making these changes. There is evidence that some learning is taking place because of these changes. The most significant major technical change was the installation of the LPG unit in response to escalating world crude-oil prices.

Minor technical changes aimed at preventive maintenance and safety are carried out regularly by the indigenous staff. These changes are internally motivated and indicate a dynamic capacity to make modifications to the plant and its machinery.

The plant has always operated with a throughput well below its design level, so there is no incentive for the staff to try to stretch refining capacity. However, technical change by SLPRC has resulted in product diversification, maintenance of high product quality, reduction of unit cost, improved personnel and plant safety, and longer plant, equipment, and machinery life.

The principal agreement allows SLPRC to produce only for the local market. Over the years, production of gasoline, kerosene, and gas oil, which are in high local demand, has remained high or increased. Production of fuel oil, which is in low demand, has declined, and raw-material throughput has also declined, indicating greater productivity.

Profitability has always been the main concern of the oil companies participating in the joint venture. The pricing mechanism, whereby SLPRC reviews

each year's revenue budget and recommends price increases to offset any expected shortfalls, ensures profitability. The company has been profitable, and shareholders have been paid dividends for most of the company's lifetime, except recently, when foreign-exchange shortages rendered the company insolvent.

Lack of foreign exchange, which causes shortages of crude oil and spare parts, is the main external factor affecting SLPRC's performance. Because of adequate forward planning, shortages of spare parts have not yet led to work stoppages, but they have caused postponements of annual overhauls. Availability of crude oil determines the product supply.

The simplicity of process and the limited scope of operations at SLPRC are two factors that have helped technology transfer. Refining consists of straight atmospheric distillation, stabilization, and blending to yield products. There is no thermal cracking, reforming, catalytic reforming, or alkylation. The maximum throughput is 10 000 bpsd (some units elsewhere in the world have throughputs of 60 000 bpsd). SLPRC does not market or transport products or carry out basic or detailed engineering of plant equipment that is to be installed. As well, plant inspection is not done by SLPRC. The lack of complexity means technology can be transferred quickly.

The organization of employees is similar to that found in other refineries. All essential functions are performed by Sierra Leoneans, and there is an adequate body of skilled technicians to carry out day-to-day operations.

The two agreements that govern SLPRC were negotiated during the postinvestment phase, when there was no explicit S&T policy in Sierra Leone. Therefore, it is no surprise that both agreements contain very few clauses concerning effective technology transfer — transfer depends on the benevolence of the TNCs. Some technology transfer has taken place because of an employment policy TNCs adopted to reduce costs.

The principal agreement gave the TNCs the sole right to supply crude oil, from sources of their choice, but this arrangement quickly led to problems:

- The crude oil from the TNCs sources was more expensive than it would have been in the open market.
- SLPRC has to pay for crude oil in foreign currency, whereas the TNCs pay for products in local currency.

These problems have resulted in SLPRC accumulating a huge foreign-exchange debt and becoming insolvent in recent years.

GOSL did not carry out adequate feasibility studies before embarking on the refinery project. At the end of the investment phase, there was a need for a large sum of money to finance a refining company that would be solvent and to start up the plant. The TNCs cashed in on GOSL's uncertainty about investing more money — they formed a joint venture with GOSL. Some of the company's financial success may be attributable to the TNCs' search for profits, but their 50% ownership of the company means GOSL does not have full control of an industry that is strategic for Sierra Leone's development.

Recommendations

Some policy recommendations can be derived from careful consideration of the conclusions:

1. GOSL should negotiate to take over 80% of the refinery and be in control of an industry strategic for development; a long-term loan should be used to

- finance the takeover.
2. The refinery should be operated at full capacity, and the excess products should be sold to neighbouring countries to generate more foreign exchange for crude-oil purchases. The installation of a catalytic reformer should also be reconsidered.
 3. All dividends should be paid in leones.
 4. All contracts awarded by SLPRC should be awarded to Sierra Leoneans, who can then subcontract to foreign firms if this is necessary. In all foreign subcontracts, local participation and training should be mandatory.
 5. Regular training visits of all SLPRC staff to refineries owned by the TNC participants should be arranged at the TNCs' expense, as part of their contribution to the development of technological capability in Sierra Leone.
 6. There should be mandatory reinvestment of some TNC profits in other sectors of Sierra Leone's economy.
 7. The TNCs should be asked to train a plant inspection team and to arrange for coding of the refinery's better welders.
 8. The laboratory, the mechanical workshops, and the fire and safety department should be upgraded, and their activities should be expanded to provide some services to other sectors of the national economy.
 9. All proposed projects should be studied carefully, and contracts should include clauses covering the acquisition of technological capabilities. Sierra Leoneans must be involved in feasibility studies, process engineering, and detailed engineering, as counterparts, right from the start. They should be involved at the investment stage and start-up so that they can benefit from the learning that goes on in these phases. There should be firm timetables for training Sierra Leoneans to replace expatriates, as well as funding schemes for such training programs.
 10. Only core technologies (rather than complete technologies) should be bought. Peripheral technologies should be acquired locally. Technical services agreements covering many areas should be replaced by technology-transfer agreements that are project oriented; each expatriate employed under such an agreement should be required to perform a specific function and to accept a Sierra Leonean counterpart as an understudy. Specific training programs should be organized under such agreements.
 11. A planning unit should be established to evaluate the personnel requirements of all future projects and decide which workers should be trained and where so that, as the project starts, technology can be transferred concurrently.

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CHAPTER 13

Technological Assimilation in Small Enterprises Owned by Women in Nigeria

O.I. Aina

Introduction

The central concern of this case study is to develop mechanisms for improving women's employment in the informal sector in Nigeria, with particular emphasis on the development of women's traditional skills.

Although many recent programs (sponsored by either the national government or international agencies) were designed to improve women's economic status, most of them have failed to ameliorate the working and living conditions of rural women. They have not been able to raise women's productivity to its full potential. Therefore, there is an urgent need to understand the forces that presently impede the acquisition of necessary skills and resources among women.

Many writers have pointed out the detrimental effects on women of technological and socioeconomic changes in the process of development (Dey 1975; Zeidenstein 1975; Palmer 1978; Whitehead 1985; Stevens 1985). Whitehead (1985) concluded that early approaches in the analysis of technological change appeared to be "sex blind," and they also neglected the effects of institutionalized social relationships on women who worked. For example, most technologies were introduced to strengthen the dominant position of the male as the head of the household. Thus, many technological-development schemes failed because they were based on the assumption that the husband was responsible for the targeted activity (Dey 1975; Palmer 1978).

Other factors also contribute to the poor track record of many technological-development programs. One is the failure to take into consideration women's accustomed tastes, beliefs, taboos, and modes of behaviour (Date Bah 1985). Bryceson (1985) stated that most of the appropriate technologies introduced to transform, for example, domestic labour have met with limited success because of limited dissemination, limited access, or poor design. Even when new technology is accessible, it is often unaffordable to women, as women lack access to critical resources. Or the new technology is impracticable; that is, women are unable to operate or maintain it. Rathgeber (1989) remarked that efforts to impose Western, technology-intensive knowledge systems on grassroots women generally have failed. She, therefore, recommended new strategies, grounded in traditional modes of interacting with the environment.

To properly fit the women's issue into a model of technological change based on the employment, productivity, and income-distribution paradigm, Whitehead (1985) argued for incorporating sociological and economic aspects of intra- and extra-household relations in the analysis. Specific historical processes within which technological change is occurring become very important. For example, the capacity

of women to be independent producers depends on a number of factors, including access to productive resources (e.g., land), which are often mediated by their dependent position in the household, and to publicly provided inputs (e.g., credit facilities, technical-skills training, and basic social infrastructures).

This paper presents an empirical study of technologies currently in use by rural women in Nigeria, constraints facing their use, and the general response of women to technical change, skills acquisition, and learning. In view of the current economic crisis, it has become imperative to upgrade women's traditional skills. But the introduction of new technologies and processes cannot succeed without an understanding of local values and beliefs.

The research problem

The Structural Adjustment Programme (SAP) was introduced in July 1986 in Nigeria, against the background of unprecedented economic crises. The primary aim of SAP is to de-emphasize the primitive accumulation that characterized Nigeria after the civil war, thereby promoting capitalist accumulation in the development process. Among its specific objectives are restructuring and diversifying the productive base of the economy and reducing its dependence on the oil sector and imports.

The effects of SAP on the total economy are varied and multidimensional. However, focusing on the macroeconomic impact of SAP, we see that the productive base of the Nigeria economy moved, contrary to SAP policy expectations, in the opposite direction, increasing the dominance of the oil sector, reducing diversification, and increasing dependence on imports. Also, the balance-of-payments problem grew during this period. The growth of the economy was no longer sustainable: the economy became increasingly more import dependent, which not only created debt problems for the country but posed severe financial strains on the budgets of women, who, traditionally, are responsible for household consumer items. With the introduction of industrial capitalism, most of the productive activities (brewing beer, making cloth, and manufacturing cooking ware), which were traditionally women's activities, were moved to modern, large-scale factories.

At the microeconomic level, Nigerian women continue to feel the impact of SAP. The concern about poverty and the adverse effects of SAP on the household standard of living and, particularly, on women, who are mainly found in the informal sector of the Nigerian economy, led to the introduction of the Better Life Programme (BLP), with the aim of mobilizing women to strive toward economic self-reliance by encouraging them to take advantage of the available opportunities.

The present economic crisis in Nigeria has brought about an ironic change — an increased demand for locally produced goods. For example, *aso oke* (a type of traditional dress woven in the cottage industry) is now popular at social gatherings and in the fashion houses. Because refrigerators have become unaffordable, rural dwellers are stuck with locally produced "water pots," which are noted for their cooling effects on drinking water. Also, many Nigerians have now resorted to using locally produced soap (*ose dudu*, i.e., black soap). Yet, the women who produce these goods are constrained by their lack of access to critical resources (capital, labour, land, infrastructures, and improved technology).

Past experience, however, proves that to break the vicious cycle of poverty, women need more than access to critical resources. More than anything else, we need to attach more value to women's work and to fully account for it in the development process. One way of making women's work more visible is to focus more research on women's productive activities.

Theoretical framework

This study is entrenched in the general framework of the theory of African political economy that gives primacy to material conditions, particularly economic factors, in the explanation of social life. The way a society produces its goods to meet its material needs, the mode of distribution, and the social relations emerging from the organization of production to a large extent determine the relative position of men and women in that society. By viewing social relations dialectically, the political-economy model emphasizes the dynamic character of reality. A focus on political economy highlights the ways that political and economic forces help to shape the contexts within which women operate. Both macrodimensions (e.g., capitalism) and micro-dimensions (e.g., household patriarchal structures) are taken into account. Thus, in Africa, both types of forces have interacted to marginalize the position of women. Women are, therefore, caught in a nexus of political and economic forces (Dauber and Cain 1981; Charlton 1984). The powerlessness of women to choose which technologies will be transferred has been aptly described by Cain (1981). He argued that the people responsible for technology choices are usually those least affected by them, whereas those most affected, who must adapt and live with the choices, often have the least to say about them.

Many writers have identified the negative impact of agricultural technology on women as food producers (Collier 1988; Jamal 1988; Afonja and Aina 1993). Stamp (1989) argued that many attempts to integrate women into development have failed because of inappropriate definitions of economic activity for women and because of stereotypes of women as "nonworkers" in any real economic sense. Agricultural intervention projects have, therefore, often resulted in gender conflict. This was succinctly described by Dey (1981), who discussed the deep rivalries between women and men in a Gambian wet-rice scheme. The Gambian women, who were traditionally responsible for wet-rice cultivation, were left out of the project design because the engineers who designed the project did not have a proper grasp of the traditional division of labour.

To make new technology appropriate for women's use, we first need to study the technology they are currently using and identify the gender relations underlying this use. According to Stamp (1989), technology transfer is successful when women are the central decision-makers and when there are effective grass-roots women's organizations.

The present study, therefore, examines macro- and microlevel factors influencing the rate of technology assimilation in cottage industries owned by women in Nigeria.

Research objectives

The broad objectives of this study are listed below, although only a few of them are discussed in this article:

1. to examine the structure of the selected cottage industries, focusing on the use of women's labour and women's access to critical resources (capital, improved technology, land, labour, raw materials, entrepreneurial skills, and marketing channels, etc.);
2. to document the technologies currently in use and their appropriateness to local conditions (i.e., to identify the problems associated with these technologies, using the users' own terms and descriptions);

3. to examine the acceptance or nonacceptance of new technologies and, when there has been technical change in cottage factories owned by women, to examine skills acquisition and learning effects;
4. to investigate the social relations underlying production in selected factories (for example, gender-based division of labour, labour relations, husbands' interference or noninterference in decision-making processes, women's power to spend money or accumulate wealth independently of a spouse, and women's ability or inability to manage the factory system independently);
5. to document information on income, expenditure, and assets of the selected village factories owned by women and the general management of finance, thereby helping to identify organizational structures that would help women gain control over increased incomes resulting from investments and improved technologies;
6. to document, in each of the four states studied, factors influencing success or failure (e.g., current government policies and programs and women's accessibility to infrastructures, such as good roads, electricity supply, health services, and water supply); and
7. to make policy prescriptions to improve and expand the scope of village factories and thereby help incorporate women in national development.

Research methodology

Study scope

Four states in southwestern Nigeria were covered in the survey: Oyo, Ondo, Osun and Ogun. Women in the four states are well known for their prominent roles in the production of household wares.

The study focused on four traditional cottage industries: cloth weaving, mat making, soap making, and pottery making. Ten factory locations and two of the largest markets selling the traditional *aso oke* dress were selected from the four states (Table 1).

Table 1. Traditional industries and markets studied in Nigeria.

State	Centre	Industry or market
Oyo	Iseyin	Cloth-weaving industry
	Saki	Cloth-weaving industry
	Awe	Soap-making industry
	Oyo	<i>Oje</i> market
Ondo	Owo	Cloth-weaving industry
	Ogotun-Ekiti	Mat-weaving industry
	Erusu	Pottery-making industry
	Isua Akoko	Pottery-making industry
Osun	Ipetu-Ijesha	Mat-making industry
	Inisa	Soap-making industry
	Ede	<i>Oje</i> market
Ogun	Abeokuta	Pottery-making industry

Data collection

For the study, I gathered both qualitative and quantitative data. The tools of social investigation included

- a survey (this was done through structured questionnaires);
- in-depth interviews;
- participant observation (this helped me document the process of production and the conditions of the women's work); and
- focus-group discussions (FGDs) (this method brought out group feelings or needs, particularly among factory owners).

On the whole, four categories of people were surveyed:

- owners of the cottage factories;
- employees and apprentices in the cottage factories;
- retailers and consumers of products from the selected village factories; and
- BLP managers, whose objective was to introduce technology to ease drudgery in the women's work.

Sample Selection

The fieldwork, which took place between August 1992 and March 1993, was carried out in the 10 factory locations and 2 markets. Using a simple random-sampling technique, I chose 1178 factory owners from a list. These were interviewed, and 10 FGDs were held (each FGD included five to eight factory owners from each of the survey locations).

At the second level of the study, male and female employees and apprentices in the 10 factory locations were randomly selected for interviews (using the questionnaires). A total of 174 employees and apprentices, 366 retailers and consumers, and 29 BLP managers were interviewed.

Results and discussion

Demographic and socioeconomic characteristics of the samples

Factory owners

Data collected from the factory owners showed that only 5.4% of the total sample were men. The ages of the factory owners ranged from 18 to over 70; the mean age was 52. The average ages of owners across factories by industry were 37 for cloth weavers, 55 for potters, 56 for mat makers, and 57 for soap makers. The younger average age for the cloth-weaving industry shows that youths are now going into that industry. The other industries are still predominantly dominated by older women. The implications of this for the life of each industry are significant.

About 66% of the total sample were married; 18.9%, widowed; 2.3%, divorced; less than 1%, separated; and 11.9%, never married. Seventy-two percent of those in the never-married category were cloth weavers, corroborating the above-mentioned finding about the relatively young age of cloth weavers. About 23% of the total sample were female heads of households, meaning that acquisition of these traditional skills can help sustain women in households headed by women.

It is, however, important to note that about 74% of the factory owners never attended any formal school, and the others possessed only basic education (i.e., modern primary school). Thus, owning a factory may be very suitable for women unable to afford formal vocational training.

Notably, these cottage industries seem to be the only source of income for the owners; more than 76% of them had been in their business since childhood. In a way, skills acquisition seems to be generational (i.e., passed down from one generation to the next) and, sometimes, lineage specific. In the case of cloth weaving, it seems many people are breaking through traditional barriers, and the production process is becoming more modernized.

Remarkably, factory owners were from families with a low socioeconomic status. Predominantly, factory owners' fathers were farmers, mostly with no formal education and with large families (an average of 11 children per household, with some households having as many as 25). Most (89.4%) of the mothers of factory owners were also without any formal education. Also, most of the spouses of the factory owners were illiterate farmers.

The majority of the factory owners had a monthly income of less than 500 NGN (in 1995, 78.5 Nigerian naira [NGN] = 1 United States dollar [USD]). Although a significant percentage (30.4%) could not estimate their monthly income, generally, income was limited — less than 16% of the whole group reported a monthly income of more than 500 NGN. Cloth weaving and soap making tended to be more economically rewarding. This is not unconnected with a growing technological capability in these two industries. However, more than 80% reported having no income from other sources, which further signifies that the selected industries are, in fact, the major sources of livelihood for these rural women and their households.

Factory workers

The 174 factory workers interviewed were apprentices (86%), paid employees (10%), and unpaid family members (4%). Of these, 173 were concentrated in the cloth-weaving industry and 1 was in the soap-making industry. Pottery and mat making recorded no workers (apart from casual labourers hired to dig clay or to carry mat stalks from the farm).

Only 2 of the 174 workers were men. This points to the predominance of women in the traditional crafts studied. The workers were up to 18 to 30 years old, but the majority (73%) were 20 or younger. More than 80% of these women had never been married.

In the past, these traditional crafts were learned only by those who were illiterate. Today, in contrast, literate and illiterate people are falling back on these informal structures for job and training opportunities: the data showed that 52.3% had basic education (modern primary school); 35.6%, secondary school education or its equivalent; 1.7%, university education; and only 9.8%, no formal education.

Data on workers' social background showed that most of them were from families with a low socioeconomic status. They had illiterate parents, who were predominantly poor farmers or petty traders, and came from large families: the workers' fathers had an average of nine children; their mothers, six. However, a new trend has emerged: children of educated and monogamous parents are now moving into the traditional crafts.

Factories

Most of the cottage factories (79.2%) were based in the home; a few were located in rented or purchased premises outside the home; some of the factory owners ran a cooperative system. The cloth, mat, and pottery factories were mostly based in the home. The soap makers, on the other hand, ran a partial cooperative system. Soap-making factories were clustered in an *ebu*, or district of town. A town could have two to six factory locations, with at least 20–30 soap makers at each location. In each *ebu*,

some facilities like water and other material inputs were shared. Because the soap makers were already organized as groups, intervention programs for them would be easy to implement, control, and monitor.

Critical resources

Land

Most of the factories were based in the home. Cloth weavers either used the open space in front of their homes or converted a room into a weaving centre; sometimes they rented a stall. Mat makers used the corridors in their homes. Potters often used any available open space around their homestead. Because of the polluting effects of soap making, soap makers had their factories far from the home.

Although only 13.4% of the factory owners indicated that they had a pressing need for land on which to locate their factories, almost all of the factory owners complained about the unsuitability of their present locale for expansion. According to the factory owners, commercialization of land and the resulting high cost made it difficult for women to have access to land. Even in cases where land was leased out to women, as found among the soap makers in Awe and Inisa, permanent structures could not be built over leased land without incurring the wrath of the landowners, who were usually men. The FGDs conducted among the Awe soap makers revealed the extent of the land problem for these women. The women reported that they were hostile to UNICEF program implementers, who wanted to make permanent structures for the Awe soap factory. The Awe women rejected this offer, for they feared that the landowner might feel that it was a conspiracy to defraud him, although the women never communicated this fear to the program implementers. This finding supports Stamp's (1989) findings on the issue of appropriate technology. She argued (p. 11) that scholars can only properly appreciate the problems with "the appropriate technology movement" when they "start from the reasonable assumption that women are refusing to accept or sustain appropriate technology on sound grounds, rather than out of 'backwardness' or 'ignorance'."

Capital

Most of the factory owners had started their businesses with initial capital of less than 500 NGN. Today this would be no longer possible: some weaving equipment, for example, now sells for more than 3000 NGN. The initial capital was obtained from the following sources: personal savings (65.4% of the owners); savings associations (14.6%); friends and relations (12.1%); spouse (11.1%); nongovernmental organizations (6.6%); and, in very few cases, the development banks and the BLP (numbers add up to more than 100% because some owners had more than one source of initial capital).

Capital needed for the day-to-day operation of the factory followed about the same pattern, but in addition the owners can use deposits paid by clients and the profits accruing from the factory operations. Notably, the women depend on traditional money lenders and the thrift and cooperative societies more than on the formal banking system. Less than 2% reported ever using the formal banking system for loans. Also, the traditional financial support, usually from husbands, seems to have shrunk. Less than 5% reported any financial assistance from husbands.

Among the four cottage industries surveyed, the capital outlay was highest in the cloth-weaving industry, and second highest in the soap-making industry. The cloth makers complained of lack of money to build large looms and buy imported thread and dye (prices were skyrocketing as a result of SAP). Soap makers reported that maintenance of soap factories had suddenly become expensive as a result of the high

price of plywood and iron sheets. Also lacking were the necessary infrastructures: water (either through pipes or from wells), electricity supply, sewage disposal, motorable access roads, and health facilities.

Potters reported the high price of the variety of clays needed for their work; they also said that the labourers they needed to dig and pound clay had become unaffordable. Worse still, children, who used to be the main source of labour, had all gone to school.

Mat makers complained of a lack of capital to buy mat stalks: these owners were competing with buyers from the university drug-research units, who were ready to buy the roots of these mat stalks at any cost for pharmaceuticals. Labour to carry mat stalks from the farms to the factory sites had also become unaffordable. Sometimes the mat makers were producing at a loss because of high costs.

Technological evolution and assimilation

Technological knowledge in the selected cottage industries is usually acquired informally. The indigenous technical knowledge is passed from parents to children, aided by the traditional division of labour based on age, sex, and the kinship system. More than 74% of the factory owners did not have any formal training in the selected skills.

The apprenticeship system is, however, emerging as a new mode of skills acquisition, particularly in the traditional cloth industry. Programs like BLP for rural women and the recently established women's education centres have trained some women in income-generating skills and provided vocational training in traditional cloth weaving and soap making, although the number of women who have benefitted from such programs is still very small. For example, only 70 women out of the total sample of 1178 factory owners had vocational training in either cloth weaving or soap making, and their training was obtained through one of the following: a Better Life Multipurpose centre, the diocesan training school, or a government vocational school.

The technology in use is, generally, very simple, manually operated, strenuous, and energy consuming. The following subsections discuss the trends in technological evolution and assimilation for each industry.

Cloth weaving

Weaving is a well-established household occupation in the towns of Iseyin, Saki, and Owo. Today, this craft has spread through the length and breadth of Yorubaland.

In Iseyin, weaving was traditionally a men's vocation until about 10 years ago, when women started to show an interest. In Owo and Saki, on the other hand, weaving is primarily a women's vocation.

The development of weaving technology is at three different stages. Stage 1 is represented by the traditional loom. This loom is stationary and has two forms. The four-pole form, used in Owo, has two vertical poles (stuck into the ground) and two horizontal poles. This loom can weave a piece of cloth that is 30 in. × 36 in. (1 in. = 2.54 cm). The three-pole form, used in Iseyin and Saki, has two bent poles (stuck into the ground) and one horizontal pole. This loom can weave a strip of cloth that is 5 in. × 36 in.

Stage 2 is represented by the portable loom. This loom is also used in Owo. The process and accessories used are the same as those for the three-pole traditional loom. The only difference is that the stage-2 loom is portable, instead of being stuck in the ground.

Stage 3 is represented by the big loom. Some of its accessories, like the shuttle, reel, and Headle's wire, are imported. Using the big loom is more strenuous

than using the smaller stage-1 and stage-2 looms: to effectively operate the big loom requires two people (one to do the weaving and one to mend the thread when cut). The big loom is much more efficient than the stage-1 and stage-2 technologies, however. As many as 10 complete "wears" can be "beamed" on this loom at once (there are two cylindrical rollers on a loom: one holds the warp threads, and the other holds the finished work; 39 stripes make a complete wear for an adult; a stripe is about 1 in. × 36 in.). Only one or two wears can be beamed on the smaller stage-1 and stage-2 looms at a time.

Increased productivity has been witnessed in the traditional cloth industry with the rise of the modern, imported Headle's wire (replacing the traditional Headle's twine) and the use of a longer reed, which accommodates the "denting" of more stripes, even up to the size of a bed sheet (a dent is the space between two wires on a loom; each warp thread is drawn through a dent). The new improved equipment can also weave towels, napkins, and trousers, etc.

Currently, the cloth industry is facing a major crisis, making the recent achievements in technology irrelevant. First, the imported spare parts, such as the reed and Headle's wire, have become very scarce and expensive. Some of the parts, which cost in the range of 200–500 NGN about 3 years ago, now sell for more than 4000 NGN. Even wood (which is locally produced) has become suddenly expensive.

Second, the graduates from the various vocational centres, who have invested their time and money in learning to weave on big looms, cannot afford to set up their own weaving business because of the exorbitant price of equipment. Some trainees are now deserting vocational schools, and independent owners are now forced to learn to use the narrow loom, which is still relatively cheap (about 1000 NGN).

Third, the owners of the efficient big looms are facing a fall in output because of lack of apprentices, for such big looms need more than one operative, especially at the whopping, beaming, drafting, and denting stages.

Fourth, the prices of the thread and glass fibre used in weaving have escalated. Within the 6 weeks I was doing the fieldwork in Owo, there was a more than 50% increase in the price of thread. Despite the high price of equipment and raw materials, factory owners often resort to buying fake products. The quality of thread is no longer predictable; sometimes a particular colour already in use for a particular cloth on the loom might not be found. Factory owners can no longer tie their money into "free production" (producing at an optimal capacity without artificial restrictions), but they demand that customers "book" (show the intention of buying before the product is made) and pay up front. To reduce the high price of thread, factory owners suggested that the government establish a thread-manufacturing industry in the southern part of Nigeria, to alleviate the continued dependence on the northern thread factory.

Designers are using the traditional cloth-weaving factories as a base for the African designs now found all over the European market. Factory owners in Saki, which is a border town, send their products to neighbouring countries — Togo, Lome, and Cameroon. The factory owners seem to have limited market channels because there is no organized market in the area. They, therefore, depend more on the booking system of sale, which is open to trade fluctuations. The peak of sales in the Owo area is usually around July or December (i.e., dictated by the festive moods of the local *ogun* festival in July and the Christmas season), when a lot of burials and wedding ceremonies take place.

Despite its present problems, the traditional cloth industry is responding to change (combining both old and new modes of production and design). Now that women dominate the industry, men are leaving. Women are joining because they can easily combine it with running a home. Innovative designs are emerging, and the cloth

texture is becoming finer, with a higher quality. Also, the average price a Nigerian consumer pays for the finished product is approximately one fifth of what similar imported material costs in the Nigerian market.

Mat making

The mat-making industry was studied in the towns of Ogotun-Ekiti and Ipetu-Ijeshu.

The equipment required for mat making includes a cutlass, a knife, pots for dyeing sliced mat stalks (*alufa*), a small plank of wood of about 5 cm thick and 20 cm long, and a small mat (*ateere*), upon which the weaver sits. All these are locally fabricated and, therefore, readily available.

No formal training is needed for mat making. A young girl can learn by sitting down by her mother and watching her work. Soon, the girl is allowed to try her hand at weaving, and she soon perfects her skill.

The procedure for making mats can be broken down into four steps: (1) on-farm activities, (2) smoothening and drying, (3) dyeing, and (4) weaving. The on-farm activities involve growing the mat stalk, weeding the farm, and harvesting the mat stalk. A mat stalk takes an average of 3–5 years to mature. Final harvesting of the matured mat stalk is done by hand. Harvesting and transporting a bundle of mat stalks to the homestead take a full day. The smoothening and drying stage commences the second day, with the slicing of mat stalks. A sickle-like knife is used to slice the content (pulp) out of the mat stalk. After sun-drying for 2 or 3 days, the sliced stalks are dyed or left plain.

Mat-making processes are reportedly very tedious. On the average, the fastest mat maker may be unable to make more than three big coloured mats in 2 weeks. Each mat sells for an average of 100 NGN. Apart from dyeing, no new technology has been introduced in this area. Its no wonder the mat makers are predominantly the aged (60–90 years): the old drudgeries still remain.

In both Ogotun-Ekiti and Ipetu-Ijeshu, there are organized local markets where these mats are sold. Buyers come from big cities like Ilorin, Oshogbo, Benin, Ede, Akure, and Ilesha to buy the mats.

Today, 60% of mats produced at Ogotun-Ekiti are bought by the Better Life Shop, where the mats are made into fashion bags, calendars, dining-table mats, conference bags, purses, shoes, etc. Many of these products are exhibited at national and international trade fairs. Like the cloth industry, the traditional industry, if it is well developed, can earn the nation a substantial amount of foreign exchange.

Although the number of mat makers is dwindling because the old ones are not readily replaced by the younger ones, more youths are showing an interest in the by-products of the traditional mat industry. Such products have also found their way into fashion houses.

Soap making

The soap-making industry was studied in Awe and Inisa.

The shelter for the soap factory is usually made of wooden columns, topped with thatch roofs and, in few cases, aluminium roofing sheets. These materials constitute a fire hazard because a lot of heat is generated during the soap-boiling process.

Traditional black-soap making is a major occupation for women in Awe, Oyo, and Inisa. The technology in use is simple but requires strenuous effort. The equipment and raw materials needed to make black soap are a drum or a clay pot, a mortar and pestle, palm-kernel oil, and ashes from cocoa pods. At the first stage, a mixture of oil and ashes is boiled in the drum or clay pot to form a thick paste (*oka*).

After the paste has cooled down, it is transferred to the mortar and pounded with the pestle. The paste is later transferred to a clay pot for further boiling, until it starts to rise (a process that takes 1 or 2 h). When the mixture (now the soap) cools down, it is moulded into round shapes. Ashes are sprinkled on each soap ball to prevent sticking.

This traditional technique of production is still used today, although new structural facilities are emerging. For example, drums are taking the place of clay pots, and water is obtained from wells, instead of from streams and rivers. Intervention projects have been introduced by agencies such as UNICEF, the Cocoa Research Institute of Nigeria in Ibadan (as in the case of the Awe soap industry), and BLP (as in the case of Inisa soap factory). On the whole, however, efforts to totally modernize traditional soap production have failed.

The soap makers frowned on attempts by researchers to make their products more like bar soap, which, according to the women, lacked the unique qualities of the native soap. At Inisa, soap makers were disgruntled with the machines introduced by BLP. The soap-slicing machine was criticized on several grounds: using the slicing machine was not cost effective, as the soap sizes produced by such a machine do not fit the women's slicing system; the manual operation of the slicers gave the women backaches and easily tired them out (the pushing system exerts too much pressure on the wrist, chest, and back). A grinding machine provided by the BLP to one of the six factories in Inisa was lying unused at the time of the survey. Although the grinding machine was appropriate, the factory "spokesman" (who happened to own a grinder that had been serving these women the past 10 years) selfishly prejudiced the soap makers against the government soap projects. This man felt he might be driven out of business if the BLP machine were accepted, and he also feared losing his traditional authority over the soap makers. At the time of the interview, he actually incited the Inisa soap makers against the field workers.

FGD reports, field observations, and the market survey showed that the traditional soap industry has a unique role to play in both the economic and the social life of the people, as shown by the list of its uses reported by both makers and consumers. Traditional soap is said to have numerous health and social values:

1. A little mixture of the soap in a glass of water reportedly cures stomach aches.
2. Traditional black soap is said to be very efficacious in the treatment of the vaginal wounds some women receive during childbirth.
3. A special water (*eyin aro*) collected during soap processing is traditionally used to cure eczema, boils, and wounds. *Eyin aro* reportedly has the effects of iodine on fresh wounds and is used to clean inflamed throats.
4. Reportedly, traditional soap clears up skin wrinkles, pimples, and other skin allergies. (At the time of the study, we found modern soap and body cream, made directly from the native soap, available in the market.)
5. Traditional soap is now widely used to wash clothes, to prevent fading and bleaching of colours.

Pottery making

Data on the pottery-making industry were collected from Erusu, Isua Akoko, and Abeokuta.

Pottery started in Abeokuta when the Ijaiyes came to this town as refugees. In Abeokuta, potters concentrate in an area of the city called Ijaiye. In Isua Akoko and Erusu, each quarter in the community is noted for a particular pottery design.

Some specialize in *agbagba* (a bowl for frying cassava); others specialize in *isasun obe* (a pot for making soup), *oru* (a pot for herbal preparation or placenta burial), or *agbagba isu* (a pot for cooking tubers).

The technology used in the traditional pottery industry is simple: a mortar and pestle, a club, a cutlass, a hoe, a digger, shells, corn cobs, and calabash, among others. Local clay and water are the production materials. The production process involves mixing the clay with water, moulding, pressing, designing (for specific shapes and sizes), sun drying, and burning.

Major improvements have been seen in designing and drying (oven drying is replacing traditional open-fire burning). As well as making cooking and water pots, the potters produce coal pots, kettles, statues, flower vases, decorative pots, plates, and clay beads. Clay beads are in high demand today and are used by kings, chiefs, and socialites.

The main problem facing the potters is the scarcity of the clay appropriate for pot making. The clay for making pots is always a mixture of different types of clay. Exploring for clay can be hazardous. Because of the great depth of the pit that has to be made, there are always cases of diggers being buried under falling clay. The diggers are, therefore, scarce, and they demand a very high fee. Other problems include the following:

- The infrastructures are poor (scarcity of water, lack of electricity, bad roads, and lack of basic health facilities in case of accidents).
- The potters suffer during the rainy season (often the rains wash away the potters' clay), and the harmattan (a dry, dusty wind from the Sahara) tends to crack pots.
- Many potters develop body aches, dizziness, and fatigue as a result of carrying heavy clays.
- Products often break when they are transported.
- The potters suffer from insufficient capital, lack of access to land and labourers, and the growing cost of inputs, especially the high cost of transportation (which has made it impossible for the pot makers to travel to other towns to sell their wares).
- The potters complained that lack of a public factory space makes them unable to organize themselves as a functional group.
- The potters are in dire need of grinding and mixing machines for the clay and ovens to bake the pots.
- The potters find it difficult to get local people to dig clays, so they often depend on Hausa, whose rates are hardly affordable.

The pottery technology appears to be inefficient, as the women reported that they were unable to meet the public demand for their products. They complained about the hazards of open-fire burning, which exposes them to heat and smoke. Firewood is also becoming scarce because of deforestation.

In Isua, BLP established some markets and provided an oven. However, the potters complained that the oven is too small to admit big pots and also produces insufficient heat, so drying is delayed, resulting in many of the pots cracking. The Country Women's Association of Nigeria has arranged some soft loans for the potters, but this has not been too effective. The potters need functional potters' associations to coordinate their activities.

In Abeokuta, potters have strong associations, through which they buy clay at great distances. Potters in Abeokuta believed that BLP was meant to cheat local

women, and, therefore, they decided to refuse any help from BLP.

Potters, however, foresee a lot of prospects for the craft. Elite women are now buying pots in large quantities for home cooking, as well as flower pots for home decoration. Many of the potters have also participated in trade fairs.

A general assessment of technology in use

To assess the technology currently in use, I asked the factory owners to agree or disagree with the 11 statements shown in Table 2. Responses were given the following weights: *totally disagree*, 1; *disagree*, 2; *agree*, 3; *totally agree*, 4. The scores were then composited.

Table 2. Factory owners' assessment of the technology they use.

Statement	Agree (%)	Disagree (%)
The technology is not time consuming	40.3	59.7
The technology is very safe	68.1	31.9
The technology is affordable (cheap)	66.7	33.3
The technology makes the work process easy	58.2	41.8
The technology is not energy sapping	38.2	61.8
The technology is easy to operate by women	75.2	24.8
The technology has a large production capacity	48.7	51.3
The technology does not need redesigning and remodification	78.8	21.2
The technology is in line with our social, cultural, and religious life	89.8	10.2
Spare parts are readily available	74.5	25.5
Repairing and servicing can be done easily and locally	79.5	20.5

Factory owners definitely wanted improved technology, to make production less cumbersome and reduce drudgeries (they gave a list of specific things they wanted the government to do to reduce the drudgeries). But generally, the potters would frown on any technology that would change the traditional flavour or texture of their products. For example, in many cases, a craft is linked to a deity. Potters in Ijaiye are all devotees of Iyamopo, a goddess who is believed to be supportive of pot production. It is believed that when this deity is annoyed, for whatever reason, there is bound to be a general cracking of pots during baking. Thus, Iyamopo is appeased at periodic festivals. Potters will never support any technology that will not allow them to obey the taboos surrounding Iyamopo.

The future of the pottery industry will depend on effective linkages between producers and city traders, who take pottery to the cities. The city traders are young and determined. The problem, however, is in getting the younger generation interested in a hazardous industry, which also needs upgraded technology to ease some of the drudgeries of production.

Policy implications of the findings

Effective technological change can only be achieved if there is a focus on the sociocultural and economic dimensions of technology. Women should be consulted when new or improved technologies are being selected, designed, and developed. The programs that trained weavers to use large looms, provided the soap-slicing machines to Inisa soap makers, and built the modern oven for Isua potters failed to make tangible, positive impacts because they failed to take account of local demand and the production needs of the factory owners. Large looms are no doubt effective for large-

scale production, but they are unaffordable to these poor women.

If program implementers want to introduce a new technology, they must first look at the issues of availability, practicality, and profitability, and there must be available and affordable infrastructural facilities for market linkages and other supportive facilities. Raw materials must be domestically sourced to reduce costs caused by frequent devaluation of the naira in the international market. The cottage industries could be made more profitable with intervention programs that use participatory approaches.

The government, at this point, can try to help small- and medium-scale industries (as part of an alternative industrialization strategy) by ensuring that market channels, both national and international, are opened up for local producers.

To expand the scope of cottage industries, I recommend that relevant vocational training be introduced at all adult literacy centres and women's education centres. For cost-effective operations, factory owners should also be trained to use a simple accounting system and some simple organizational management.

The present intervention programs, such as BLP, tend to have good objectives, but they often fail because of some bad managers, who are corrupt and try to divide and rule the women's groups. A higher level of social mobilization is achieved if there are functional women's groups and women's cooperative societies. Grass-roots women's associations may be strengthened by better program interventions.

More intervention programs could be developed to inform local producers of the technological innovations already developed at the universities and other research institutes in the country. Because of the current low level of education among factory owners, they need to be instructed in the usefulness of new technologies and encouraged to change traditional values that are retrogressive. Encouraging these women to make time to go to adult literacy centres will also go a long way to improving the present mode of production, particularly in designing products.

The local producers should have factory houses, with the necessary infrastructures. Small-scale factories could be built by the government, with a token fee paid by local users.

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CHAPTER 14

Translating Technological Innovation into Entrepreneurship in Nigeria: Social and Policy Implications

S. Adjebeng-Asem

Introduction

Theoretical and empirical investigations have emphasized the crucial role that technological innovation and entrepreneurship play in fostering the development of today's industrialized nations. These types of investigation are now seen as crucial to the development of the Third World, and they are, accordingly, recognized as important components of technology policy and indigenous socioeconomic planning. The present emphasis on indigenous technical innovation and entrepreneurship stems from the failure of past attempts to stimulate Third World development by borrowing or transferring advanced technology from developed nations.

In most Third World countries, governments are criticized for paying no more than lip service to the need for accelerated growth and for not harnessing the abilities of their own citizens for technological innovation and entrepreneurship. Critics also lament that these countries depend too much on exogenous and often exploitative technology, and they point out the inappropriate choices of technology made by many developing countries.

This article is offered as a contribution to the search for ways to harvest indigenous capabilities. Specifically, it is an in-depth investigation of the social factors that influence the translation of new technologies into entrepreneurship and a summary of a major study of innovation and entrepreneurship in Nigeria.

The study included six cases — three cases of innovations accepted into general use and three of innovations that, though introduced into the market, were not accepted. Of particular interest were the nature of innovation, the need for it, its assessment by users, the socioeconomic characteristic of the inventors and users, and the factors that helped or frustrated the inventors in the commercialization of the product.

The investigation rested on a set of assumptions:

- There are in Nigeria (especially in the states of Lagos and Oyo) economically feasible inventions.
- The nation cannot fully exploit the inventiveness of Nigerians because of Nigeria's political economy, the dominance of mercantile capitalism, and on overdependence on foreign technology.
- The difficulties in commercializing inventions are partly due to the attitudes and methods of some inventors and entrepreneurs.
- Despite all the constraints, some inventors and entrepreneurs will succeed in the large-scale commercialization of inventions.

The last assumption implies that the inventors who succeed in commercializing their innovations, either by themselves or through an entrepreneur, are the people to mobilize for an indigenous technological development in agriculture, which is important to Nigeria's socioeconomic development.

The problem

The main concern of this chapter is to explain why technical innovations of potential value to agriculture in Nigeria are not widely diffused. This concern stems mainly from two observations from an exploratory study by Tiffin et al. (1987) of mechanical technology in postharvest operations: (1) there seems to be a tremendous amount of postharvest waste; and (2) there is a lot of mechanical inventiveness among those who work in these postharvest operations, but the inventiveness is not exploited.

All this is particularly puzzling at a time when the poor economic condition of the country is largely attributed to a failure to develop indigenous technology. The literature is full of accounts of Nigeria's ample natural resources. Nigeria has a variety of export crops — cocoa, groundnuts, palm products, cotton, timber, and rubber — in addition to its abundant food crops. Nigeria is blessed with vast, rich lands, but 50–60% of it is untilled (Aribisala 1983). It has rich mineral resources, notably oil and iron. Afonja (1986) pointed out that Nigeria has a significant proportion of the world's tin, columbite, and titanium; if these were exploited using indigenous inventiveness, the result would be a considerable acceleration of the country's technological development.

Nigeria also invests relatively heavily in human resources, especially in technical training (Table 1). During the 1980s, great attention was paid to training intermediate- and high-level scientific, technological, and technical personnel through universities, technical colleges, polytechnical institutes, and trade centres. By 1989, there were at least 13 federal universities and three federal colleges of technology. In 1979/80, 40.7% of all students were in science and technology.

Nigeria's crop of scientific and technical personnel has made modest advances in technological innovation, showing a fairly high level of inventiveness in not only the universities and research institutes but also the informal sector.

Of the 15 inventions shown in Table 2, only 2 were widely diffused, although all reached the testing stage. Two successes out of 15 inventions would not be regarded as a problem in many countries; indeed, the literature is full of examples of unsuccessful inventions, and the point is often made that few new technologies are successful. But these findings point to a serious problem in the agriculture of a country that cannot afford to invent for its own sake. In this instance, 12 of the 15 inventions were obviously simple and valuable but did not get to the market place, even though the inventions would have led to the use of indigenous products, rather than goods continuously imported.

Food-processing machines are imported, as are many finished products, although local products could well supply the need. For example, we could replace expensive imported vegetable oils with oils made from local crops. We cannot overemphasize the need for a country to commercialize and widely diffuse its own innovations. Tiffin et al. (1987) established that invention, the initial step of innovation, is much commoner in Nigeria than people realize; if these inventions were backed by appropriate public policies, some of them would undoubtedly become successful entrepreneurial ventures.

Table 1. Distribution of selected categories of personnel, Nigeria (1977–1981).

	Year	Nigerian	Non-Nigerian	Total
Administration management personnel	1977	90 019	5 690	95 709
	1981	207 116	4 050	211 166
Scientific, technical, and technological personnel	1977	39 649	2 754	42 403
	1981	38 055	2 988	41 043
Other professionals	1977	—	—	—
	1981	47 367	867	48 234
Agricultural personnel	1977	7 892	210	8 102
	1981	15 103	147	15 250
Health personnel	1977	20 112	1 281	21 393
	1981	24 881	1 155	26 036
Artisans and trades people	1977	219 888	332	220 220
	1981	304 877	4 129	309 006

Source: Nigerian National Manpower Board.

Objectives for the study

The present study was designed to establish why indigenous technical innovations are often not translated into feasible business ventures despite the fact that Nigeria has both the technological capacity and the need. Several related issues were of interest: What factors are critical in the commercialization and diffusion of an innovation? What is it about Nigerian society that makes it produce creative but not entrepreneurial people? How can the positive factors be harnessed and the negative ones be neutralized?

These issues imply a link between technical innovation, nascent entrepreneurship, and a much broader level of technological development, although the study focused only on narrow aspects of the link. The study, therefore, had these primary objectives:

- to identify three postharvest innovations that were commercialized;
- to discuss the innovations in detail, tracing their history;
- to identify and analyze the social factors bearing on the success of these innovations;
- to study and analyze the common aspects of successful innovations; and
- to specify the conditions most likely to lead to successful, large-scale commercialization of technical innovations in agriculture and the conditions most likely to inhibit this.

An important secondary objective of this study was to recommend ways to harness the positive factors.

Definitions

In this work, *innovation* refers to the introduction of a technical or mechanical process involving

- a potential market (need pull) or a basic scientific idea (technology push);
- the ability to conceptualize the need or idea in practical terms;

Table 2. Innovations from selected Nigerian research organizations.

Product	Invention stage		Market stage		
	Idea	Prototype manufacture	Testing and development	Introduction to market	Diffusion
Yam pounder	x	x	x	x	x
Maize sheller	x	x	x		
Palm-oil digester	x	x	x		
Cassava planter	x	x	x		
Maize planter	x	x	x		
Cowpea thresher	x	x	x		
Melon sheller	x	x	x		
Gari processor	x	x	x	x	x
Kiln to smoke fish	x	x	x	x	x
Rolling injection planter	x	x	x		
Auto-feed jab planter	x	x	x		
Fertilizer band applicator	x	x	x		
Cassava lifter	x	x	x		
Rice pedal thresher	x	x	x		
Multipurpose bean dryer	x	x	x		

Source: Tiffin et al. (1977).

- the concretization of the idea, that is, the production of an invention and the creation of a prototype or the adaptation of an old idea;
- a test of the new invention or idea to show that it is workable and acceptable; and
- the introduction, usually on a small scale, of the invention in the market-place.

Technical innovation refers to innovation in mechanical hardware. An *original* technical innovation is one that originates from a basic idea or the recognition of a social need. It is concretized as a prototype and polished through research and development (R&D) before it is manufactured. An *adaptive* technical innovation starts with an existing product, process, or system that needs modification or improvement, and R&D is carried out on it until the desired result is obtained.

In the technologically advanced societies, uncommercialized inventions or laboratory-bound innovations do not generate serious concern. But in developing countries, where social and economic problems are in serious need of technical

solutions, this state of affairs seems unacceptable. Hence, there is an interest in analyzing the factors that hinder or promote entrepreneurship of technical innovation. This is the subject of the next section.

The literature on entrepreneurship

Despite the growing awareness among economists and policy-makers that entrepreneurship is a critically scarce resource in many parts of the world, particularly in developing countries, and that it is not economic opportunity alone that calls it forth, little attention has been given to the social and cultural factors that influence it. The work of Akeredolu-Alu (1975) and Mansfield (1978) are notable exceptions.

The entrepreneur has been described as the one who starts an enterprise; the one who puts new forms of industry on their feet; the one who shoulders the risks and uncertainty of using economic resources in a new way; and the one with the right motivation, energy, and ability to build something by his or her own efforts. Managerial ability is an essential ingredient.

For this review, we shall regard the entrepreneur as a combiner of resources. This is a courageous, independent, and tenacious individual who can surmount difficulties created by the social milieu to combine or marshall such resources as initiative, risk taking, know-how, organizational ability, leadership, and marketing skills to establish a profit-oriented enterprise.

Weber (1930) and Schumpeter (1947) argued that entrepreneurship appears to be more appreciated during economic depression than when times are good. Studies of entrepreneurship lapsed after the Great Depression but had a resurgence in the 1970s and 1980s (e.g., De Bono 1971; Dobb 1976; Thring and Laithwaite 1977; Sounder 1981), when more attempts were made to find practical solutions to economic recession, high inflation, and mass poverty. Now there is a burgeoning literature of several theoretical perspectives; some of these are summarized here.

The economic perspective on entrepreneurship

The economic importance of the entrepreneur in world history has been recognized for several decades. Weber (1930) put forward the thesis that the protestant ethic is spirit of capitalism (Green 1959). Other writers have discussed, from different perspectives, the importance of entrepreneurship to different countries in the postindustrial era. Recently, some development economists have said that the expansion of high-grade personnel (such as entrepreneurs), rather than the increase of physical capital, is the major determinant of economic development. Schumpeter (1947), who was, perhaps, the first major economist to analyze the role of entrepreneurship in economic development, attributed innovation to the entrepreneur. He argued that "to study the entrepreneur is to study the central figure in modern economic history."

In the theory of distribution put forward by Say (1824), a neoclassical economist, the entrepreneur plays a crucial role, though he or she is not a production factor. Unlike the capitalist, the entrepreneur directs the application of acquired knowledge to the production of goods for human consumption. Say postulated that, to be successful, the entrepreneur should be able to estimate future demand, determine the appropriate quantity and timing of inputs, calculate probable production costs and selling prices, and have the arts of superintending and administration. As this combination is not common, the number of successful entrepreneurs is limited, especially in industry.

Adam Smith, the 18th century philosopher and economist, made the distinction

between the "undertaker" (a translation of the French *entrepreneur*), who manages his or her own capital and receives a profit, and the "inactive capitalist," who receives interest. Although Smith did not articulate the entrepreneurial function, he strongly emphasized the importance of the business class.

It could be argued that these differences in the conceptualizations of the entrepreneur are the result not only of differences in intellectual viewpoints but also of differences in time and cultural perspective. Smith's influence is, perhaps, the reason that the classical economists of the 19th century merged the entrepreneurial and capitalist functions and did not develop a theory of the entrepreneur. The belief of the classical school that economic relationships were determined by natural law may also have forestalled the idea of a conscious agent, such as the entrepreneur, at the centre of the economic process.

For Schumpeter (1947), as mentioned earlier, the entrepreneur is the centre of an integrated model of economic development, incorporating a theory of profit and interest, as well as a theory of the business cycle and the capitalist system. The entrepreneur is an innovator, one who carries a combination of the following: the introduction of a new product; the opening of a new market; the conquest of new sources of materials; and the organization of new industry.

Clark (1985) asserted that there is a certain artificiality to isolating entrepreneurship in the way Schumpeter (1947) did. Schumpeter admits that entrepreneurs can be other people, such as managers and capitalists, and are subject to complex behavioural motives. It has been further argued that there is a tendency for innovating firms to move beyond commercializing just one invention and to continue striving for a competitive edge in the market place. Writers such as Cooper (1973) maintain that there are powerful reasons for thinking that firms attempt to institutionalize the capacity for innovation in a far more permanent sense than allowed by Schumpeter. Indeed, Schumpeter came to realize this and to recognize that corporate R&D is a major source of industrial innovation.

The neoclassical economists were not the only ones to fail to recognize the full functions of the entrepreneur. Most Marxist economists are equally guilty. To Marx, the capitalist is the central figure in the economic process. The capitalist's major role emanates from ownership of the means of production and not from any personal activity. Generally, the entrepreneur is excluded from Marxian analysis, although Marx's "active capitalist" has some of his features. The Marxist theory of distribution does not distinguish between profit and interest.

According to Baran and Sweezy (1973), the emphasis on the supply function of the entrepreneur is misplaced. The entrepreneur is not the major figure in capitalist development but is, along with the capitalist, someone who exploits and benefits from modern capitalism. The study of entrepreneurship applauds its genius, without trying to explain why this genius turned to the accumulation of capital. Thus, although the entrepreneur has tended to become a captive of bourgeois scholars, nothing in the concept, in its broadest sense, prevents its application to socialist economies.

The foregoing suggests that the whole discussion of the entrepreneur and his or her functions is invariably an examination of economic and business phenomena. In most cases, the first stage of an analysis is the survey of an economic institution, largely in economic terms. Indeed, the recognition of the importance of the entrepreneur has been couched in economic terms and, perhaps, has come to be understood as mainly an economic phenomenon. One of the indictments of this approach is that of the psychologist who seriously questions the rationale behind the general assumption in economic models. Many entrepreneurs, the psychologist points out, appear irrational and even romantic. Their behaviour is not handled well by the

pecuniary maximization models of neoclassical economists, who see the entrepreneur as having a purely instrumental orientation.

However, the realities were recognized by some orthodox economists. Schumpeter, for instance, frequently argued that such motives as the desire to found a private dynasty, the will to conquer in competitive battle, or the sheer joy of creation could rule the judgment of the entrepreneur. Keynes also argued that the animal spirit might be far more important than any other factor in explaining stockmarket or real-estate investments. Despite the great influence of the classical and Marxist economists, entrepreneurship has not received much attention in economics; only in recent years have economists been calling for a systematic theory of the entrepreneur.

However, entrepreneurship cannot be understood mainly as an economic phenomenon or as a phenomenon of a developed economy. Indeed, the kinds of entrepreneurship that find a fruitful soil in a given society and the forms and mechanisms that most adequately provide savings and channel them into productive investments cannot satisfactorily be identified by economists because the factors that determine the form and rate of innovations and entrepreneurship lie largely in cultural and social conditions, not the economy alone. Entrepreneurship, therefore, should have a multidisciplinary focus, which should include sociological, psychological, and technological perspectives.

In the literature, it has been established that the development of technical innovation and the capacity to translate such innovation into entrepreneurial ventures is a positive step in the direction of socioeconomic development. There is underdevelopment when this step is missing. But history tells us that the ability to innovate and to translate innovations into entrepreneurial ventures is subject to constraints dictated by the political economy of a nation and to the attitude of people and their reactions to the structural constraints of the economy.

In Nigeria, technical innovation and entrepreneurship are conditioned by the political economy: the institutions, the sociocultural opportunities and constraints, and the orientations of individual actors in the social structure.

The survey

This study used certain a priori variables in a survey of 45 innovators, and the findings on the basis of these variables are summarised below.

Venture capital

Capital constitutes a major constraint for the entrepreneurs. Of the 45 innovators studied, only 5 have access to royalties from previously successful innovations. Almost 50% identified government support as crucial, while about 30% said they would need institutional support.

The commercialization stage is the most crucial. Developing the equipment and machinery costs money. Working capital is also hard to come by. Small businesses have problems securing bank loans. Innovators perceive government as being uninterested in their work.

Infrastructure

The infrastructure is lacking, and entrepreneurs sometimes have to provide generators, dig boreholes, etc. by themselves. Only 4 out of the 45 innovators were satisfied with the available infrastructure, 31 felt it was inadequate, and 10 indicated that it could be better.

Technical capability

Forty-one of the innovations were made by people with a reasonably good education; 23 were made by PhDs; and the rest were made by people with little education. All respondents felt that a "good education," but not necessarily a higher education, would make them innovators.

Basic research

More than three quarters of the innovations resulted from some basic research, but the commercially successful ones did not. In most cases, research to improve the innovation was undertaken only after a prototype had been built.

Extended-family obligations

Extended-family obligations did not constitute a serious constraint on the translation of innovations into entrepreneurial ventures, although I had assumed that it would. Support from the family was generally nonfinancial. This finding contradicts that of Hopkins (1978), who found that the extended family in African societies ordinarily provided venture capital.

Use of patents

There is lack of faith in the *Nigerian Patent Law*, which respondents found to be fluid and to provide little protection for local innovations. Innovators consider this a major problem in the commercialization of their products and processes. Eighty-nine percent had not explored the use of the patent law. (The law has been enforced since 1970, and 6644 patents have been registered. However, only 177 are owned by Nigerians; the rest belong to foreigners.)

Size of organization

Size may refer to the volume of capital or to the size of the work force. Most of the entrepreneurs had a work force of fewer than 10 people and an initial capital of 50 000 NGN (in 1995, 78.5 Nigerian naira [NGN] = 1 United States dollar [USD]). Small size obviates the need for large capital.

Early market identification

The size or spread of the market and its dynamics were considered crucial by all the innovators. Market competition is not limited to indigenous versus foreign; there is competition, for example, between local engineers and local blacksmiths. The blacksmiths often make a crude and cheap imitation of innovations. Foreign products seem to stifle local initiative.

Political factors

The survey identified two influences of Nigeria's body politic on the innovation process:

1. There was less entrepreneurship in the colonial era than at the time of the survey, as economic growth was low. Colonialism brought economic growth to Nigeria; however, it thwarted indigenous entrepreneurship by encouraging consumer-oriented business, known locally as (*karakata* trade), rather than production-oriented initiatives. The roots of this lamentable process were traced by 22 of the surveyed innovators to the flooding of the indigenous market with foreign goods and the siphoning of local material to support

Western industrialization.

2. The political instability that has plagued the country since the 1970s was said to have created an atmosphere of uncertainty for potential investors and of frustration for entrepreneurs. Rapid changes of government were seen to affect the policies governing import licences. The consensus was that uncertainties that attend efforts to get import licences discourage the high-risk investments crucial to technical entrepreneurship.

Effective coordination of production and marketing

The most challenging problem reported by engineers and innovators in the study is the need for technical skills and aggressive marketing, which all innovators identified as crucial but severely lacking. Only 14 expressed the wish to take business administration courses if they were available. Most would leave the commercialization of innovations to the orthodox entrepreneur.

Links between government and consumers

Respondents said that links between government and innovators and between government and consumers were virtually nonexistent in Nigeria. The innovators felt that government has no interest in local technical innovations. The link between innovation and entrepreneurship was also considered crucial but absent. Recent government policies are beginning to address the problem.

Support

Three kinds of support were identified: (1) tax relief and special loans for manufacturers; (2) research funding, especially for the development of prototypes; and (3) recognition of the quality and potential of local innovations. Recognition was surprisingly important. Forty-two out of 45 respondents wanted more of it. They reasoned that recognition would elicit support from government.

Other findings

There appeared to be a good deal of institutional support for innovations in Nigeria. There were no institutional constraints on the choice of project or the production and testing of prototypes. Most institutions provided seed money for projects. Nevertheless, it was the consensus of the respondents that teaching and research institutions did not offer enough of an avenue for the commercialization of innovations.

In contrast to the findings of Harris (1967), this study found that innovators consider financial support essential to their work. If we include tax relief and research funding in the general category of financial support, we may conclude that 57.8% of the respondents considered such support important. Unlike the printing and sawmill industries that Harris studied, manufacturing requires much more capital than personal savings can provide, in most cases.

It is generally agreed that an entrepreneur is a person with the drive and tendency to create a profitable enterprise. In response to a question about their self-identity, 34 of the respondents, mainly in the public sector, said they were not entrepreneurs, even though most were in the advanced stages of setting up their innovation-based enterprises. Perhaps they did not see themselves as engaged in profitable enterprises or did not see their efforts as entrepreneurial. In general, however, there appeared to be an increase in the number of institution-based researchers aspiring to set up their own businesses. This development appears to be the result of structural shift of the Nigerian economy toward self-sufficiency. More

attention is being paid to the possible commercial exploitation of research results.

From our unscheduled interviews with entrepreneurs and a few users of the innovations, other significant findings emerged. First, the entrepreneurs confirmed that the innovators were interested in high returns from the commercialization of technical innovations, which tends to be capital intensive and have long gestation. The entrepreneurs argued that frequent changes in government regulations and the import-licence scheme, combined with a high degree of corruption, rendered manufacturing and technical innovation far too risky. Some, however, added that the country's economic crisis is causing a positive change: as buying and selling become less lucrative more attention is being paid to manufacturing.

The major complaint of the users was about the cost of the products of innovation. The users argued these were beyond the means of average people. Women who used the yam pounder lamented that their husbands preferred the traditional way of pounding yam; most of the time, yam-pounding machines were seen as prestige gadgets for decorating kitchens.

The pepper grinders (which the women all agree were very useful) were too expensive to be purchased for household use. Most of them either bought them and put them to commercial use or had their vegetables ground by others. Yet others, notably those with small families, simply used imported blenders.

We concluded that market-driven innovations appeared to be better received than technology-driven ones.

The case studies

The three successful innovations selected for detailed case study were the maize sheller, the *gari*-processing machine, and the yam pounder. The three unsuccessful ones selected were the cassava peeler, the manioc machine, and the cowpea thresher.

The maize sheller

Maize is one of Nigeria's staple foods. It is used in preparing morning, noon, and evening meals. Its supplies a sizable proportion of the population's carbohydrates. It is widely cultivated — two crops a year is the norm — and its yield per hectare is high. With adequate storage and processing of maize, Nigeria could become self-sufficient in this crop. However, because of inadequate postharvest technology, farmers are compelled to dispose of their crops quickly. The result is an abundance of maize during the two harvest seasons and a shortage during the rest of the year.

Maize is better preserved for storage when it is shelled than when it is in the husk or on the cob; after shelling it is easier to treat the maize against weevils and other organisms. Traditionally, women and children shell the crop by hand, which is a long and tedious process; thus, the maize machine is an important postharvest innovation.

After the maize has been dehusked, the machine shells it in a rotary action that is 98% efficient. The shelled grain then drops into a storage chamber. The machine is about six times faster than manual shelling.

The innovator was an agricultural engineer. He developed the innovation at an institution, where he had access to the workshop and research facilities. The innovation was developed in response to a public need. Two farmers had asked at different times for such a machine, and the engineer, accordingly, developed it from scratch. These farmers bought the first machine, and 20 other machines were subsequently sold. The idea has been replicated by other researchers, and the sheller is now in general use.

I interviewed two entrepreneurs who bought the machine and were using it commercially. The first, one of the two original buyers, suggested that an adjunct function be added to the machine to sort bad grains from good ones. The second bought a sheller after observing the two original buyers using one. Both of the entrepreneurs had been using the machine for more than 2 years and commended its performance and efficiency.

Two women were also interviewed. They recognized the efficiency of the maize sheller and its contribution to high output. However, they did not perceive the machine as offering them more leisure; the time gained from not hand shelling maize was spent doing other things on the farm, such as dehusking, picking out bad grains, and other odd jobs. From the women's point of view, the main advantage of the machine was that it performed the most laborious part of the postharvest work.

Thus, the maize sheller could be said to have scored a success as a demand-pull innovation.

The *gari*-processing machine

Gari is a local staple obtained from cassava, which is a root crop grown widely in Nigeria. Cassava normally rots quickly and is difficult to preserve whole or as a fresh tuber. It needs to be processed and adequately stored if products derived from it are to be available on the market all year. Most Nigerian varieties of cassava have a high cyanide content, another reason for processing the fresh crop.

There are several ways of processing cassava to prevent postharvest waste. Converting it into a flour is one method; another is to process it into *gari* (roasted pulp). The latter, however, is a long, tedious process. The harvested cassava has to be peeled, washed, grated, pressed, granulated, and dry roasted before it becomes edible *gari*, which can be bagged and stored. Despite the length of the process, *gari* is produced extensively and is the cheapest food on the Nigerian market, being consumed on a large scale by the lower and middle classes.

Nearly all the *gari* is produced by women, and a lot of rural women spend a great deal of their time producing it with the traditional, inefficient, manual methods. The labour-intensive nature of the process reduces productivity. It keeps rural women glued to their hearths, with little time for leisure, adult education, personal development, or participation in politics.

Several researchers and entrepreneurs have recognized the need to mechanize all or part of *gari* processing. Some successful attempts have been made, but only the Federal Institute of Industrial Research at Oshodi has developed a *gari*-processing plant that integrates all the processing stages (except peeling) and has been commercialized.

Another innovation is a set of machines that combines the grating and pressing parts of the process. This innovation has been widely commercialized. In the hammer-mill pulper, peeled cassava is fed into a hopper, whence it moves into the milling chamber, where it is milled into a pulp and ejected through an outlet into a perforated basin. A motor-operated pressing block forces the mash against the basin. The juice produced, which is toxic because of a high hydrocyanic acid content, escapes through the perforations and is collected in a drainage tray. There is no wastage in the two machines.

The innovator had only a primary education. He fabricated his machines, which he admitted adapting from others, with the help of four young apprentices. Production methods were largely the traditional ones of heating and beating scrap metal. Thirty machines were sold in 4 years. A set of the machines without electric motors originally cost 1050 NGN. With the increase in the price of scrap metal, paint,

and other inputs, the price nearly doubled, to 1750 NGN. Venture capital was a problem at first.

The innovator had been inspired by a hammer mill he saw at Enugu. He took a year to produce the first prototype and another year to produce a better looking one, which he sold to a friend for minimum profit. After the machine's efficiency was demonstrated, the innovator produced another type, which sold quickly. At the time of the survey, his business was self-supporting. His key to success were drive, hard work, perseverance, and an efficient team.

The yam-pounding machine

Yam is another staple that is cultivated and consumed across Nigeria. It is also seasonal, and, at present, it is very difficult to preserve, as it tends to rot. It is, generally, a middle- and upper-class staple, especially when out of season. But nearly all Nigerians consume it on a large scale during the harvest season. It is particularly favoured by the Yoruba, especially those of Ijesha lineage, and the middle-belt people.

The commonest way to prepare yam is to pound it into a sticky mash, after which it can be eaten in soup or a sauce. But pounding yam is a laborious process, and the pounding generates a large volume of sweat, not all of which escapes the food.

The yam-pounding machine is not precisely a postharvest innovation, but it is an important processing machine in Nigeria, and there are important lessons to be learned from studying it. Essentially, the machine is a mechanized mortar and pestle. The industrial-size version has a huge basin, whereas the portable one looks much like a bread mixer or a large blender. There are allegations that a Japanese manufacturer copied the prototype and produced a much more compact and aesthetically pleasing model solely for the Nigerian market.

The yam is first boiled and placed in the machine, the smaller version of which can pound enough yam in 60 s to feed five people. There is no loss of the product, and the machine is more hygienic and produces a lump-free mash.

The innovator of the domestic model was highly educated. His research was motivated by a desire to make yam pounding less laborious. The prototype was produced in 1976, after 2 years of work. After demonstrating its functionality and marketability, the innovator, who had access to a modern workshop and trained technicians, produced three of the machines to sell.

After the Japanese model began to dominate the market, the patent for the domestic model was sold to Addis Engineering, a local manufacturer that has since produced the machine on a large scale; the firm claims to have sold hundreds of them since 1977. The corporate entrepreneur for this innovation was Leventis Nigeria Ltd, the main distributor of Addis products. The distributor was able to provide Addis with user feedback. Addis then improved the innovation, adding an all-purpose grinder to the unit. This advance gave the Nigerian machine a competitive edge over the Japanese one, which by this time had captured the market with its better-finished machine.

The original domestic machine sold at 150 NGN, motor included. At the time of the survey, the machine with the grinder attached was selling at 1050 NGN. The Japanese model, which can prepare yam right from the uncooked, peeled stage, was selling for 250–300 NGN.

The success of the domestic model can be attributed to its original low cost and the need for status that it satisfied. The renovation added to its success.

The cassava peeler

The cassava peeler is one of the unsuccessful innovations. The cassava peeler is a simple, robust, but large piece of equipment. It consists of a big drumlike grater that rotates horizontally above an even bigger triangular basin. The unpeeled cassava tubers are fed, in succession, into the forum, where the skins are grated off and the tubers washed. A tonne can be processed in this way in a few minutes. Unfortunately, more than 50% of the cassava goes to waste.

Although the peeler has been commercialized to some extent, it has not stayed on the market. Indeed, processing mills, like Texagari, that installed the peelers have stopped using them and have gone back to manual labour, which is cheaper and much more efficient. The unacceptability of the machine has inspired its renovation, which is now at the R&D stage.

This innovation seems to have failed not only because it had technical problems but also because it was a technology-push innovation and not a demand-pull one; the impetus for its development was academic, and little account was taken of the availability of cheap labour in the Nigerian economy.

The manioc machine

The manioc machine was an unsuccessful attempt to diversify the use of cassava and preserve yields. The innovator, who was trained in the United States, wanted to replace the imported potato chips that were flooding the Nigerian snack market, so he designed a unit that would make similar chips from cassava.

The unit is a continuous-process plant, with only one manual stage (peeling the cassava). The cassava is fed into a hopper and then the machine ejects 2 mm thick chips into a polyethylene bag held by an operator. When the bag is full, the operator drops it into a sealer, which makes it ready for marketing. Only 2% of the cassava is lost in processing.

Although the innovator demonstrated the functionality of the machine, he has failed to sell more than one unit since 1976. Actually, he was using the firm's unsold machines to produce cassava chips for distribution to big supermarkets like Leventis, UAC, and Kingsway Stores. Sales were slow, but he reasoned that if austerity continued and the sales of imported snacks declined, he would capture the snack market and also sell some of his machines.

A major impediment to the success of this innovation was that it was the result of a technology push and did not satisfy immediate local needs. The Nigerian economic problem makes it difficult for the majority of the population to afford three square meals a day; snacks have become luxury items. Other impediments identified by the innovator were the indiscriminate import of foreign goods, especially potato chips, and the problems he had getting adequate publicity.

The cowpea thresher

Protein is important in the human diet, but animal protein is expensive in tropical countries. Most people in Nigeria depend on legumes, like cowpea, for much of their protein. Cowpea is the most popular legume consumed by the Yorubas. However, despite its nutritional importance, not much research had been done on it. The International Institute for Tropical Agriculture recognized this deficiency and undertook research to enhance the resistance of cowpea to diseases. That research is in the realm of agrotechnology. However, the cowpea thresher represents a first attempt in Nigeria, perhaps in the whole world, to develop hardware to thresh cowpea and save women the drudgery. The machine can thresh 700 kg h⁻¹, with a loss of only

0.1% of the cowpea.

In 1972, on a trip to the rural areas, the innovator, who was a highly educated man, found women struggling to thresh cowpea by putting it in cocoa bags and beating the bags with big sticks, sweating profusely in the process. He sympathized with these women and resolved to find an easier, more effective way of shelling cowpea. On his return home, he started working on a machine. He based his initial R&D on the traditional threshing method but, in fact, built four prototypes; each was modified, and the last ended up drastically different from the first. The first commercial product was launched in late 1976. He sold one to an entrepreneur in the area where he originally thought of his idea and another to an entrepreneur in Ibadan. But there have been no sales since. Both purchasers were interviewed. They were using the machines on their farms to thresh their own cowpea for sale; they confirmed the 99.9% figure for the efficiency of the machines. Four women in two farming villages were also interviewed. They too confirmed that the machines were very efficient. However, they saw them as displacing hired labour, which depends on the shelling for income. These four women did not receive any direct benefit from the machines, as they were not normally involved in the threshing, but they saw it as helping the men and “unsuccessful husbands take better care of their families.”

I tried to understand why such an efficient a machine wasn't commercialized on a large scale. The innovator, although claiming to be anxious to satisfy a social need, was uninterested in the commercialization process. His immediate interest was research for its own sake or, at least, for the sake of academic recognition. And the machine was too expensive for the farmers the innovator wanted to help. However, if this machine were commercialized by a few entrepreneurs, as happened with the milling machine, more units would be sold.

Conclusions

On the general level, it was discovered that the success of an innovation can be hindered by conditions that contribute in a major way to the economic strangulation of Nigeria — notably, the quest for the quick returns from retail trade rather than the delayed returns from production; and the domination of the local market by mercantile capitalism, which discourages receptivity for local innovations.

The six case studies established that successful innovations in Nigeria tend to be

- adaptive, better finished, and developed by innovators with easy access to capital;
- commercialized by entrepreneurs who had easy access to bank loans, undertook market research, were willing to take risks, knew how to capture distribution channels, and were efficient managers;
- perceived as satisfying immediate social needs and as better alternatives to existing machines or technologies;
- disseminated faster and well received and, thus, quickly adopted.

The reverse was true of unsuccessful innovations. Though the sample was small, making generalizations difficult, the pilot study of 45 innovators confirmed these conclusions.

The implication is that if Nigeria expects its technical innovativeness and entrepreneurship to play a crucial role in its socioeconomic development, it should endeavour to harness the positive factors and counteract the negative ones. To this end, the following recommendations are made.

Recommendations

President Babangida said the following in a speech, reported 22 January 1986, on the new Nigeria:

It has been gratifying to note the positive and enthusiastic reception by the nation of the policy package contained in the 1986 budget. It has also been instructive to observe the fear, and sometimes the cynicism, being expressed about the successful implementation of the various policies and programmes... Government recognizes that in a period of economic emergency, policies, no matter how soundly formulated, become empty words unless they are vigorously implemented. We cannot, therefore, afford to allow the machinery of policy implementation to jog at its leisurely pace.

This quotation underpins my attitude toward policy recommendations. Academic papers of this genre usually conclude with a catalogue of beautiful policy recommendations. These recommendations almost always fail to go to the appropriate quarters; even when they do, they do not get implemented. Indeed, most of them end on library shelves, collecting dust, or find their way into the footnotes of yet another paper.

This could be the result of several factors. For instance, it could be that policy recommendations are so utopian that they just cannot be implemented. It could also be that there is a communications gap between government and individual researchers or corporate research institutions. Or there could be a general lack of commitment by government to policy research.

The last two are beyond the powers of individual researchers to correct, but the first is not. I believe that stating recommendations clearly, simply, and realistically enhances the likelihood that they will be implemented, and this, accordingly, is what I will try to do in my recommendations.

1. A national inventory should be taken of all technical innovations in Nigeria. This can be done effectively by a team of researchers, each assigned to different sectors. This inventory would become an important database for the government to consult as it formulates policies to promote national technological takeoff.
2. The government should create social and political conditions that are favourable to indigenous innovation and entrepreneurship. The government needs to make special efforts to support new technologies that are in the interest of the nation. The government should also support innovative and entrepreneurial efforts that would develop productive local industry, rather than encouraging a merchant economy that distributes luxury goods. The government could provide support and incentives to the private sector. The new industrial policy is a step in the right direction.
3. The government should drastically limit the participation of foreign capitalists in certain crucial areas of the economy where there is local capability, such as in banking, and encourage private Nigerian capitalists to do the job instead. Where local capital is absent or weak, government should define the terms of multinational involvement at each level of the economy, monitoring each stage of the process closely and evaluating the output continually. The pervasive and negative influence of multinational corporations on the Nigerian economy persists only because the state sanctions it.
4. To support innovations, international agencies and multinational corporations should invest in small-scale industries. These organizations should provide simple technology for which local entrepreneurs can supply peripherals or spare parts, rather than imposing, through grants and investment, technology

that is either too costly or too cumbersome to operate.

5. A receptive climate for innovation and entrepreneurship should be created. A rural-development program should educate villagers on the need for, and the advantages of, innovation in their economically productive activities.
6. The government should raise the quality of life of rural people by providing a better infrastructure and ensuring that people are sufficiently rewarded for their work. For some time, it has been the case that innovations are not adopted because of insufficient rural income; the government could improve this situation by buying agricultural surpluses at good prices for processing and storage. This is being pursued by the present government and should be supported.
7. The quality of locally produced goods should be raised to the standards of the imports. With sufficient financial support, local producers could make better and more appealing goods.
8. Research should be undertaken to develop better processing equipment. Research costs money. Research funds and venture capital are needed to exploit the results of research. Funds could be attracted by publishing findings and soliciting federal and state governments and their agencies, industry, philanthropic organizations, wealthy people, and financial institutions. A proposal by the Continental Merchant Bank to set up a venture capital company is a step in the right direction. The federal government should encourage such moves.
9. An institution, like a National Innovation and Entrepreneurship Board, should be created to take patents, find entrepreneurs, and provide them with venture capital. Innovators should try to set up workshops and farms where they can commercially test their own innovations. The government should encourage universities and research institutions to commercialize their findings and put about 20% of their proceeds back into more research.
10. The government should use appropriate national agencies to develop in entrepreneurs the aggressive marketing skills they need to commercialize innovations.
11. The government and the research institutions should try to bridge the communication gap between the producers of technologies and potential users and thus move the innovation from the workshop to the doors of the people. This could be done in two ways. The government could organize small trade fairs in rural areas to demonstrate technologies. Research institutions could periodically hold open house for users to inspect finished or ongoing projects and make suggestions for improvements or new research.
12. A comprehensive system of links should be established between all the actors in technical entrepreneurship: government, funding agencies, universities, research institutions, innovators, manufacturers, entrepreneurs, and users. Coordination of existing public organizations would be of value. The government should modify the organizations' mandates to eliminate overlap and make the support of innovation an explicit goal.
13. The government should formulate truly protective patent laws. The assurance of protection against copying can stimulate an inventor. However, patent laws in Nigeria are said to be so fluid that they provide hardly any protection. The ineffective patent system is a disincentive to innovation.

14. Nigerian consumers should demand better quality. Consumers have a crucial role to play in indigenous innovation — as Rothwell and Gardiner (1985) pointed out, tough customers make for better design.
15. Nigerian innovators should be more tenacious in the face of peer jealousy and unfair criticism. They should encourage public receptivity by advertising their inventions in journals and the mass media.
16. Nigerian entrepreneurs should have tax relief and easy access to venture capital to encourage them to invest in manufacturing, rather than in buying and selling.
17. Parts of the engineering curriculum at Nigerian universities should be critically examined and reorganized. The current curriculum — a mix of those from Britain, North America, and eastern Europe — creates problems. It is time Nigeria evolved an engineering curriculum that is more appropriate for its own needs. There is a need for engineers who can think *and* work with their hands, so the curriculum needs to be more practical. There is also a need for trained technicians to support the efforts of the graduate engineers.
18. Technical entrepreneurs should receive training in basic engineering, business management, finance and accounting and should have an understanding of the social, legal, and political realities of the country. Education for technical entrepreneurship is rapidly developing in North America, and Nigeria can benefit from its experience. There should be centres where all interested innovators can from time to time take a course or a workshop in business administration. Retired engineers could be used in such programs, benefiting both the retired person and the trainee.

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CHAPTER 15

Technology Adoption by Small-Scale Farmers in Ghana

S. Owusu-Baah

Introduction

The low agricultural production of the Third World has been a long-term concern of agricultural experts. In Ghana, the government spends a significant amount of foreign exchange to import food items, especially cereals, to supplement local production. Since 1970 the Northern Region has developed into Ghana's largest rice and cotton producer, but the yields could still be higher (Government of Ghana 1978). However, several factors are preventing the region from reaching its full potential (Northern Region Rural Integrated Project [NORRIP] 1982):

- inefficient agronomic practices that tend to promote soil degeneration;
- lack of improved crop varieties;
- poor farm- and water-management practices;
- lack of a favourable pricing policy for crops and agricultural inputs; and
- poor transportation and credit facilities.

In 1981, in an attempt to increase the yield of northern farms to meet Ghana's food requirements, the Canadian government established NORRIP to plan and design projects for the region. NORRIP cooperates with several other organizations in the north to assist small-scale farmers to increase their productivity through the use of improved farming techniques and appropriate technology, a package comprising agricultural inputs and farming practices.

This study focused on technology adoption by small-scale farmers in the Mamprusi area of the Northern Region. Mamprusi was chosen because of its potential for agricultural development and because (according to NORRIP) there are positive attitudes toward change in this area. Farming in the Mamprusi area is done on small holdings by farmers using traditional and inefficient agricultural practices and technology.

The central hypothesis was that the strategies used for diffusion of improved technology to small-scale farmers in the north have been inadequate or inappropriate and that this is why the aims of the development agencies have not been realized in this region.

Objectives

The objectives of the study were

- to review the available literature on the adoption of technological innovations by peasant communities in and outside Ghana;
- to review the aims and strategies pursued by rural-development projects, such as NORRIP, in their attempt to diffuse improved technology among the

peasants of the Mamprusi area;

- to conduct a preliminary survey of the area's farming community to outline the factors relevant to the adoption of technologies in this district;
- to conduct formal and quantitative surveys to test hypotheses suggested by the preliminary survey;
- to suggest to decision-makers ways to facilitate the adoption of technology by rural farmers.

Methodology

A reconnaissance survey was made of the study area to obtain a general overview and to collect secondary information relevant to the study. Interviews were held with personnel from the Ministry of Agriculture (MOA) regional headquarters, Tamale; the District Agricultural Office, Walewale; NORRIP; the Ghana–German Agricultural Development Programme (GGADP); the Crops Research Institute, Nyankpala; the Ghana Seed Company Ltd, Tamale; the Langbensi Agricultural Station (LAS), Langbensi; the Catholic Agricultural Project (CAP), Walewale; and the Global 2000, Walewale.

Interviews were also held with farmers: checklists were used to find out why farmers behave the way they do and to help me develop appropriate questionnaires. In Walewale, Gbimsi, Langbensi, Wungu, Guabiliga, and Mimima, village leaders and others respected in the community were asked for their opinion.

An in-depth (informal) survey of 20 selected farmers was conducted to obtain information on farm households and farming practices and to identify some of the constraints to increased food production. Information was gathered by means of checklists, as well as by visits to the farmers' plots.

Questionnaires designed on the basis of information obtained in the two previous surveys were administered to 69 randomly selected farmers in the Mamprusi area.

Historical background

The northern region was until 1970 largely neglected. It has, however, been developed into the nation's largest rice and cotton producer. This was as a result of the German-financed GGADP (Government of Ghana 1978). It was felt there was a need to introduce modern and appropriate technology because the traditional mode of farming, using simple hoe and cutlass on small plots of land, hadn't the potential to increase agricultural output. Production of maize and rice, which stood at 418 000 and 68 000 t, respectively, in the 1974/75 cropping year, was too low. At the same time, it was estimated that national demand for maize and rice would be 751 000 and 171 000 t, respectively, by 1985 (Government of Ghana 1978, table 11).

The policy of the 1970s was to encourage large-scale commercial farming, with mechanized systems. The Agricultural Development Bank was encouraged to advance loans to farmers to go into large-scale rice cultivation, using mainly tractors and high-yielding rice seeds. Earlier, in the 1930s, Bullock Traction Technology (BTT) had been introduced. In 1975, the Government of Ghana thought BTT was not the right kind of technology for modern agriculture. This led to the government scrapping its support for the project. Tractors were considered appropriate for modernizing Ghana's agriculture. The policy of this time was no different from that of the 1930s: both failed to take account of the interests of the small-scale farmers.

Several types of tractors were imported to support increased agricultural

production. At some point, as many as 17 different makes were imported, and spare parts obviously became a problem. The rising cost of tractors, parts, fuel, and lubricants discouraged the use of tractors, and many were abandoned. This affected agricultural production, making the policy antiproduktive.

Aid agencies in the region continued to support the BTT program, with little success. After several years of problems with the tractors, coupled with the problems in Ghana's economy, the government changed the policy, once again favouring the BTT. Ever since this policy change, the emphasis has been on developing appropriate technology for use by farmers in the northern region. Several aid agencies have been in the forefront in the development and transfer of appropriate technology, a package comprising the use of bullocks or donkeys, fertilizers, irrigation, and improved, high-yielding seeds.

Previous research

The debate about the use of tractors to increase agricultural output has been continuous. Basically, there are two views in this debate: the substitution and the net-contribution views.

The substitution view portrays tractors and animal and human labour as substitutes. The main considerations are the factor prices of these inputs. If the costs of animal and human labour rise high enough, it may be economical to adopt the use of tractors; otherwise, vice versa.

The net-contribution view argues that inadequate power is the main constraint in agricultural production. The greater power of tractors allows them to do greater work in a shorter period of time. This releases labour for other jobs in the household and on the farm.

In response to this argument, the substitution view suggests that in the labour-surplus countries of the Third World, labour-intensive practices are more appropriate. In these countries, labour is cheaper than in the advanced countries and the newly developed countries of Asia. In Duff and Kaiser's (1982) study of the mechanization of small rice farms in Asia, the authors showed that the rising rural wage, induced by industrialization and urbanization in Japan, South Korea, and Taiwan, was the principal motivation for substituting machines for animal and human labour.

In the same study, Duff and Kaiser (1982) argued that in countries like the Philippines, West Java, and South Sulawesi, the introduction of mechanized land preparation displaces family and animal labour. It is only when mechanized threshing is introduced that hired labour is displaced. This is because, in most developing countries, threshing is traditionally done by hired labour. Without alternative jobs, therefore, displaced laborers suffer low income.

The aim of any improved technology is increased production. Several studies have been conducted to determine the impact of improved agricultural technology on incomes, production, and employment, but they failed to account for the effects of other agricultural inputs. Generally, results from such studies have been mixed. Tan and Wicks (*in* Duff and Kaiser 1982) found a significant difference in yields from mechanically and traditionally tilled fields in Asia. This finding contradicts that of Duff and Kaiser (1982), who found no significant difference; however, their study made adjustments for fertilizer use. In yet another study (Sukharomana 1982), it was found that mechanization did actually increase rice yields in Thailand. However, the regression analysis used in the study failed to account for the role played by other inputs, such as fertilizer and pesticides. An increase in agricultural production may also result from (1) extending the area under cultivation or (2) more intensively

farming an existing area. Obviously, the first can occur only in areas where there is an abundance of land.

The study area

The study area is in the Mamprusi area, the northernmost portion of Ghana. The area is sparsely populated, with an estimated population density of 19–22 people km⁻². Agriculture is the most important economic activity in the area, employing more than 90% of the labour force. Most of the farmers are subsistence oriented.

The main towns in the study area are Walewale, Wulugu, and Langbensi. Other towns that influence farming in the study area include Gamboga, Nalerigu, and Nkpanhuri. Walewale is located some 110 km north of Tamale. (Northern Region capital) and lies on the main road between Tamale and Bolgatanga (Upper East Region capital).

The study area receives an annual rainfall of 900–1000 mm, the lowest in the region. Rainfall distribution is unimodal, with much of the rain falling between May and September. The rainy season is followed by a long and severe dry season. During this period, the area comes under the strong influence of the harmattans (winds that originate in the Sahara and blow across the Sahel region). The harmattans are very dry, and, as a result, humidity may be as low as 10–20% during the dry season. Dryland farming is virtually impossible during this period, so the farmers produce only one crop a year.

The mean temperature is around 29°C. March, April, and May are the hottest months, when temperatures exceeding 35°C are not uncommon, and the coldest months are August and September.

The study area is served by a number of small rivers, many of which dry up during the long dry season. A few have been dammed to provide water for people and livestock. The small rivers drain two major rivers, the White Volta and Nasia, which are outside the study area.

The topography is generally flat, becoming undulating and hilly toward the northeast. Altitudes range from 150 to 330 m in the northeast, with its rocky hills.

The soils are fairly good, belonging to capability classes II and III, and are somewhat uniform across the study area. Two distinct soil classes can be identified: the Savanna glysols, or Entisols (United States Department of Agriculture [USDA] classification); and the Savanna ochrosols, or Alfisols (USDA classification). The Savanna glysols occur in river valleys and are alluvial or colluvial, whereas the Savanna ochrosols, which are common in upland areas, are moderately well drained soils developed over voltaian sandstones.

The natural vegetation is Guinea Savanna woodland, with tree cover in most areas. Many of the trees are felled for fuelwood. Trees of economic value, such as the shea (“butter tree”) and the baobab (“monkey bread tree”), are common and grow in the wild.

Infrastructure

A network of dirt roads and tracks connects the villages studied. Many of the roads were found to be in bad condition, even during the dry season, and to be virtually impassable during the rainy season, a period of intense farming activity.

The main government clinics are found in Walewale and Kpasinkpe and in Upper East Region.

The District Agricultural Office is located in Walewale, and there are technical assistants in charge of villages in the area. Many of these technical assistants are not

well trained, and they have to rely on public transport to visit the farms. Input supply depots are generally lacking in the area, and there are virtually no government silos. Marketing facilities are poor and are mainly operated by the farmers. All the markets are periodic: most convene every third day.

There are no banks or credit agencies in the study area; thus, credit is largely unavailable to the farmers.

Socioeconomic factors

The major ethnic group in the study area is the Mamprusi, who are predominantly crop farmers. Other important ethnic groups, who originated in other parts of Ghana and the neighbouring countries, include the Kusasi, Frafra, Mossi, and Fulani. The Fulani people are mainly cattle herders. Islam is the main religion in the area, although Christian denominations, such as Roman Catholic, Presbyterian, and Adventist Mission, are active there.

The farms

Farm households

Sixty-nine farm households were interviewed during the formal survey. The average household size was 5.3 persons. The number of wives per household ranged from zero to four (one farmer was found to have five wives).

The farmers in the sample were young: the average age of the heads of households was 43.4 years ($CV = 0.27$). Table 1 indicates that two thirds of the farmers were younger than 50 years. The age distribution shows only a slightly positively skewed distribution, with a Pearson correlation of $r = 0.61$.

Table 1. Age distribution of heads of households.

Age	<i>n</i>	Proportion of farmers (%)	Cumulative distribution (%)
20–29	5	7.3	7.3
30–39	24	34.8	42.1
40–49	17	24.6	66.7
50–59	14	20.3	87.0
60–69	9	13.0	100.0
Total	69	100.0	

Source: Calculated by researchers.

The average household owns two plots; the compound garden and the main plot (or farm), which is usually 2–6 km from home. The average farm size is estimated at 3.9 ha, with more than half of the households owning <3 ha (Table 2). Land for farming is acquired from the village chiefs or elders.

Land is easily obtainable because the population density is low in the area. No rents are paid, except for occasional gifts of cola, fowls, rams, etc. The head of the household is usually responsible for decisions concerning farming operations, often in consultation with the spouse(s). Family labour is the main source of farm labour and, in view of the availability of land, usually determines the size of the family farm. The correlation between family size and farm size was highly significant ($P = 0.002$, $r = 0.4288$).

Table 2. Size distribution of farms.

Area (ha)	<i>n</i>	Proportion of farms (%)	Cumulative distribution (%)
1.0	3	4.4	4.4
1.0–1.9	11	15.9	20.3
2.0–2.9	22	31.9	52.2
3.0–3.9	7	10.1	62.3
4.0–4.9	14	20.3	82.6
5.0	12	17.4	100.0
Total	69	100.0	

Source: Calculated by researchers.

The roles of family members in farming operations are distinct, although each member can take part in any activity. The men and the boys are often responsible for land preparation, particularly preparation of ridges, mounds, and ploughing, whereas the women's main role is seeding or planting. All family members take part in the first and major weeding of the farm, but women and children are mainly responsible for subsequent weedings. (Women and children also gather fuelwood for the home.) Harvesting of produce is often done by all family members, but threshing and winnowing operations are performed by the women and girls. Where rice is grown, young boys are often employed to scare away birds just before harvesting. Young boys are also often seen herding livestock or conveying farm produce in a cart pulled by a bullock or donkey.

Farmers' objectives

The objectives and resource endowment of the small-scale farmer strongly influence the farmer's choice of enterprise and activities within the farming system. The surveys revealed that the main objectives of the small holders were

- to satisfy the household's subsistence requirements (the main staples — millet, sorghum, and maize — are grown on all farms);
- to satisfy household cash needs through the sale of surplus crops (economic necessity forces many farmers to sell crops, although they may not have produced enough); the growing of cash crops, such as groundnuts (i.e., peanuts) and cotton; the sale of livestock; or off-farm work; and
- to keep livestock as insurance against crop failure or as a customary and religious practice.

It is worth mentioning that, apart from being an important staple crop, sorghum (or guinea corn) is also grown for brewing local beer (*pito*), which is a major off-farm income earner for women. The mash from *pito* brewing is used as livestock feed supplement.

Farming practices

Crop husbandry

The main reason for growing crops is to meet the family food requirements. The major crops grown in 1987 are shown in Table 3. The 1987 season was disappointing because although the study area (like the rest of the country) received adequate

rainfall, the distribution was poor, and the rains came when they were not expected. Therefore, the proportion of farmers growing the various crops is likely to have been lower than usual, particularly for beans. The important beans grown are cowpeas, pigeon peas, and the roundbean (or bambara). In addition, rain-fed rice is also grown, especially in valley bottoms.

Table 3. Crops grown in the 1987 crop season.

Crop	Number of farmers	Proportion of farmers ^a (%)
Maize	65	94.2
Millet	62	89.9
Groundnuts	51	73.4
Sorghum	48	69.6
Cotton	6	8.7
Beans	5	7.2

Source: Compiled by researchers.

^a *N* = 69.

Land preparation and planting

The farming season begins with land preparation in February or March; the slash-and-burn method is used. Seed-bed preparation begins with the onset of rains in April or May and mainly involves ploughing of fields and making ridges. Sometimes mounds are made. Ridging is very important because it permits farmers to take advantage of early rains to do their sowing. Labour shortages are acute, as there are virtually no landless people in the study area and everyone is working on the family farm. Ridging is done with a hoe or with bullock or donkey traction. Hoe ridging is laborious and time consuming, sometimes taking days to complete 1 ha of land. Hoe farmers tend to have smaller farms, and seeding is often delayed. A few hoe farmers are able to hire bullocks or donkeys for ridging, but the demand for these animals is very high during this period because they are labour saving.

About 38% of the farmers own bullocks, and 19% own donkeys (see Table 7). Bullock ploughs are owned by about 23% of the farmers, whereas ridgers are owned by only 16%. For farming operations, two bullocks are needed at a time. This has been found to impede the adoption of bullock-traction technology, as bullocks are expensive, costing, on average, 32 000 GHC each (in 1995, 1175 Ghana cedis [GHC] = 1 United States dollar [USD]), and require more attention. CAP is focusing more attention on the introduction of donkey-traction technology because only one donkey is required for farming operations and donkeys are less expensive (about 11 000 GHC each), require less attention, and are not often stolen.

Seeding is done soon after the ridges have been made. On farms where bullocks are used, women commonly do the sowing while the men and the boys make the ridges. The crops are grown on the ridges, and groundnuts and beans are often planted on the side of the ridges. According to advice from the extension service, spacing of crops should be 90 cm on the ridges, with 40 cm between the ridges. Although many farmers are aware of this advice, they do not take it: those with smaller holdings aim at attaining higher planting densities, and others believe that taking accurate measurements is time consuming.

Input use

Farm inputs are basic and essential to any farm enterprise; without them, no output is possible. Consequently, major efforts aimed at developing efficient and effective technologies to improve farm productivity have focused on high-quality inputs. These efforts have, however, achieved limited success in the case of small-scale farmers, who are often regarded as resistant to change (Sands 1986). Some researchers have attributed small-scale farmers' failure to adopt improved technologies partly to the inadequacy of support systems, such as extension services, credit, and input supplies.

Sands (1986) contended that technology must be evaluated not only in terms of its technical performance under environmental conditions typical of small farms but also in terms of its conformity to the goals and socioeconomic organization of the small-farm system. The second criterion is crucial to the small-scale farmer's adoption of improved technologies, although this criterion is often ignored, or its importance is taken for granted. The proportions of farmers using various types of farm inputs are shown in Table 4. The reasons the nonusers gave for not using them are presented in Table 5.

Table 4. Use of various farm inputs.

Farm input	Number of farmers	Proportion of farmers ^a (%)
Improved seed	12	17.4
Farmyard manure	25	36.2
Compost	5	7.2
Inorganic fertilizer	63	91.3
Pesticide	10	14.5

Source: Calculated by researchers.

^a *N* = 69.

Table 5. Reasons for nonuse of farm inputs.

Reason	Proportion of nonusers (%)				
	Improved seed (<i>n</i> = 57)	Manure (<i>n</i> = 44)	Compost (<i>n</i> = 64)	Fertilizer (<i>n</i> = 6)	Pesticide (<i>n</i> = 59)
Lack of knowledge, skill	5.3	18.2	28.1	—	11.9
Cost	45.6	13.6	—	66.7	30.5
Nonavailability	28.1	40.9	—	16.7	6.8
Lack of credit	38.6	—	—	50.0	23.7
Labour requirement	—	11.4	35.9	—	—
Lack of material	—	—	20.3	—	—
Waste of time	—	—	31.3	—	—

Source: Compiled by researchers.

The farmers mainly use seeds from the previous harvest for planting, or they purchase seeds from local markets. Some of these seeds are improved; however, only 17% of the farmers regularly purchase improved seeds. The main sources of these seeds are MOA, CAP, and LAS. A number of farmers have to travel some distance to purchase seeds and other farm inputs. The popular varieties of improved maize seed are *dobidi*, *Safita 2*, and *Laposts*. Next, sorghum seeds and groundnut varieties, such as *Florispán* and *Manipints*, are commonly purchased. The majority of farmers who

do not purchase improved seeds indicated that they were discouraged by the cost of the seeds and lack of credit to purchase them.

Farm-yard manure and compost are relatively inexpensive ways to add nutrients to the soil and to improve the soil structure. Inorganic fertilizers, on the other hand, are expensive and do not improve soil structure. About 36% of the farmers indicated that they used farm manure regularly, whereas only 7% of the farmers used compost. Farmers who did not use manure regularly indicated that manure is not available nearby and also mentioned the difficulty conveying the manure from the krafs to their plots. However, about 36% of the farmers who did not use compost said that the labour requirement impeded their use of it, and 31% thought that composting was a waste of time.

We found that more than 90% of the farmers use inorganic fertilizers on their plots. The reason for using fertilizers varied, but the farmers were unanimous in their belief that the use of fertilizers results in higher yields. About 41% used fertilizer because they took the advice of the extension service, and one third said they used sulfate of ammonia to combat the parasitic weed *Striga gesnerodites*. *Striga* tends to have devastating effects on cereals and legumes and is very difficult to eradicate. The attempts to eliminate the weed with strong herbicides, like 2,4-D and oxyfluorifen, have not been successful. However, it is known that *striga* does not perform very well on fertile soils, and, according to the farmers, the ammonia fertilizer causes their crops to outgrow the weed, thereby uprooting it. The extension officers, however, do not recommend the use of ammonia on cereals because it stimulates vegetative growth at the expense of grain yield. Until an effective way of combating *striga* is found, it will be difficult to make the farmers change their methods.

Compound fertilizers, such as 15-15-15 and 20-20-0, are the main fertilizers supplied to farmers in the area. Fertilizer recommendations are not based on any detailed soil survey; instead, they appear to be uniform across the region. The Northern Region receives its fertilizer allocation from Accra, and the quantity of it is almost invariably less than the region requires. In addition, fertilizers usually arrive late, mainly as a result of transportation problems. It is, therefore, rationed, and, as a result, the farmers can purchase only suboptimal quantities. With fertilizer recommendations not attuned to the soil nutrient requirements, it is obvious some nutrients are wasted and others are not supplied in adequate quantities.

Pesticides are used by less than 15% of the farmers. The cost of pesticides and lack of credit were the main reasons the other farmers gave for not using them. The farmers buy pesticides from a number of sources: MOA, the various agricultural projects, other farmers, and the market.

The farmers were asked to indicate the year when they adopted certain farm inputs, and the results are shown in Table 6. It is evident that their use of fertilizers began earlier than their use of pesticides. The majority of the farmers began using inputs in 1980-1984, but agricultural production suffered greatly, mainly from drought. In 1984, when weather conditions improved, all resources were used in an attempt to reverse the decreasing trend in agricultural output. As a result of government measures and foreign aid, large quantities of farm inputs were made available in 1984, and farmers were encouraged to use them.

Harvesting and use of crop residues

All members of the farm household harvest the crops and transport the produce. In some cases, carts pulled by donkeys or bullocks are used. The crop residues have various uses. Cereal residues are often burned in the field, and the ash is sprinkled on

Table 6. Adoption of farm inputs.

Period	Seeds		Fertilizer		Pesticide	
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
1970–1974	—	—	3	4.8	—	—
1975–1979	1	8.3	13	20.6	—	—
1980–1984	7	58.3	27	42.9	7	70.0
1985–1988	4	33.3	20	31.7	3	30.0
Total	12	99.9	63	100.0	10	100.0

Source: Compiled by researchers.

the soil. In some cases, cereal residues are used for making compost or are buried in the soil to improve the soil structure. Groundnut and bean residues are commonly fed to animals.

Crop storage and sales

All the farmers stored at least some of their crops at home, although a few stored crops on the farm as well. The crops are stored for varying lengths of time in different types of containers. Crops are stored for 4–6 months, on average, and the storage period rarely goes beyond 10 months. The storage time is influenced by the space available, the quantity of crop output (many farmers do not produce enough to last them throughout the year), sales, and losses to fungus, insects, and pests. Some farmers are forced by short-term cash shortages to sell produce soon after harvest, when prices are low, and purchase food during the dry season, they are very high.

The crop-storage techniques used by the farmers are basically traditional and have not changed much over the years (this is a facet that has been neglected in research). Cereals are commonly stored in homemade straw bins, which last from 3 to 5 months. These bins are usually placed on wooden platforms and are often covered. When the bins are full, they are sealed and cow dung is smeared on the outside to make them waterproof. Groundnuts and beans are often stored in jute bags, but because they are cash crops, they are not often stored for long.

Crop losses during storage are estimated at between 20 and 25%. Much of the damage is caused by insects, especially weevils, rodents, and fungus. All farmers take measures to prevent or reduce storage losses. They dry cereals before storing them, and they use smoke and ash to prevent insect damage. Farmers also use insecticides, such as Actellic™ dust, Adtrex™, Gammalin™ dust, and even dangerous ones like DDT and Carbaryl™. It was disappointing to observe that many farmers bought insecticides from neighbours, as well as from the local market.

Crops are sold in local markets or the markets of neighbouring villages, depending on when the markets convene. The modes of transport to the markets are most inefficient, and, as a result, trading picks up only in the afternoon. On market days, farmers are commonly seen travelling, dangerously, on trucks that have not been designed to convey passengers. Others are seen trekking over long distances. This limits the amount of produce they can send to the market, and the time spent is often at the expense of farming and other activities. At the market, the farmers sell their produce and use the money to purchase things they need for their households and farms, and they return home with scarcely any cash.

Livestock husbandry

Livestock occupies an important position in the farming system and is owned by 62% of the farmers interviewed (Table 7). The livestock numbers are likely understated because farmers are generally apprehensive about revealing the size of their herds.

Table 7. Livestock holdings.

Type	Owners (n)	Livestock numbers (n)	Mean holdings (n)
Cattle (including bullocks)	28	240	8.6
Bullocks	26	57	2.2
Donkeys	13	18	1.4
Sheep	29	140	4.8
Goats	31	152	5.0
Poultry	31	561	18.1
Pigs	9	62	6.9

Source: Formal survey (1988).

Cattle are mainly kept with the Fulani, who are responsible for their upkeep and grazing, and they release the animals to the owners on demand. The cattle are kept in kraals overnight and sent for grazing in the morning. During the dry season, the cattle often trek over long distances in search of good pasture and water. Dry-season feeding of livestock is a problem. The Fulani commonly set fire to large tracts of land to force grass to regrow for the cattle. Agricultural scientists and environmentalists advise against this, but the practice has not abated. A Fulani cattle herder usually keeps livestock for several owners, and the quantity may not encourage good husbandry.

Livestock production in the study area receives inadequate technical support from MOA's Department of Animal Health and Production, which becomes noticeable during outbreaks of livestock disease. But for the past 2 or 3 years, diseases like rinderpest and, more recently, anthrax, have been contained. The farmers often buy drugs and antibiotics from the local market.

Analysis

Technological inadequacies

Any agricultural-technology system has three main parts: (1) production, (2) storage, and (3) sales and marketing. Unfortunately, however, several agricultural-technology systems developed for the Third World concentrate mainly on increased production and neglect storage and sales and marketing. This was characteristic of the agricultural technology developed for northern Ghana. No adequate preparation was made for the storage of surplus output, and marketing facilities were nonexistent.

One can argue that most farmers in the Mamprusi area are aware of the importance of fertilizers and are also ready to use them; however, the quantities of fertilizers sent up north by the central government are inadequate. The high-yielding seeds respond better to fertilizer, and if adequate fertilizer is not applied, less than optimum yields will be achieved. The small quantities of the fertilizer usually arrive late, normally after farmers have tilled their lands and planted their crops. The central government imports fertilizers without consulting with the experts on the types of fertilizer to use. When considering what fertilizer to buy and where to buy it, the

central government is more concerned about prices and conserving foreign exchange.

Storage poses a considerable challenge for farmers in the Mamprusi area. Almost all the farmers use some traditional method for storage, which limits the length of time that the crops can be stored. There is always the pressure to sell off whatever is stored before it goes bad. Under such circumstances, farmers accept low prices for their produce. The Ghana Food Distribution Corporation (GFDC), a state-owned enterprise, is the only government agency set up to buy and store the farmers' produce. The GFDC has the capacity to store 17 500 t, but this capacity is said to be idle because of a contractor's faulty design. In any case, the storage capacity is far from adequate in view of the levels of cereal demand and supply. The GFDC hopes to increase its storage capacity to more than 120 000 t in the second and third phases of its program. Private participation in the purchase and storage of farm produce is virtually nonexistent. A few firms do buy vegetables and fruit for processing, but these firms do not have the production capacities to allow them to buy large quantities.

The farmers can only store produce by drying and bagging it. The bags are then kept in the farmers' bedrooms or in mud silos. Several of these farmers do not apply any insecticides. Those who do apply them buy them indiscriminately, without any advice from the extension service. This is dangerous to the farmer and to the farmer's family, as well as to the consuming public. There are examples of farmers using Gammalin 20 or DDT to both kill rodents and preserve food.

There is a big problem with food marketing in the Mamprusi area. The method for transporting produce to market limits the amount that can be sent. The roads are especially difficult during the rainy season. Even in the dry season, these roads are so bad that not many trucks can use them. For that matter, many farmers walk to market with their produce on their heads. Several of the markets open every third day. They open late but close early to allow the farmers time to walk back to their homes.

Often, farmers' produce is priced very low because of the pressure on the farmers to meet expenses and pay their debts (or the interest on their loans). The pressure to sell may also be due to inadequate storage.

Areas of intervention

The government should intervene in certain areas to ensure the farmers adopt technology. Farmers will not be induced to adopt technology if it just means higher yields, with no ready markets for their produce.

The unimodal rainy season in the region results in inadequate irrigation. During the rainy season, farms are flooded and crops are destroyed. Canals should be constructed to conserve this extra water for future use. Such water-control measures have been ignored by both the government and the development agencies.

Another important issue is that of credit. There is no financial institution in the whole area. The nearest bank is at Bolgatanga, more than 50 km from Walewale; the Agricultural Development Bank at Tamale has an agency at Malerigu, several kilometres away. However, the farmers who took an interest in going to the bank for help were frustrated. In several instances, these farmers made many trips to the agency at Malerigu only to be given loans that were just adequate to pay for their transportation there and back. New technology is expensive if one also takes into account the prices of fertilizers, high-yielding seeds, implements, and so on. Farmers need to raise loans to buy all these inputs. Development agencies in the district should find a way to grant loans to farmers.

The calibre of extension staff leaves much to be desired. Many of the extension staff are unable to explain technological innovations to the farmers.

Moreover, the extension officers, usually referred to as technical officers, have to depend on public transport to do their work. Development agencies should consider buying bicycles and motorbikes for the technical officers. Some in-service training should be provided; some technical officers could also be sent to agricultural schools.

Storage and sales and marketing must be addressed seriously. When these are improved, they will provide incentives for farmers to produce more. As rational entrepreneurs, farmers will respond to market trends. A ready market for their produce will encourage them to produce more. To do so, they will need to adopt appropriate technologies.

Conclusions

On the whole, several agencies are actively involved in the dissemination of technological information to small-scale farmers in the Mamprusi area. The objectives of almost all these agencies overlap. Unfortunately, however, there are examples of the agencies competing, instead of cooperating, to achieve their common goals. This has normally led to duplication of work and, sometimes, confusion for the farmers. LAS and the Adventist Development Relief Agency (ADRA) both operate at Langbensi. LAS was the first to operate in the village, and then ADRA moved in. ADRA used food aid to win some support from the local farming community. It is a mistake for an agency to provide farmers with food when it is trying to help them increase their output — food relief is a disincentive. LAS and ADRA were also doing the same things, and this confused the farmers. (NORRIP is not an executing agency. It only makes plans and invites external organizations to come in to implement those plans. NORRIP is still in the process of trying to execute its own plans.)

The essential ingredients are missing in the technological package introduced to the small-scale farmers. Farmers know of the technologies being developed for them and are ready to adopt them. However, they have many frustrations. They do not get their fertilizers supplied at the right time or in the right quantities, and the prices are too high. With the exception of Global 2000, all the other projects rely on Walewale for their supply of fertilizer. This completely frustrates the projects' operations.

Technology policies for Ghana are not in the hands of the central government. Evidently, therefore, the government has very little to do with the innovation and dissemination of agricultural technology. The control of this is in the hands of several nongovernmental organizations.

Recommendations

The following recommendations are made for implementing and diffusing technology in Ghana:

1. The Government of Ghana should take control of agricultural-technology policies and play a leading role in achieving their objectives.
2. NORRIP should be restructured to coordinate the activities of the development agencies and eliminate duplication in their work.
3. The development agencies should come up with strategies to advance loans to farmers. (These loans could be in the form of cash or agricultural inputs.)
4. Canals should be built to conserve excess water from the heavy rains. (Ultimately, rivers will have to be dammed for irrigation. Agricultural technology of the kind being introduced to farmers in the north cannot rely on the rains.)

5. The development agencies operating in the Mamprusi area should take advantage of the government's new policy on fertilizer imports to import their own fertilizers and other agricultural inputs for farmers in their catchment areas.
6. MOA should team up with the development agencies to solve the marketing and storage problems. (For example, some of these agencies have silos that could be used by the GFDC to store what they have to buy from farmers in the area.)

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CHAPTER 16

The Impact of University Research on Industrial Innovations: Empirical Evidence from Kenya

Mohammed Mwamadzingo

Introduction

Almost all schools of thought in economics agree that industrial innovations provide the main driving force for economic growth and that they contribute to the creation of competition among firms and countries. However, there are many theories to explain the source, rate, and direction of innovation and its effects on economic growth. Two principle theories are the demand-pull theory and the science-push theory. The demand-pull theory emphasizes market forces as the prime determinants of technical progress. The science-push theory defines science and technology (S&T) as a relatively autonomous process leading to industrial innovation.

Many observers have come to the conclusion that there is no real boundary between the two schools. It is argued that both demand pull and science push are required for the success of industrial innovations. A successful innovation needs to take account of the interaction between market needs and the changing S&T environment. The study of the role of innovations in economic growth becomes a study of the interaction between research institutes or universities (the suppliers of scientific information) and the industry (the users of research results).

In Kenya, the mechanism linking universities and research institutions with the productive sector appears to be ineffective, despite numerous efforts. There is widespread concern that the research at universities and scientific institutes in Kenya is not focused on the needs of industry. The research results, therefore, remain largely unused, and this has limited the effectiveness of the S&T infrastructure in Kenya.

Objectives

The aim of this study was threefold:

- to examine the importance of academic research to industrial innovation and industrial growth, with the objective of understanding how research findings are brought into the productive sector;
- to identify the strengths and weaknesses in the links between universities and the productive sector in developing countries, particularly Kenya, with the objective of understanding why research findings are often ignored by industry; and
- to make recommendations for promoting cooperation between academia and industry.

A review of the literature

Academic research and innovations in industrialized countries

The importance of universities in promoting technical change and innovation is widely recognized. This has prompted increasing concern about university–industry linkages, as shown by the ever increasing literature in this area.

Various arguments have been used to justify the growing interest in university–industry interactions (see Stankiewicz 1986). First, industry–university relations have been influenced by short-term economic considerations and today’s cutthroat competition. Because of the global economic recession, many countries have found it imperative to marshal their S&T capacities to improve their competitive position. Because academic research and development (R&D) receives a very large portion of the national research funding in most countries, academic institutions must in turn contribute to development. In addition, the general feeling is that institutions of higher learning are underused resources and that explicit policies are required to effectively incorporate them in the development process.

Second, it is argued that the current interest in university–industry relations has been caused by “conjectural considerations” and this relationship is merely a stage in the innovation process. Stankiewicz (1985) argued that this stage may have started a long time ago, but its impact only began to be felt recently. This stage of the innovation process is characterized by the interaction and interdependence of many new technologies, such as information technology, new materials, and biotechnology. These new technologies require high degrees of academic interaction in basic research and call for cooperation among people in diverse fields, with highly specialized S&T backgrounds.

The role of universities and other institutions of higher learning in the innovation process is natural because of their multidisciplinary nature, their competence in undertaking basic research, their reservoirs of knowledge and information, and their ability to recruit young talent. Therefore, the university should be incorporated in the national-development planning process.

For the universities to be effective in stimulating innovation and industrial growth, they must cooperate with industry. But, unfortunately, this is not always the case in developing countries. The universities in the Third World are normally concerned with their own internal, urgent problems of staffing, finance, and expansion. On the other hand, industry is preoccupied with its own problems, such as lack of adequate markets, institutional rigidities, and inefficient and inadequate infrastructures, and is usually unaware that the professors might have plausible solutions to its problems. To bridge this gap in communication, effective linkage between industry and university should be established.

Project HINDSIGHT (Sherwin and Isenson 1967) was one of the pioneering studies to quantitatively assess the effects of R&D inputs to technical innovation. The study identified 710 “research events” (important discoveries or breakthroughs) that made possible successful development of weapons systems. These research events were identified as “science events” or “technology events,” depending on the original intention of the research. Science events include mathematical and theoretical studies dealing with natural phenomena, “experimental validation of theory and accumulation of data concerning natural phenomena,” or a combination of these two. Technology events include the development of new materials, “conception and/or demonstration of the capability to perform a scientific elementary function, using new or untried concepts, principles, techniques, materials, etc.” Sherwin and Isenson concluded that only 9% of the 710 research events deemed essential to the development of the

weapons systems took place at universities.

Project TRACES (IITRI 1968) was also one of the first systematic studies of the role of research in the innovation process. Table 1 presents the distribution of performers of key events documented by IITRI. The table shows that only 7% of the applied research (development and application) emanated from academic institutions.

Table 1. Distribution of research performers in project TRACES.

Research component	Universities and colleges (%)	Research institutes and government laboratories (%)	Industry (%)
Nonmission research	76	14	10
Mission-oriented research	31	15	54
Development and application	7	10	83

Source: IITRI (1968).

Langrish et al. (1972) showed that out of 158 key technical ideas used in innovations, 56 (35%) originated at firms, and of the remaining 102 (65%), 7 came from a British university and 17 came from a British government laboratory. To determine the relative contribution of university research in organic chemistry and the use of this research by industrial researchers, Langrish (1974) examined seven review articles in the *Journal of the Society of Chemical Industry, London*. The review articles contained 567 references to other articles or patents. The institutional origins of 396 of these were then identified, and only 23 (6%) were traced to the work of British universities (Table 2). Of those articles, seven stated that some industrial finance supported the research. British government institutions seemed to be of more interest to the industrial reviewers, as 45 (11%) of the references cited were articles written in such institutions.

Table 2. Institutional origins of literature cited in British industrial research.

	Industry (%)		University (%)		Government (%)	
	British	Foreign	British	Foreign	British	Foreign
102 ideas	22	40	7	3	19	9
396 references	10	40	6	21	11	19
452 abstracts	19	68	1	5	1	6

Source: Langrish (1974, table 1).

The Langrish (1974) study also showed that there had been a marked change in the main institutional sources of abstracts, from universities in Europe (particularly German universities) at the end of the 19th century to American industry during the latter half of 20th century. This also confirmed that British university research has little impact on British industry.

Langrish (1974) proposed two explanations for the decline in importance of university research: (1) Industry has increased its research activities. (2) A new branch of science is useful to industry only in the early stages — the relationship between university research and industry may be a function of the maturity of the discipline. Once a new discipline has been established, the aim of science is to understand it, and the aim of technology is to make it work, but industry has been very successful at making things work without too much reliance on understanding.

The decline in the impact of British university research was also explained by Rothwell (1985, p. 7):

In certain areas of science the role of universities is to make the initial fundamental breakthrough, followed by many years of basic research to understand the nature of the process; the role of industry is commercially to utilize the breakthrough, concentrating on understanding and harnessing its effects while being largely unaware of their causes. Given the very rapid growth in industrial R&D capability, industry would largely be unable either to utilise the potential of the breakthrough or progressively to enhance this potential. Industry has thus needed increasingly to take over the relevant fields of research itself. At the same time the universities have gone on to open up new fields of research, paving the way for the next generation of industrial applications.

The British Universities and Industry Joint Committee (see CBI 1970) looked at the ways companies use university R&D by size of company. On all the measures of contact between industry and universities, there was a marked pattern: the small firms had by far the fewest contacts. Moreover, out of 403 firms employing fewer than 200 people (out of a total of 1097 firms), 75% had little or no contact with universities, whereas out of 96 firms with more than 5000 employees, only 9% had little or no contact with universities. A correlation analysis of the data revealed that having a higher proportion of scientists in its senior management increased the likelihood of a smaller firm's having contacts with universities. Further analysis showed that nearly one quarter of the firms approached universities for technical advice, and just under one third of them approached research associations. Companies used universities mainly for the specialists' advice or experimental facilities. The general impression given by the analysis was that most companies did not regard universities as a major source of technical advice, except when the universities could offer specialized knowledge or expertise.

The Science Policy Research Unit (SPRU) databank of important British innovations introduced since 1945 has shown that universities and research associations have provided major initiating knowledge in a (combined) average of 4.7% of 2293 innovations in 1945–1980, as shown in Table 3. Both universities and research associations have decreased in importance as sources of innovation, whereas the contributions of governments and individuals have fluctuated. The databank also yielded information on the level of university input to firms of different sizes: on average, small firms used the universities less than their larger counterparts did.

In contrast, Gibbons and Johnston (1974) suggested that British university research has made a significant and direct contribution to industrial R&D. They investigated the role of scientific information in the resolution of technical problems arising during the course of an industrial innovation and revealed that of 887 inputs of information, 34% were from outside the firms. The study showed that, of the information inputs obtained from outside the firm, the major science sources (accounting for 36% of the inputs) were scientific journals and scientists at universities, whereas the major technology sources were trade literature and companies supplying material or equipment. Contact with scientists from outside the firms

(usually in universities or government research establishments) furnished the firms with very useful information on the theories and properties of materials. Moreover, the scientists also provided direct contributions to industrial R&D, such as suggesting alternative designs or providing the location of specific information or specialized facilities and services of direct relevance to the problem at hand (Gibbons and Johnston 1974).

Table 3. Sources of major knowledge inputs to innovations.

Source	1945–1959	1960–1969	1970–1980	Average
In-house (%)	63.7	69.3	77.0	70.0
University (%)	2.8	1.6	1.6	2.0
Government (%)	5.0	6.7	7.5	6.4
Research association (%)	3.6	2.8	1.7	2.7
Related industry (%)	14.3	11.9	13.2	13.1
Unrelated industry (%)	8.6	10.4	5.5	8.2
Individual (%)	1.5	0.6	2.6	1.6
Parent company (%)	14.0	12.2	9.1	11.8
Interactions (<i>n</i>)	559	872	862	2293

Source: Townsend et al. (1981, table 6.1).

Note: Columns add up to more than 100% because some innovations were attributed to more than one source.

Other contacts with universities included occasional direct employment of academics as consultants and the provision of funding for research relevant to a company interest. In some cases, a university scientist acted as a sort of “gatekeeper,” “translating” information from scientific journals to make it meaningful to the problem solver. University-educated personnel in a firm were also able to contribute substantially to problem solving as a result of their greater access to scientific information sources, such as journals and their acquaintances at universities.

Gibbons and Johnston (1974) concluded from their analysis of information flows that the interactions of basic applied in-house and external research are so complex that it is not easy to establish normative criteria for the optimal allocation of government funding to research. These researchers also concluded that the basic research infrastructure at universities and government installations contributes to commercial innovation in more ways than simply providing the private firm with exploitable scientific discoveries.

Mansfield (1991) estimated the extent to which technological innovations in various industries were based on “recent” academic research (i.e., ≤15 years old) and estimated the lag between the investment in those research projects and the industrial use of their findings. The study considered a random sample of 76 major American firms in seven manufacturing industries: information processing, electrical equipment, chemicals, instruments, drugs, metals, and oil. Mansfield came up with interesting results. He found that about 11% of the firms’ new products and about 9% of their new processes could not have been developed without substantial delay without recent academic research. He also identified interindustry differences: the percentages of new products and processes stemming from recent academic research was highest in the drug industry, “which has an obvious interest in the large amount of medical, biological, and pharmaceutical research carried out at universities,” and it was lowest in the oil industry (p. 3). These interindustry differences were accounted for by differences in R&D intensity among firms. He found, on average, a 7 year lag

between the conclusion of the academic research and the commercial introduction of the research-based innovation, but the lag tended to be longer for large firms than for small firms. Finally, Mansfield estimated that the social rate of return from academic research in 1975–1978 was 28% by comparing (p. 6)

the stream of social benefits if investment in academic research takes place with what it would have been without this investment, holding constant the amount invested in nonacademic research. In other words, what would happen if the resources devoted to academic research were withdrawn—and not allowed to do the same or similar work elsewhere.

Rosenberg (1992, p. 382) argued that American universities play an important role in the development of scientific instruments:

A central part of the “output” of university research enterprise has been much more than just new theories explaining some aspect of the structure of the universe or additional data confirming or modifying existing theories. An additional output (or by-product) has been more powerful and more versatile techniques of instrumentation including, in many cases, an ability to observe or measure phenomena that were previously not observable or measurable at all.

In most of the studies reviewed here, industrial sources accounted for the largest single, external source of S&T innovation, although the actual proportions varied somewhat, from 26% in the Gibbons and Johnston (1974) study, to 82% in the Townsend et al. SPRU study. Universities reportedly provide around 20% of the externally sources of inputs, according to the SAPHO study (SPRU 1972); 10%, according to the Langrish (1974) and Gibbons and Johnston studies; and only 5%, according to the Bolton Committee of Inquiry on Small Firms (Freeman 1971).

Together, these studies tell us a great deal about the contribution of academic research to industrial innovation and about the direct and indirect channels through which information from this research enters the innovating organizations. Unfortunately, the same cannot be said of developing countries, as the following section will explain.

Academic research and innovations in developing countries

Universities and public research establishments are among the most important scientific institutions in most countries, including Third World countries. Universities usually account for a significant proportion of national research expenditures, a large share of the scientists engaged in R&D, and the bulk of a nation’s production of S&T research. Unfortunately, despite all this, the contribution of public R&D institutions in developing countries is negligible, and studies on the role of universities and research institutes in industrial technological change in developing countries are scarce.

Industrialized countries and developing countries are faced with completely different environments: both skilled labour and capital are in short supply in the Third World. Studies of the innovation process (reviewed above) show that demand-pull and science-push factors tend to influence technical change. But in developing countries, according to Utterback (1975, p. 667), “most users do not have the expertise to define and clearly communicate their needs or problems in such a way that technical expertise can be brought immediately to bear upon them.” The problem has persisted for quite some time. As Nayudama (1967, p. 323) commented, the results of research from universities and other institutes in developing countries “flow rather slowly, irregularly, and inefficiently . . . [and] even this scant flow seldom reaches as far as industrial use, and very often there is no flow at all.”

Various factors that created and have sustained the problem have been

suggested. For instance, Crane (1977) and Zilinskas (1993) attributed the gap to the absence of indigenous technological innovation, which, in turn, is caused by the lack of demand for such innovations and by obsolete but tenacious legal and social barriers. Subsidiaries of multinational companies (MNCs) in the developing countries have not contributed to domestic research because the MNCs perform almost all their research in their own countries. Crane (1977) also mentioned that few local firms are motivated to undertake research to develop innovative technology because (1) they operate under monopolistic conditions; (2) their managers lack scientific knowledge and therefore are incapable of using it effectively in their operations; (3) they are too small to use technology effectively; or (4) they operate with many assembly plants and turnkey projects that literally do not need any locally produced technology.

The studies in the previous section showed that most of the ideas successfully developed and implemented by firms in developed countries originate outside the firms. One would expect that obtaining up-to-date information would be difficult for research institutions in the Third World because of their overreliance on existing technology and information, their scarcity of resources and professional personnel, and their isolation from the international scientific community (Utterback 1975).

The lack of an effective link between S&T research institutions and the productive sectors in developing countries has been noticed by the larger international community and has resulted in various programs of action. An awareness of the importance and complexity of the problem led the United Nations Industrial Development Organization (UNIDO) to organize an expert group meeting on industry-university linkage. The emphasis of the meeting, held in Vienna in 1973 (UNIDO 1974), was action to be taken by bilateral and multilateral agencies.

Further attempts by the United Nations (UN) include the 1979 Vienna Programme of Action on Science and Technology for Development, which showed that the development of strong linkages between producers and users of R&D is one of the challenges facing developing countries in the reinforcement of their S&T capabilities (Nichols 1984).

In 1983, the Lima Panel, under the UN's auspices, called for the formation of a network of institutions (including R&D and educational institutions, consulting and engineering firms, private companies, and public enterprises) to apply the classical demand-pull and supply-push theories in the developing countries like they are applied in the developed countries.

Other meetings organized under the auspices of UNIDO included the Regional UNIDO-ESCAP Workshop and National Consultations on the Commercialization of Research Results, held in Bangkok, Thailand, in 1984; and the Ad-hoc Expert Group Meeting on Co-operation among Universities, Industrial Research Organizations and the Role of UNIDO in this Co-operation, held in Vienna, Austria, in 1976.

However, despite these and many other efforts, the developing countries have largely remained, as Clark and Parthasarathi (1982) wrote, on the "techno-economic periphery." This feeling of the futility of these efforts was also realized much earlier on in the 1970s, when it was decided that what needs to be done to understand why underdevelopment has persisted in developing countries is to carry out policy-oriented empirical studies. On this note, Cooper (1974, p. 59) specifically commented that

it seems to me that we have reached a point in the analysis of science and underdevelopment where there is little to be gained by making endless logical refinements to the kind of very general hypothetical framework The only way to further our understanding of the problems is to push ahead with empirical studies.

Various empirical studies have been commissioned by the UN Conference on

Trade and Development (UNCTAD) to assess the contribution of R&D institutes to technological innovation in Senegal (UNCTAD 1988a) and Sri Lanka (UNCTAD 1988b). The general conclusion drawn by the Senegal and Sri Lanka studies was similar to that drawn by a later study on R&D institutes in other developing countries (UNCTAD 1990a, p. iii):

The overall output efficiency is unsatisfactory compared to the allocated financial and human resources. On the other hand, even in the cases where the R&D institutes have succeeded in building up specialised technological capabilities or where they have produced improved or new products and processes, they have little impact on the productive sectors because many of the R&D results have not been used industrially.

The Senegal study (UNCTAD 1988a), which focused on the food industry, found that the research institutions achieved significant results, but their results had very limited application in the productive sector. The main bottlenecks were identified: "the structure of the research institutes, the attitude of those in control of the agri-food system [the enterprises] and the role of the authorities." The argument was that the research institutes were not structurally equipped to efficiently disseminate information about their research results. There did not appear to be an adequate infrastructure to provide the industrial entrepreneurs with the technical and financial information needed to apply the research results on a commercial scale.

The same conclusions were drawn in the study of R&D institutes in Sri Lanka (UNCTAD 1988b). The lack of linkage between the R&D institutes and the productive sector was attributed to the lack of communication between the institutes and the potential users, the inappropriateness of institutes' output for domestic technological needs, and the inadequate arrangements for the implementation of research results. Other independent surveys that have reached similar conclusions include those of Collinson (1991), Ehikhamenor (1988), and Eisemon and Davis (1992).

The role of academic research in industrial innovation: empirical evidence from Kenya

Kenya like most other developing countries, has assigned industrial programs a central role in its efforts to create economic growth and increase the pace of industrialization with S&T (Odhiambo and Isuon 1989). Many S&T institutions have been established, often at a great cost. Unfortunately, most of these institutions work in isolation, without effective linkages with the productive sector. There is, thus, a need for a greater understanding of the factors that could lead to improved interactions between scientific research institutions and industry and to the enhancement of Kenya's industrialization process.

Government policy statements on industrial research relationships

Probably the earliest attempts by the government to coordinate industry–research interactions can be traced back to the late 1960s. According to the National Development Plan, 1970–1974, the government was proposing to establish a national council for scientific research. This council was to have (para. 10.62) an "industrial research committee which will meet regularly to discuss, assess, and co-ordinate industrial research projects. It will also identify and select new projects and recommend them for implementation."

However, since the proposed council did not take off until later in the 1970s, no overall body oversaw the implementation of research results. The government's participation in the R&D in the manufacturing sector was restricted to the activities

of the Industrial Survey and Promotion Centre of the Ministry of Commerce and Industry, the East African Industrial Research Organization, the Department of Design and Development of the Faculty of Engineering of the University of Nairobi, the Kenya Polytechnic, and the Kenya Industrial Estates Technical Service Centre.

All the subsequent development plans simply set aside a single paragraph to state the government's intentions to coordinate industrial research activities. For instance, the National Development Plan, 1979–1983, commented (para. 7.55) that

the Kenyan institutional base for industrial research will be strengthened, particularly in regard to development of appropriate technologies for processing indigenous materials. Programmes at KIRDI (Kenya Industrial Research and Development Institute), Industrial Survey and Promotion Centre and the IRCU (Industrial Research and Consultancy Unit of the University of Nairobi) will be expanded, carefully interrelated and, where appropriate, coordinated with development activities in agriculture, forestry and other sectors.

However, the next two national development plans (1984–1988 and 1989–1993) seemed to make specific policy statements regarding industrial research. The 1984–1988 plan put it more clearly, saying (para. 6.60) that

Efforts will be directed to the development of appropriate technologies by assisting institutions including schools which indicate an ability for innovation, improvisation and inventiveness. Some of the funds of NCST will be used for this purpose.

It is clear from the National Development Plan, 1984–1988, that National Council for Science and Technology (NCST) was to coordinate industrial research institutions (including universities) and the transfer of the S&T research findings to the productive sector. The mode of coordinating was further fine tuned in the 6th National Development Plan, 1989–1993 (Government of Kenya 1989), which specifically associated (para. 5.62) the establishment of the Kenya National Scientific and Documentation Centre (KENSIDOC) at NCST with the need to implement Kenya's S&T research findings for social and economic development. The plan lists the medium-range objectives of KENSIDOC as follows:

- to put appropriate tools for the identification of sources at the disposal of planners, research workers and technologists (information referral services);
- to provide information on research institutions, on-going programs and projects, and research scientists in various disciplines;
- to disseminate results of research obtained in Kenya or those about Kenya obtained by local or foreign researchers; and
- to strengthen information sources in priority scientific areas (such as agricultural, industrial, health, and development planning) identified in national development plans and strategies.

NCST and KENSIDOC have not had noticeable impacts on the linkage of scientific research and local industry. Expenditures of NCST are very low, and those of KENSIDOC are even lower. For instance, in 1990/91, KENSIDOC spent only 700 000 KES (in 1995, 59–62 Kenyan shillings [KES] = 1 United States dollar [USD]). Between 1987 and 1990, NCST spent 5–11% of the total development expenditure on KENSIDOC, basically refurbishing the library and purchasing personal computers. Because of severe financial constraints, there were no development expenditures in 1991/92. But between 1992 and 1995, the council should have spent an annual average of 129 000 KES on KENSIDOC. Moreover, the situation seems even worse when you visit NCST offices in Nairobi. Its national documentation centre is virtually nonexistent. The creation of the centre was actually just a mere change of the

inscription on the door leading to the existing library.

The Kenyan government's latest statements regarding the development of industry–research relationships are given in the Ndegwa report (Republic of Kenya 1991). The report points out that (para. 8.47) even at “present Kenya does not possess a comprehensive technology policy but improving dissemination and use of appropriate technology are of great importance for the long-term future of the informal and small scale industries.” Some of the specific recommendations contained in the report are the following:

1. KIRDI should be restructured so that it assumes additional responsibilities for modifying existing technologies and adapting those being imported.
2. Research institutions should have greater autonomy so that they can manage their own affairs independently, free from dependence on government administrative and budgetary routines.
3. The Ministry of Research, Science and Technology should develop guidelines for technology development, transfer, and use, stressing the importance of interaction between researchers and those who apply the results in their own businesses.
4. Universities should be encouraged to do even more to attract funds from the private sector, either as donations or as payments for research or other services.

Since the submission of the report to the government nothing has been said about how the objectives will be achieved. The report may end up as a mere reference document, which is what happened to the reports of many earlier commissions.

Another way of looking for official strategies for industry–research relationships is to review speeches and recommendations given by high-ranking government officials at conferences, workshops, and seminars. One of the earliest discussions of linkages of research institutions and industry in Kenya may have been the 1972 conference on “the Coordination of Production, Dissemination and Utilisation of Social Science Research Findings,” organized under the auspices of the Institute for Development Studies, University of Nairobi (Barnes 1972). The conference explored the supposition that the application of research in Kenya is characterized by severe lack of communication among of various sectors of the economy.

This conference gave rise to another one in 1973, “In Search of a System for the Dissemination of Research Findings and Technology in Kenya” (Burke 1973). As at the earlier conference, the general feeling of the participants was that the problem was not so much the absence of dissemination machinery as a lack of coordination of organizations. There are many independent bodies in the country, but most of them work in isolation, often unaware of each other's existence. This sentiment can be summed up by a quotation from a speech given in the opening address (Burke 1973) by the Minister of Finance and Planning, Mwai Kibaki:

We who deal with planning are all too aware that we do not make full use of the available information and knowledge in this country. We are aware of the gaps existing in the plans we publish . . . and we are aware that there are people in the country who know what should be done, but because of the system existing in Kenya they have no short cut to inform those who are taking the decision The channels of communication are not as efficient as they should be.

The next step toward the recognition of the importance of linking national industrial research activities with the productive sector was the organization of a symposium in 1981 by the Industrial Sciences Advisory Research Committee. Like

the earlier 1972 and 1973 conferences, the 1981 symposium came to the conclusion that there was a lack of adequate procedures for disseminating and exchanging information about R&D activities in the country. It was suggested that the existing institutions be examined to improve the research interface with the local private sector. The government volunteered that it was ready to "risk" some money for the implementation of R&D results. It was also recommended that an investment promotion centre be established and that its activities include these functions.

Yet another seminar, "The Role of R&D Institutes in the Development of Kenyan Industry," was held in Nairobi in 1987. The main objectives were (1) to review R&D institutes' functions in developing the public and private sectors; (2) to provide an opportunity for local industrialists to interact and to discuss research programs; (3) to examine the government's policy on the development of industry and the use of local resources; and (4) to provide an open forum for industrialists and researchers to deliberate on the mechanisms of cooperation among themselves.

One outcome of this seminar may have been the formation of the National Research and Development Committee (NIREDCO), whose secretariat is at KIRDI. The committee enjoyed the top-level representation of institutions and drew up programs to bring about interaction and cooperation among research, industry, government, implementing agencies, and financiers of industrial projects. NIREDCO has not actually lived up to its expectations and has not been effective in linking research and its industrial application. Another outcome of the 1987 seminar was the establishment at KIRDI and NCST of industrial databanks to be used for determining high-priority national industrial programs. So far, none of these databanks has had any profound effect on industry-research interactions in Kenya.

The latest attempt to bridge the gap in industry-research collaboration in Kenya was the 1989 conference on "Cooperation between the Private Sector, Public Research Institutes and Universities in Research, Innovation and Diffusion of Technologies," which examined ways the private sector can be promoted using local R&D potential (Makau and Oduwo 1989).

Probably the strongest statement on research collaboration was contained in an NCST (1990) report, which commented (para. 4.2.3) that

Academic and Research Institutions are never ends in themselves. They have reason to exist only as they meet the demands of existing firms or serve as toll for technology policy development and propagation. Hence their creation, objectives, structure and programmes must be measured against their ability to make these ends Institutions have been created without sufficient consideration of what their role should be in carrying out adopted policy. These institutions, as well as their programmes and activities, have been established without sufficient thought as to whether they are in accord with overall national industrial policy.

The university administration's view on collaborative research

Just like the government, the University of Nairobi does not seem to have any explicit policy regarding its association with local industries. Many of its consultancy units were established at the university as a result of influence from outside the university, mostly from the UN bodies, with the university acting merely as an implementing organ on behalf of the government.

I was unable to obtain formal documentation or consult with liaison offices about the university's efforts to establish industry-research interactions and so decided that the only way to obtain the views of the university administration was to search for statements given in speeches delivered at official functions, such as seminars and

workshops at the departments and in the faculties of the university. Such statements could not constitute the official policy of the university, but they are an indication of the thinking of those in charge of policy at the university. One of the earliest views on the concept of university–industry interaction was expressed in a 1984 report of a subcommittee set up to evaluate the performance of the Industrial Research and Consultancy Unit of the Faculty of Engineering and the Faculty Projects Office of the Faculty of Architecture, Design and Development (de Sousa et al. 1984). According to its report, the team interviewed Vice-Chancellor Philip Mbithi, who expressed the feeling that, though the university was willing and able to participate in industrial interactions with the local productive sector, such efforts would be more encouraged if the specific projects came from the public sector. However, no recommendations were given on how such interactions could be promoted.

Mbithi also spoke at the Department of Chemistry's seminar, "University–Industry Co-operation in Chemistry," in 1986. His devotion to the topic was evident (UNESCO and University of Nairobi 1986, pp. 33, 36):

I have been invited to open many functions before, but there is none that gives me greater pleasure than the duty I have been requested to perform this morning. The joint workshops and seminars on university–industry interaction you are attending today are the first of their kind in the African region We in the University of Nairobi are willing to explore such joint ventures in the interests of overall national development, as part of our contribution to the national technical effort.

The only other forum for the university administration to air its perception of industry–research interactions has been during seminars and short courses organized by the UN Educational, Scientific and Cultural Organization (UNESCO) Pilot Project on Engineering Education–Industry Co-operation. There was no further official documentation to show the place of industry–research interactions at the central-administrative level. Several interviews with the vice-chancellor and deputy vice-chancellor (in charge of administration and finance) revealed that the administration was well aware of the lack of policies to govern such activities. They knew that the existing mechanisms were not operational, but they had not investigated the issue thoroughly enough to understand the pitfalls and how to rectify them. The administration was more concerned about the more urgent problems facing the university, such as the ever-increasing student population, declining levels of education, and severe financial constraints affecting the staff morale and depleting the already limited and outdated university infrastructure.

R&D at the University of Nairobi

From my search of official statements and the interviews with high-ranking officials, it was clear that there was no specific or definite policy mechanism to guide the university in its interaction with local industries. My next step was to inquire about the activities of the individual faculties, departments, and consultancy units at the university, with the aim of describing what was going on independently of support from the university administration.

This study examined the industrial research activities of 13 departments in four S&T faculties at the University of Nairobi and 1 department at Kenyatta University. Table 4 lists these departments and the corresponding number of staff engaged in industrial collaboration. The table shows that only 5 (35.7%) of the 14 departments studied had established formal mechanisms for industrial cooperation: the Industrial Research Consultancy Unit (IRCU), the Faculty Projects Office, and the departments

Table 4. Selected industrial R&D activities at University of Nairobi and Kenyatta University.

Faculty or department	Formal mechanisms for industrial collaboration	Total staff (n)	Staff involved in industrial collaboration (n)	Staff interviewed (n)
<i>University of Nairobi</i>				
Central administration				
University-Industry Links Committee	No	8	8	6
Faculty of Engineering				
Industrial Research and Consultancy Unit	Yes	2	2	2
Mechanical Engineering	Yes	25	9	6
Civil Engineering	No	30	4	1
Electrical and Electronics Engineering	No	28	5	2
Faculty of Science				
Chemistry	Yes	24	4	1
Microbiological Resources Centre	No	16	0	2
Biochemistry	Yes	28	2	1
Institute of Computer Science	No	15	3	1
Glass Blowing Unit, Science Workshops	No	2	1	1
Faculty of Architecture, Design and Development				
Housing and Building Research Institute	No	11	2	2
Faculty Projects Office	Yes	1	1	1
Faculty of Agriculture				
Food Technology and Nutrition	No	16	3	2
<i>Kenyatta University</i>				
Appropriate Technology Centre	No	9	1	1
Total (Yes = 5; No = 9)		215	45	29

Source: Field survey, 1991/92.

of Mechanical Engineering, Chemistry, and Biochemistry. The formal industrial interactions undertaken by three of these (IRCU, Chemistry, and Mechanical Engineering) were actually initiated by UN agencies, particularly UNIDO and UNESCO.

Table 4 also shows that 20% of the staff in the selected departments were involved in industry–research interactions, but this proportion is actually an overestimation — the departments were surveyed because they had the highest concentration of such interactions. Some departments not surveyed that may have links with local industries include the Centre for Nuclear Science Technology and the departments of Physics, Agricultural Engineering, Geology, Soil Science, and Crop Science. Some of the staff who were supposed to be involved in the interactions were merely listed by the chairs of departments interviewed, not necessarily fully committed to the idea. This could be deduced from the fact that only 29 of the 45 members of staff who were supposed to be involved in industrial collaboration were willing to be interviewed. In addition, only 11 of the ones interviewed were carrying out industrial projects on behalf of their departments, whereas the others were undertaking such projects in their individual capacities.

At the level of the central administration there was the University–Industry Links Committee, which was set up in 1986 after much pestering by the Kenya Association of Manufacturers. This committee could not be sustained beyond the level of specifying its own objectives because of what some members referred to as “problems of self-ego.” Most of the members at the committee were high-ranking staff at the university, who could not find the time to attend even a few meetings. The committee was somehow “hijacked” by some members to advance their own opportunities to obtain consultancy contracts. The committee was also reluctant to seek the views of the very beneficiaries and initiators of the mechanism — the industry.

A review of the research going on in the faculties and departments showed that the university does have the expertise and technological know-how to offer a wide range of services and to generate improved products and processes. This is confirmed by several technologically successful consultancy projects and the generally high inventive activity of the individual members of staff. Some of the notable R&D undertaken at the university includes laboratory services in water, soil, and structural engineering; professional services in the treatment of fresh and waste water; work on foundations for roads; and the designs for engineering services, mechanical plants, and a prototype industrial oven. Other areas worth noting include foundry technology, chemical engineering (specifically health care and food production), architectural and design work, environmental science, low-cost building technologies, and legume inoculants.

Despite the potential, very few interactions have occurred because of the lack of incentives to participate in industrial projects, rigidities in the managerial and institutional structures of the individual research units, and inadequate and obsolete research facilities. In the productive sector, there is the problem of a lack of awareness of what the university has to offer local entrepreneurs.

Characteristics of industry–research interactions

To measure the extent of collaborations resulting from an industry–research interface, it is important to identify successful and unsuccessful linkages and the benefits and impediments connected with such collaborations. I found it difficult to compare the levels of success or failure of linkages and the resulting impacts on the collaborating partner because the collaborative projects were dissimilar, reflecting differences in organizations, personalities, disciplines, institutional and economic contexts, and stages of development and operation. The measurement of success was also affected by the method of interaction (formal or informal) and by the modes of interaction, that is, the modes of industrial financial support for research (donations, transfers, and

exchanges and sharing of staff, equipment, and information).

For the sake of simplicity, we assumed that successful interactions were those that both parties were pleased with. However, this does not imply that there was a net financial gain in the exercise. Unsuccessful programs were those that failed to bring about or sustain institutional interaction, despite various efforts to do so.

Description of successful linkages

From an in-depth investigation of 22 organizations, I found a total of 48 interactions (Table 5), giving an average of just more than 2 interactions per organization. It should again be stressed that the current study was not aimed at comprehensively identifying the interactions at the university, and this was due to the limited time and financial resources, as well as the obvious difficulties in identifying less formal interactions, which were prevalent.

Table 5. Success and failure of interactive mechanisms.

Type of interaction	University of Nairobi		Total
	Successful	Unsuccessful	
Knowledge transfer (<i>n</i>) ^a	19	6	25
Technology transfer (<i>n</i>) ^b	8	3	11
Research support (<i>n</i>) ^c	3	3	6
General cooperation (<i>n</i>) ^d	1	5	6
Total (<i>n</i>)	31	17	48
Total (%)	65	35	100

Source: Field survey, 1991/92.

^a Attendance at (and, in the case of one of the parties, the organization of) seminars and workshops for the purpose of exchanging information and ideas.

^b Interactions structured with a view to integrating technological results from the university or research institutes into private-sector programs or commercial products.

^c Industrial contributions to the interactive process (gifts, money, equipment, etc.) in support of research excellence at institutes, not necessarily with the aim of strengthening research ties.

^d Linkages that require some degree of cooperative planning with the aim of establishing formal research consortia for the benefit of the entire industrial and scientific community.

For the study, interactions could include financial support of research (donations, transfers, and exchanges and sharing of personnel, equipment, and information). I did not take any account of the duration of an interaction; that is, an interaction between a research institute and industry could have occurred for a couple of minutes or for several years. An interaction could be as simple as a discussion imparting information or could be as elaborate as a formal venture, with a contract.

Table 5 shows that the rate of success (simply taken as the proportion of successful interactions) was impressive (31 of 48, or 64.6 %). The high rate of success for the interactions was mainly attributable to the large number of knowledge-transfer mechanisms at the University of Nairobi. Table 5 also clearly shows only half of the interactions involving research-support mechanisms were successful. However, the university has a good rate of success with interacting involving its technology-transfer mechanisms. The most problematic mechanism was general cooperation: only one interaction out of six was successful.

Table 6 gives more specific information on successful interactions at the

Table 6. Description of successful interactions at the University of Nairobi.

Description of project	Department or unit	Company (category) ^a
<i>Research-support mechanisms</i>		
Kenya car project	Central administration	Kenya Railways Corp. (PP)
Joint supervision of PhD student and provision of laboratory facilities, etc.	Food Technology and Nutrition	Unga Ltd (MSE)
Student project on standardization of sand for use in cement manufacture	Civil Engineering	Bamburi Portland Cement Co. Ltd (MNC)
<i>Knowledge-transfer mechanisms</i>		
Engineering education seminars and short courses	Mechanical Engineering	Kenya Railways Corp. (PP) Kenya Bureau of Standards (PP) Firestone East Africa (1969) Ltd (MNC) General Motors (K) Ltd (MNC) Kenya Assn of Manufacturers (NGO)
Materials testing and consultancy	Mechanical Engineering	Kenya Railways Corp. (PP) Kenya Bureau of Standards (PP) General Motors (K) Ltd (MNC)
Background studies of the water sector	Industrial Research and Consultancy Unit	National Water Construction and Water Corp. (PP)
University-Industry Co-operative Workshop in Chemistry	Chemistry	Dawa Pharmaceuticals Ltd (MNC) Firestone East Africa Ltd (MNC) CPC Industrial Products (FF) East Africa Industries Ltd (MNC) Bamburi Portland Cement Co. Ltd (MNC) Kenya Breweries Ltd (LSE) Magadi Soda Plc (MNC)
Promotion and dissemination of low-cost building technologies	Housing and Building Research Institute	Makiga Engineering Works (ISE)
Student attachment	Chemistry	Kenya Breweries Ltd (LSE)
Staff exchange	Mechanical Engineering	Kenya Bureau of Standards (PP)
<i>Technology-transfer mechanisms</i>		
Small-scale processing of cultured-milk products	Food Technology and Nutrition	Technoserve (NGO)
Engineering design, fabrication, and installation of drug-packaging equipment	Mechanical Engineering ^b	Sterling Products (MNC)

Table 6 (concluded).

Description of project	Department or unit	Company (category) ^a
Chemical formulation for the manufacture of liquid foliar fertilizer	Chemistry ^b	Nova Chemicals Ltd (SSE)
Engineering, design, fabrication, and installation of machinery for the manufacture of liquid foliar fertilizer	Mechanical Engineering ^b	Nova Chemicals Ltd (SSE)
Fabrication and testing of low-cost building technologies	Housing and Building Research Institute	Makiga Engineering Works (ISE)
Engineering consultancy on material testing and localization of motor vehicle parts	Mechanical Engineering ^b	General Motors (K) Ltd (MNC)
Engineering design, fabrication, and installation of bar-soap-making machinery	Mechanical Engineering ^b	Nyumbani Soap (ISE)
Engineering consultancy on fatigue corrosion of heavy machinery and equipment	Mechanical Engineering ^b	Magadi Soda Plc (MNC)
<i>General-cooperation mechanisms</i>		
General contacts on fibre-concrete roofing tiles and other low-cost building technologies	Housing and Building Research Institute	Makiga Engineering Works (ISE)

Source: Field survey, 1991/92.

^a FF, foreign firm; ISE, informal-sector entrepreneur; LSE, large-scale enterprise; MNC, (subsidiary of) multinational company; MSE, medium-scale enterprise; NGO, nongovernmental organization; PP, public parastatal; SSE, small-scale enterprise.

^b Interaction undertaken at the individual level.

University of Nairobi, showing that six of the eight successful technology-transfer mechanisms at the university involved individual lecturers, without any assistance from their respective departments or the central administration. The highest concentration of successful links were with subsidiaries of MNCs, which accounted for 12 of the 31 interactions (i.e., 38.7% of the total). Small- and medium-scale firms (including the very small, informal-sector entrepreneurs) and the government bodies each reported seven successful interactions (22.6%). A firm could have more than one interaction: for example, the company may obtain specialized information from an institute, have student attachments, help develop the university's curriculum, etc. The most active department at the university was Mechanical Engineering, with 14 of the

31 interactions (45.2%), followed by Chemistry, with 9 such interactions (29%).

Most of the successful mechanisms at the university involved the transfer of knowledge through seminars and courses for people from the industries. However, most of the seminars attracted only personnel from the public bodies, MNCs, and large-scale firms. If we remove the effect of the knowledge-transfer mechanisms, then half of the core interactive links (research, technology transfer, and general cooperation) would be between the university and small- and medium-scale firms, with MNCs accounting for 33.4%. Again, unlike previous studies, this one demonstrated that the small firms have into the most successful interactions.

Mechanical Engineering still tops the list, having 5 of the 12 core links, with the Housing and Building Research Institute and the Department of Food Technology and Nutrition each contributing to 2 core links. Although there was no single section or division of KIRDI with a discernible lead in contributing successful core interactions, it is a pity to note that the most comprehensive and expensive infrastructure of the institute (the Leather Development Centre and the Engineering Development and Service Centre) had not established interactive mechanisms.

FACTORS INFLUENCING SUCCESSFUL INTERACTIONS — For the field study, scientists and industry were asked to rate the significance of nine factors in successful industry–research interactions. Respondents rated the factors on a scale of 1 to 5 (1 = dominant; 5 = insignificant). A similar method was used by Fowler (1984) to determine the impediments to university–industry relationships in the United States.

The results of our survey are shown in Table 7. From the scientists' point of view, the factor that most influenced the success of an interaction was "financial implications." Two thirds of the respondents from the University of Nairobi indicated that the success of a project depended solely on this factor. No scientist rated this factor as insignificant. The second most important factor was the position of personnel in the industry involved in the project. Tied for third place were previous collaboration with the partner and geographical proximity.

Table 7. Factors influencing the success of technology dissemination (mean responses).

Determinant of success	University ^a (<i>n</i> = 12)	Industry ^a (<i>n</i> = 16)
Position of personnel in collaborating organization	2.50 (2)	2.25 (2)
Extent of previous collaboration	3.17 (3)	3.44 (7)
Proximity of collaborating partners	3.17 (3)	3.00 (3)
Financial implications involved in the partnership	2.08 (1)	3.38 (4)
In-house research capabilities in industry	3.67 (7)	3.19 (4)
Informal methods of collaboration	3.33 (5)	3.44 (7)
Organization of R&D framework in industry	4.42 (9)	3.20 (5)
Type of partnership, agreement, or contract	3.67 (7)	3.75 (9)
Technical sophistication of product or process	3.33 (5)	1.94 (1)

Source: Field survey, 1991/92.

Notes: *n*, number of respondents; numbers in parentheses refer to the ranking of the determinants by order of importance.

^a Significance conversion table:

≤1.49	Dominant
1.50–2.49	Very significant
2.50–3.49	Significant
3.50–4.49	Occasionally significant
≥4.50	Insignificant

Industry's satisfaction with the interactions was derived from the impressive technical ability of the research institutes. The industrialists considered the interactive processes a success when the institutes undertook projects with a higher degree of technical sophistication than was available in the industry. In fact, half of the respondents rated this factor as dominant in the success of the interactions, and a further 31.3% rated the factor as very significant. Industry ranked the position of personnel in the institute and their geographic proximity as other important factors. One quarter of the industrialists rated the position of personnel in the institute as dominant, another 37.5% rated it as very significant.

Description of unsuccessful linkages

Table 8 lists the types of unsuccessful links that involved the university, revealing that 8 (47.1%) of the 17 unsuccessful interactions at the university were with subsidiaries of MNCs and 6 (35.3%) were with large-scale firms. There was only one unsuccessful link involving an informal-sector entrepreneur. Three of the projects were carried out by individual members of staff in their capacities as individuals.

Significance of impediments to industry–research interactions

Scientists and industry used the same scoring scheme to rate impediments to industry–research interaction. According to industry, the chief obstacles to negotiating projects with national research institutes include (1) their lack of understanding of what industry needs; (2) conflict of interest — institutions are interested in basic research and industry is interested in new and improved products and processes; (3) attitudinal factors; and (4) industry's lack of in-house research capabilities. The results are shown in Table 9.

The main hindrances identified by research institutes were more or less the same as those identified by industry, although they rated the significance of these hindrances differently and for different reasons: (1) industry's reluctance to support basic research — many researchers felt they restricted themselves by agreeing to follow industry's direction on what research to conduct and when to conduct it; (2) attitudinal factors and lack of mutual understanding — researchers believed that industry was uninterested in their work, just as industry tended to see nothing offered by research institutes; (3) conflict of interest; and (4) industry's lack of in-house research capabilities.

Summary

The broad aim of this study was to examine the relationship between academic research and the productive sector, with the purpose of identifying the factors affecting the strength or weakness of the links between the research at Kenyan universities and scientific institutions and the industrial sector. The experience of industrialized countries has shown that there is a link between universities and industry. But this does not seem to be the case in most developing countries. Universities and research institutes in developing countries, particularly in Africa, seem to be predominantly concerned about their internal problems of staffing, finance, and expansion. On the other hand, industry is preoccupied with its unique problems — a lack of adequate product markets, some institutional rigidities, and inefficient and inadequate infrastructures — and is usually not aware that local scientific institutions might have plausible solutions to their problems.

Table 8. Description of unsuccessful interactions at the University of Nairobi.

Description of project	Department or unit	Company (category) ^a
<i>Research-support mechanisms</i>		
Research collaboration on <i>Matricaria chamomilla</i> L. project	Chemistry	Dawa Pharmaceuticals Ltd (MNC)
Proposed research project on salt and soda quality	Industrial Research and Consultancy Unit	Magadi Soda Plc. (MNC)
Extension of research project on sand analysis for cement production	Civil Engineering ^b	Bamburi Portland Cement Co. Ltd (MNC)
<i>Knowledge-transfer mechanisms</i>		
Kenya car project	Central administration	Naciti Engineers Ltd (LSE)
Student attachment, participation in 2nd Conference on University–Industry Co-operation Workshop in Chemistry	Chemistry	Dawa Pharmaceuticals Ltd (MNC) CPC Industrial Products Ltd (MNC) East Africa Industries Ltd (MNC) Kenya Breweries Ltd (LSE) Magadi Soda Plc. (MNC)
<i>Technology-transfer mechanisms</i>		
Energy auditing in a large dairy	Food Technology and Nutrition ^b	Kenya Co-operative Creameries (LSE)
Foundry technology for local enterprises project	Mechanical Engineering	African Marine and General Engineering Works (LSE)
Engineering consultancy on refurbishment of existing foundry	Mechanical Engineering ^b	African Marine and General Engineering Works (LSE)
<i>General-cooperation mechanisms</i>		
Attempts to form a national forum for university–industry interactions	Central administration	Kenya Assn of Manufacturers (NGO)
Co-opted membership of the University–Industry Links Committee	Central administration	Naciti Engineers Ltd (LSE)
General cooperation on UNESCO-sponsored projects	Chemistry	Dawa Pharmaceuticals Ltd (MNC)
General cooperation on the development and dissemination of low-cost building materials	Housing and Building Research Institute	Undugu Society, Metal Workshops (NGO) Shelter Works (ISE)

Source: Field survey, 1991/92.

^a ISE, informal-sector entrepreneur; LSE, large-scale enterprise; MNC, (subsidiary of) multinational company; NGO, nongovernmental organization.

^b Interaction undertaken at the individual level.

Table 9. Barriers to institute–industry interactions (mean responses).

Impediments to interactions	University ^a (<i>n</i> = 12)	Industry ^a (<i>n</i> = 16)
The orientation of the institute's research toward basic research is a mismatch with industry's needs for new and improved products	2.53 (3)	2.53 (2)
The need for the institute to publish research results is in conflict with industry's needs for protection of its trade secrets	3.35 (7)	3.44 (9)
Research performed by institutes is generally more expensive than in-house research	3.65 (9)	3.44 (9)
The institute often does not understand what industry needs in the way of product-oriented research or industry's need to maximize profits as return on investment	3.29 (5)	2.39 (1)
Legal matters regarding the institute's research inhibit the commercialization of these innovations	3.77 (10)	3.59 (10)
National industrial property policies hamper relationships	3.82 (11)	4.06 (12)
National research institutes are unable to efficiently undertake industry-sponsored applied research	3.47 (8)	3.03 (5)
Collaborations could affect the normal research environment and processes	4.35 (12)	3.97 (11)
Industry is reluctant to support national research institutes in basic research	2.24 (1)	3.03 (5)
Industry lacks its own in-house research capabilities	3.06 (4)	2.83 (4)
Attitudinal factors create a generalized culture gap and lack of understanding	2.41 (2)	2.83 (3)
Distance is a factor — some activities depend on close proximity between collaborators	3.29 (5)	3.36 (8)

Source: Field survey, 1991/92.

Notes: *n*, number of respondents; numbers in parentheses refer to the ranking of the determinants by order of importance.

^a Significance conversion table:

≤1.49	Dominant
1.50–2.49	Very significant
2.50–3.49	Significant
3.50–4.49	Occasionally significant
≥4.50	Insignificant

Policy recommendations

Right from the outset, one aim of this study was to provide recommendations on the interaction of universities and industry, with special reference to Kenya. The study identified issues relevant to the transformation of policy, not only in Kenya but also in many other developing countries. If attention is paid to these issues, relationships between scientific research establishments and industry could be made more effective.

Changes in the structure of funding: The customer–contractor principle

The importance of S&T to economic development and the nature of scientific research make it imperative for countries to take deliberate steps to manage institutions open handedly. Governments have supported R&D because the central authority has a responsibility to train and educate its own scientific people. Government should support the types of research that are important to national needs and aspirations but are unlikely to be undertaken by the private sector.

Although there are marked differences among countries, the best way to use public research establishments is probably to adopt the contract mechanism (Gummett 1980). Examples from advanced countries show how the mechanism works.

After World War II, the United States developed a deliberate policy of having more research done by nongovernmental bodies, under contract with the federal government. The strategy was supposed to be advantageous because the government would not only have access to the wide spectrum of existing expertise but would also promote the cross-fertilization of competing institutions. This approach was successful and made the scientific infrastructure very flexible, able to respond to changing programs and project requirements.

More or less the same outcome was observed in the United Kingdom. The concept of linking the work of the research establishments to the manufacturing sector gained momentum in 1964, when the British government established the Ministry of Technology. However, despite a relatively high level of R&D, the economy, in general, and the manufacturing industry, in particular, left much to be desired, so in 1967 the ministry adopted the contract mechanism.

In 1970, the ministry issued a discussion document, outlining the proposal that a British R&D corporation be set up outside the civil service to run the civil laboratories. The proposed corporation was to be financed partly by a general grant from the government, partly by specific government contracts, and partly by sale of services, royalty income, joint ventures, and other contract work from industry. The aim was to ensure that the organization and management of R&D were logical, flexible, and decentralized.

The Rothschild (1971) report, which was accepted and implemented by the British government during the 1970s, advocated the customer–contractor principle for government-sponsored applied R&D, together with the appointment within each department of a chief scientist (to provide scientific advice and to formulate research policy) and a controller of R&D (to be responsible for the execution of the departmental research programs). The Rothschild report (para. 6) was based on “the principle that applied R&D, that is R&D with a practical application as its objective, must be done on a customer–contractor basis. The customer says what he wants; the contractor does it (if he can) and the customer pays.” The report also recommended that a “general research surcharge” of about 10% be added as a contribution to research not directly concerned with the programs commissioned by the customers. The intention was to support basic research, which no customer would be willing to contribute to. The implication was that the government research laboratories would have to apply to the ministry for funds for programs only in areas the minister had defined.

Perhaps the most important of these measures was the requirement that projects be partly supported by an industrial customer. This condition not only guaranteed a genuine industrial demand for the project, but also fostered a new kind of relationship between government and private industry.

Examples of programs designed to accord with the government’s priority objectives include the Alvey Programme. Similar programs have also come into place

in other countries, such as the various programs of the Agency of Industrial Science and Technology of Japan's Ministry of Trade and Industry and the programs of the German Federal Ministry of Research and Technology (OECD 1989). The common characteristics of these programs are that they have their own management structures, they are visible in the budgets of the governments, and they clearly promote industrial objectives and the stated intention of mobilizing all of the sectors within the research network: the institutions of higher education, the industrial sector, and the public research establishments. There are now several hundred contract research organizations, with total sales in the European Economic Community (EEC) amounting to 1 billion USD, representing 1.5% of the total R&D in the EEC (Haour 1992). The United Kingdom contract research market was estimated to be worth 670 million USD in 1988/89, excluding contract R&D performed by industrial companies for the Ministry of Defence and other government departments and for other industrial companies (Ringe 1991). It was also estimated that in 1986/87, contracts accounted for 15% of university revenue (Bossard Consultants 1989). About 80% of the developing countries listed in the 1987 UNESCO *Statistical Digest* have science expenditures, including those on research, of less than 0.5% of their gross national product (Mwamadzingo 1993). Moreover, it has also been observed that the concern to gain contract research funds, coupled with the availability of such funds, has led to a high level of submissions from the United Kingdom research associations, which were mostly successful. This had the effect of actually increasing the level of revenue (in real terms) from government sources (Kennedy et al. 1985).

The present study recommends that links between the government research infrastructure (including higher education institutions) and industry (the users of the research) be systematically and deliberately encouraged. The aim should be to ensure that the research establishments emphasize the users needs. The contract mechanism and competition will have the advantage of boosting the dynamics of research institutions, as well as the quality of their services.

One of the ways advanced countries encourage the adoption of the customer-contractor principle has been a reduction in government funding. For instance, the cutback of nuclear R&D programs forced many government nuclear-research establishments to diversify their operations and to fund these operations with contracts with industry. However, this would not be appealing in developing countries, which already spend too little on R&D in proportion to their national incomes. What is required is to institute closer government monitoring of the missions and aims of its research infrastructure but, at the same time, allowing the research institutes greater autonomy. The problem with government research establishments has been the incompatibility of, on the one hand, the public sector's administrative and financial roles and its rules governing the conditions of employment and, on the other, the very nature of research activities. This incompatibility becomes even more detrimental when it is no longer merely a matter of conducting research, but also, and above all, of promoting its use within the economy and society. This objective of S&T policies will not be achieved unless the management of government establishments is allowed a greater degree of autonomy, which implies a correspondingly far greater degree of responsibility.

The adoption of the contract mechanism will also have a number of advantages in addition to its providing a further channel for funding. First, the use of contracts can be seen as a guide for making S&T findings serve the needs of economic development by forging a link with the industrial sector. The existing system, under which research institutions just receive finance from above, does not ensure that the projects and programs undertaken are actually of any interest to the

end users. Second, the contract mechanism will break the existing barriers between the different research institutions in the country, making it easier to serve the needs of production. The argument here is that if there is money to be made, it may well lead to various research institutions pooling their resources (knowledge and facilities) for specific projects and programs. Third, the increased funding derived from the contracts will make the institutes better able to reward their staff, improving the terms and conditions of employment, thus raising the enthusiasm of the scientists and engineers.

Commercialization of research results: Industrial liaison units

The university is already sensitive to the opportunity to obtain income from commercialization of research results. The university has been successfully developing its potential in specific areas of S&T, but the significant problem is that its work in these areas is ignored by industry. The lack of interest is due to poor marketing strategies, as the industrialists are not aware of what is available. Thus, the institutes should establish industrial liaison offices (ILOs) to act as marketing agents. If the ILOs are adequately staffed and properly organized, they could bridge the gap, and enhance the interaction, between the research institutions and industry.

An ILO is affiliated with a research institution and has the objective of providing contact between the research institution and industry. ILOs act, partly, as a switchboard or single window, guiding industrialists to the most appropriate expertise. They also take the initiative of going out to look for consultancies with the industry. There has been massive growth of ILOs throughout the Organization of Economic Co-operation and Development (OECD) countries since the 1970s (OECD 1984), although the ILOs differ considerably in their resource endowments, functions, and locations. For example, whereas the Swedish ILOs are linked administratively to the universities, those in France are linked to various industrial research associations (Rothwell 1982a, b).

One of the most developed forms of the ILO is to be found in the Ruhr area of Germany (OECD 1984). UNIKONTAKT (*Kontaktstelle für Informationstransfer Universität-Industrie Ruhr Universität Bochum*) provides a useful example, as it shows, first, how the simple concept of an ILO officer may be developed and, second, the constraints that the university structure may place on the effective working out of this idea. UNIKONTAKT also performs other functions, such as obtaining financial support for joint university-industry projects; providing advisory services and conferences and seminars to bring about a flow of information between the university and industry; obtaining and licencing patents derived from university research; and making university faculties more familiar with the basics of industrial and business practices.

Experience suggests that ILOs are to some extent handicapped by the rigidities of the university structure; the administrative difficulties in handling research contacts at the universities; and the rather limited interest of university scientists in the short-term practical questions of the industrialists. The liaison officer alone is also unlikely to have a really significant influence on a university's overall level of interaction with industry. Some academic scientists with well-developed contacts with industry see ILOs as superfluous and even objectionable (Menon 1987).

Conditions under which ILOs are effective include (Stankiewicz 1985) the following:

- the local officers are intimately familiar with the departments and their activities;

- the officers are perceived as competent, particularly by the scientific community;
- the liaison function has high visibility and status within the university structure;
- the ILO adopts an active marketing approach, rather than taking a passive service-when-demanded approach; and
- the liaison function is linked to other interface mechanisms (such as research institutes, technology-transfer units, and research parks), rather than operating entirely on its own.

Just as it is impossible to characterize ideal technology transfer — it can take many forms, from academic consultancies faculties, contract research organizations, university spin-offs, and innovation brokers to research and science parks (Stankiewicz 1985; Rothwell 1985; Moe 1983; Menon 1987; Kenney 1986; OECD 1984) — it is impossible to identify the characteristics of an ideal ILO. What is important, however, is to view the mechanism as a process in which learning is the key factor. Even the best-conceived structure will not produce quick results. UNIDO has published a guide on how to establish such units in developing countries (UNIDO 1985).

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CHAPTER 17

University-Based Applied Research and Innovation in Nigeria

Babajide Alo

Introduction

Applied scientific research has been going on in Nigeria for close to a century now. Because of the strategic role of science and technology (S&T) in the procurement of raw materials for British industries, the British colonial government developed an implicit S&T policy to support and guarantee the production and supply of export crops, such as cocoa, palm produce, groundnuts, and cotton. In the early 1920s, this led to the establishment of agricultural research stations at Moor Plantation, Ibadan, Umudike, Umuahia, Samaru, and Zaria.

In the 1940s, the British colonialists also set up several West African research institutes for its colonies on the west coast. Since then, about 26 research institutes have been established in Nigeria. A national policy on S&T was instituted in 1987, and S&T establishments were set up in the West African region, particularly training institutions, such as Yaba College, to train middle-level personnel.

With the establishment of the first Nigerian university in 1948, university-based research entered the scene. Over the last 45 years, the number of universities in the country has increased to 31. These can be divided into three groups. The first-generation universities are Ibadan, Lagos, Nsukka, Zaria, Ife, and Benin. The second-generation universities include Jos, Ilorin, Sokoto, Maiduguri, Calabar, Kano, and Port-Harcourt. The third-generation universities, established mainly for technology, are Bauchi, Yola, Owerri, Minna, Akure, Abeokuta, and Makurdi. Abeokuta and Makurdi have since been transformed into universities of agriculture.

The annual allocation to the Federal Universities System is at least 1% of Nigeria's total revenue. In 1986, this represented 0.6% of the gross domestic product (GDP). The proportion of the nation's resources allocated to universities increased slightly in the 1990s (Table 1). The National Policy for Education stipulates that at least 80% of federal allocation to education must be devoted to higher education.

Table 1. Recurrent allocation to Nigeria's Federal University System.

	Allocation (million NGN)	% of national revenue	% of GDP
1986	394.9	1.10	0.64
1987	304.5	0.90	0.39
1990	634.6	1.30	0.74
1991	699.9	1.02	0.70

Notes: GDP, gross domestic product. In 1995, 78.5 Nigerian naira (NGN) = 1 United States dollar (USD).

The first-generation universities receive a large proportion (>50%) of the total grants to the Nigerian university system (Table 2). Each university in the group draws 0.23% of the nation's GDP, on average. These institutions are expected to account for a significant proportion of the university-based research and development (R&D).

Table 2. Recurrent appropriations to Nigeria's six first-generation universities (1981-1992).

University	Total (million NGN)	Proportion of total ^a (%)	Mean % of GDP
Ibadan	769.4	10.2	0.25
Lagos	712.0	9.5	0.23
Nsukka	763.1	10.2	0.25
Zaria	762.5	10.2	0.24
Ife	734.6	9.8	0.24
Benin	529.5	7.0	0.18
Total	4271.1	56.9	

Notes: GDP, gross domestic product. In 1995, 78.5 Nigerian naira (NGN) = 1 United States dollar (USD).

^a Proportion of total allotment to the Federal Universities System (31 universities).

Research questions

This study sought answers to the following questions:

- What is the nature and level of patentable R&D in Nigeria's six first-generation universities (where all substantial research has taken place for more than a quarter of a century)?
- Has there been demand for university-based research solutions to national problems? To what extent have the demands been met or innovations adopted?
- How effective are the mechanisms to promote diffusion of university-based innovations and to promote their adoption?
- What is the status of acquired research capacity (human resources and infrastructural)? Is capacity fully utilized? If not, why?
- What are the major constraints causing the gap between university-based R&D and the productive sector? How extensive are they?
- What is the impact of university-based applied research on development?
- How does the relevant experience of developed countries compare with that of developing economies?

Roles and mandates of the universities in national development

The primary and traditional role of universities is the transmission of knowledge, the training of minds. Another role of universities is to engage in basic research that could lead to the advancement of knowledge. The importance of the universities' pursuit of knowledge is recognized in the developed countries (Davis 1991). Through research and its results, universities are expected to contribute to the improvement of the quality of life and to social and technological change.

The involvement of universities in S&T is usually threefold. (1) The primary role is providing education and training in S&T. However, this educational function is always evolving — specialization and differentiation of programs are increasing in response to the growing body of scientific knowledge and the demands of the work environment. The university's need to advance knowledge through discovery, explanation, and classification has continuously modified its educational mission. University researchers are expected to keep abreast of new developments in their disciplines and train students in research methodology. (2) Through research, the universities contribute indirectly or directly to economic progress and to the quality of life. (3) Universities perform the role of an active change agent. By diffusing best-practice knowledge and technology to the other institutions within the society, universities help to transform the production of goods and services. The universities can perform this function through consulting activities, systematic exchanges, and application-oriented research. As Davis (1991) stated, the performance of the diffusion mission depends to a large extent on how well the other two roles are performed. The success of diffusion depends on the structure and dynamics of the industries with which the universities interface. However, the view that universities should act as catalysts in the transfer of S&T knowledge to industry and government is not shared universally. In some countries, the educational function is seen as primary, indirectly contributing to economic development. The transfer of S&T knowledge is left to other institutions.

In Africa, the universities are among the most important institutions for the development of S&T and they consume a significant amount of the national resources devoted to research. As well as turning out highly trained human resources, the universities provide S&T services to the productive sector. In Africa, steps have been taken to formulate a new philosophy of university education. At a 1972 Accra workshop, "Creating the African University: Emerging Issues in the 1970s," it was concluded that the African university must go beyond the conventional functions of a university (teaching, research, and diffusion of research results) and commit to the struggle for economic progress and sociopolitical transformation.

Research at Nigerian universities

Most of commercializable industrial R&D in Nigeria is carried out by government-owned research institutes; only a limited amount of university research reaches a commercial state (Igwe 1990). Indeed programs at the universities have not responded adequately to the developmental needs of Nigeria. As Musa (1988) emphasized, the bulk of research at the universities is conceived in terms of publications and career advancement and tends to have little social relevance. Notwithstanding this, appreciable research is done, and an awareness of the need for more research at Nigerian universities has been created.

Kumuyi and Igwe (1989) found that Nigeria has not developed revolutionary new products and processes, despite the claims that there have been inventions and breakthroughs. According to Kumuyi and Igwe, most earlier research was in agriculture and its allied industries. A ready explanation for this is that, traditionally, agriculture has attracted more funds from the government for R&D. Fields like engineering, chemistry, and astrophysics developed only much later.

Research at Nigerian universities has been said to be mainly basic research, not applied. Moreover, it is presumed that many academics are not carrying out research relevant to local problems. Okigbo (1985) asserted that at Nigerian universities it seems priority is given to applied research only to justify or attract

support. In the 1970s, basic research and applied research at universities were estimated at about 6 and 24% of the national research capacity, respectively (Okigbo 1985). These percentages are glaringly low if research is expected to contribute significantly to national development.

The first-generation universities

The first-generation universities get about 57% of the total recurrent grants available to the entire Federal Universities System (see Table 2), so they are expected to provide a significant proportion of the national R&D. Table 3 shows that close to 50% of the staff and students in Nigerian universities are at the first-generation universities.

Table 3. Academic staff and student enrolment by institution in the six first-generation universities (1989/90).

University	Academic staff (Nigerian and non-Nigerian)	Total enrolment
Ibadan (<i>n</i>)	1129	12 128
Lagos (<i>n</i>)	716	12 226
Nsukka (<i>n</i>)	899	14 911
Zaria (<i>n</i>)	1186	14 911
Ife (<i>n</i>)	924	14 862
Benin (<i>n</i>)	617	14 862
% of national total	45.8	43.8

Source: NUC Annual Report (1990).

Nature of the research

Statistics on the research capacity of universities in the developing world are limited. However, according to Nduka and Falayojo (1985), Nigerian scientists have become more widely known through their research. For more than a generation now, Nigerian scientists have striven to put the products of their research on the international intellectual scene. Evidence from our investigation shows that researchers at Nigerian universities have carried on their work despite the economic downturn in Nigeria.

Research at Nigerian universities occurs in all the major branches of science. However, our survey suggests that Nigerian scientists have made more contributions in the applied sciences — medicine, agriculture (biological), veterinary science, metallurgy, etc. — than in the physical and mathematical sciences. During our field survey, we administered 300 questionnaires to participants in S&T research at the six first-generation universities in Nigeria. Table 4 shows the various categories of university-based research projects. Respondents were categorized in five major groupings, according to the appropriate sectors of the economy: medicine, engineering, agriculture, metallurgy, and other. Among the 129 projects sampled, agricultural research was predominant (33%). Much of the research in agriculture is directed to increasing food production through higher yields or less spoilage.

Although the data gave no clear indication of which faculty or department accounts for most of the research at Nigerian universities, Ahamadu Bello University at Zaria, which had the highest number of respondents (38 of 129 respondents), also had the largest number of research projects in agricultural science. This may be related to the Agricultural Extension and Research Liaison Services (AERLS), which has established excellent linkage with local farmers all over the north of Nigeria. The

Table 4. Category of university research projects.

Category	<i>n</i>	%
Medicine	11	8.5
Engineering	30	23.3
Agriculture	43	33.3
Metallurgy	3	2.3
Other	42	32.6
Total	129	100.0

almost insatiable demand of farmers for improved agricultural practices provides a continuous stimulus to agricultural research.

Research in engineering ranked second. Some petroleum engineers are working on the enhanced recovery of hydrocarbons; others are developing catalysts for refinery operations. Mechanical engineers are studying the properties and uses of materials and other aspects of manufacturing technology. Studies on the development and use of solar energy are common. The design and building of structures, roads, highways, and transport engineering, along with research in water and public engineering, constitute the bulk of civil engineering studies.

Nigeria's university-based research is known internationally, and Nigeria's advancement of knowledge appears to be mostly in the field of medical research. Nigerian university research has led to some important findings in surgery, neurology, pathology, pharmacology, and hematology, especially.

Other S&T research at Nigerian universities is in the physical and mathematical sciences. Research on mineralogical exploration was pursued at three of the universities. Such studies have led to the location of economic mineral deposits. Although most of the mining companies use non-Nigerian advanced technology to tap the minerals, it is noteworthy that Nigerian scientists play a big role in identifying areas for exploration. Most of the other research in the physical sciences is basic research, solving fundamental problems in an effort to advance knowledge. However, a modest showing in research on atmospheric physics was recorded. Research is done on the characteristics of tropical thunder and lightening, as well as on point discharges in atmospheric electricity. Frontier research in the chemical sciences in Nigeria is essentially basic research. Apart from tangential incursions into applied research, especially in analytical chemistry, most chemical research at Nigerian universities tends toward the solving of fundamental, internationally recognized problems.

Human resources to conduct research in S&T were still present at Nigerian universities, despite the excessive and on-going brain drain. The largest number of researchers in the survey were lecturers or research fellows (Table 5).

Table 5. Designation of researchers.

Designation	<i>n</i>	%
Professor	14	10.9
Senior lecturer	33	25.6
Associate professor	10	7.8
Lecturer	47	36.4
Research fellow	25	19.4
Total	129	100.1

More than 50% of the respondents had fewer than 10 years of university-research experience (Table 6). Because university research seems to be conducted mostly to earn promotions, most of the researchers are the aspiring and relatively new PhD holders — the older professors, unfortunately, seem overwhelmed by the constraints of teaching or are inundated with administrative chores that allow them very little time for research.

Table 6. Experience of researchers.

Experience	<i>n</i>	%
0–5 years	40	31.0
6–10 years	30	23.3
11–15 years	25	19.4
16–20 years	15	11.6
21–25 years	14	10.9
25 years	5	3.9
Total	129	100.1

Most scientists at Nigerian universities work alone on their research projects. In a few cases, the researchers are assisted by their graduate students. Only occasionally are projects executed in collaboration with other scientists. The few cases commonly emerge “from accidental convergence of individual lines of research rather than as a result of a planned attack on a major scientific problem” (Nduka and Falayojo 1985). Major collaborative research groups (consisting of a lead scientist, postdoctoral fellows, and doctoral and other graduate students) like those found in the developed countries generally do not exist in the Nigerian university system. The exceptions do not usually stay together long because of the high mobility of the local academics, who want to set up and lead their own groups.

Despite the relevance of R&D to Nigeria’s technological takeoff, there has been little increase in scientific activity at the country’s universities. The following factors have been identified as some of the constraints on R&D at Nigerian universities: poor research facilities; inadequate human resources; poor linkage with the production system; inadequate funds, incentives, and motivation; and lack of clear-cut enabling policies. The leading factor seems to be poor funding for S&T research.

The use of scientists at the universities needs to be examined. Ukaegbu (1985) asserted that there is a need to redefine the status of S&T professionals if effectiveness is to be expected from them. As Ukaegbu emphasized, the motivation and effective use of scientists need further examination. Other scientists, like Schweitzer and Bergh (cited in Ukaegbu 1985), have suggested that poor working conditions were a factor constraining the innovative activities at the universities.

In 1978/79, the funding per scientist for R&D at the universities was about 3200 Nigerian naira (NGN) (in 1995, NGN 78.5 = 1 United States dollar [USD]), whereas at the research institutes it was 11 600 NGN (Okigbo 1981). Emovon (1988) also alluded to the lack of sufficient funds for research. Although the National Science Policy recommends 5% of the gross national product (GNP) be set aside for research, the country invested less than 1% in R&D in 1992.

Demand for and use of Nigerian university R&D

Table 7 shows that more than 90% of the respondents thought poor funding for S&T prejudiced the productive sector against the use of university results. Poor or indifferent attitudes of the productive sector to research results (64%) ranked with poor communication links between the two sectors (64%). The lack of clear-cut enabling policies was also considered an important factor (49%). Other possible factors, such as socioeconomic or political factors, bureaucracy, paucity of university-based research results, and inadequate personnel, were not considered as important.

Table 7. Constraints to use of university research results by the productive sector.

Constraint	Yes	%	No	%
Poor funding of research	118	91.5	11	8.5
Lack of clear-cut enabling policies	63	48.8	66	51.2
Poor or indifferent attitude of industrialists to results of university	83	64.3	46	35.7
Poor or indifferent attitude of university scientists	16	12.5	113	87.6
Bureaucracy	41	31.8	88	68.2
Poor communication between universities and the productive sector	83	64.3	46	35.7
Paucity of university-based research results	7	5.4	122	94.6
Inadequate research personnel	22	17.1	107	82.9
Economic reasons (e.g., SAP)	47	36.4	82	63.6
Political reasons	29	22.5	100	77.5
Security reasons	6	4.7	123	95.3
Other	7	5.4	122	94.6

Source: Field analysis, 1991.

Note: SAP, Structural Adjustment Programme.

An analysis of the demand for university-based research showed that the expertise of only about 30% of researchers across the universities was in demand in the productive sector (Table 8). In fact, only 19% of projects sampled were commissioned by the productive sector.

University-based research in Nigeria is commonly designed *ab initio* to solve specific problems applicable to Nigeria's productive sector. Eighty percent of the projects analyzed in our survey were of this nature; the other 20% of the respondents considered their research a normal scientific endeavour. It is interesting that only 19% of the applied research was commissioned by the productive sector — the majority of the studies were at the initiative of the researchers themselves. It is not surprising, therefore, that industry demand for local R&D is low. Only 21.7% of respondents had their project results actually applied in the productive sector. Though many of the investigations were in basic research, some results deserved patents. Unlike some universities in the developed countries, none of the first-generation universities in Nigeria had a patent office. The need for copyright protection was ignored as a matter

of course because few research results are ever adopted. Commercialization of research results, therefore, is still in its infancy at most Nigerian universities. In our study, only 10% of the research projects had been commercialized.

Table 8. Use of university expertise or research results by the productive sector.

	Yes	%	No	%
Was your research commissioned by industry?	25	19.4	104	80.6
Is your research expertise in demand in the productive sector?	39	30.2	90	69.8
Has your research result been applied in the industry?	28	21.7	101	78.3
Has your research result been commercialized?	13	10.1	116	89.9

Source: Field analysis, 1991.

The role of the productive sector

In the productive sector, there is a low level of awareness of university-based research results. Informal interviews and questionnaires on the demand for, and use of, university results were administered to technical professionals at 25 industrial establishments in the Lagos area. The majority of the respondents indicated that though they sought information on university-based research and innovation, no relevant information was obtained. They also asserted that they adopted research results and innovation only when they were relevant and feasible. However, adequate information and validation of a process change introduced by a university result, coupled with the economic feasibility of the innovation, assisted the firms in making their decision. Many of the large conglomerates indicated that there was no need for linkage between them and the university researchers.

The reasons for the responses varied among the firms. Some of the firms indicated that decisions to adopt an innovation come from their parent companies; therefore, they were not in a position to establish links with the universities. Some of the firms with parent companies abroad said their parent companies carried out their research activities and innovation abroad. One firm indicated that after sourcing innovation locally, results were usually forwarded to a central research laboratory in the United States or the United Kingdom for consideration. Many firms stated that no decision was made in Nigeria to adopt innovations until their overseas parent bodies had considered and approved the scientific data. Efforts within these local firms were limited to in-house process modifications. Fifty-six percent of the firms revealed that they had no demand for university expertise, research results, or innovations, and 59% reported that they do not provide grants to universities for research. Notwithstanding, many of the firms indicated the desire to adopt research results and innovation relevant to their production systems. It is obvious from these responses that many firms in Nigeria do not look to universities for results and innovations and, hence, do not maintain or need to maintain any form of linkage with them.

In sum, the findings of this study corroborated those of Kumuyi and Igwe (1989), who found that only a limited number of the R&D results at institutions of higher learning ever mature into commercial innovations. The authors identified factors in the graduation of a product or process into commercial production:

- expressed need for the invention by the industry;
- demonstrable advantages of the invention;
- low risks in the commercialization of the invention;
- nonalteration of the user's habits; and
- good packaging and presentation of the invention, making it attractive to end-users.

The two major prerequisites are effective communication between researchers and end-users and the marketability of the products or the innovation.

Overall, it was recognized that there was little or no interaction between the universities and the productive sector. Interactions (if any) have been very limited in scope, and it may be reiterated that industry has shown sufficient interest in research results or prototypes from local universities. Similar problems have been encountered in developed countries. Particularly in Canada, it was found that most industries were slow in partaking of the diffusion of new technologies, and there were three reasons for this: (1) the late start in adoption of new technology in Canada compared with other nations; (2) interregional time lags in the diffusion of innovations; and (3) the resistance of managers to the adoption of new technologies.

Suggestions to ensure the application of research results

The efforts of Nigerian universities to ensure the application of research results have been inadequate. The organ adopted by most universities in Nigeria has been a university consultancy firm, which handles all activities that could generate income for the university.

Unlike some universities in the developed countries, Nigerian universities have no patent offices. Efforts by researchers to obtain research funding from industry have been largely futile. The desirability of industry support for university-based research cannot be overemphasized. Apart from helping to improve the research environment, it would ensure diffusion of innovations. The absence of well-laid-down procedures at the universities for contracts or linkages with industry is unfortunate. However, the major constraint has been the lack of cooperation from the productive sector or even indifference on the part of industry. Government funding remains a problem.

The emphasis placed presently on ensuring the active involvement of the productive sector at all stages of university research is very limited and ineffective. Although there are exceptions (e.g., AERLS at Ahmadu Bello University, Zaria), it seems the universities are not yet clear about how to improve in this area. The productive sector in Nigeria, on the other hand, does want to benefit from the work of research laboratories at the universities. Some suggestions to achieve better application of university results include the following:

- The universities should advertise their capabilities.
- Research at universities should be in areas relevant to the needs of the private sector.
- The university researchers' autonomy should be restored so that they can establish direct links with the industries.
- Industry and research institutions should jointly sponsor relevant scientific publications.
- University laboratories should hold regular workshops and seminars for industry to disseminate their findings and discuss their applicability.

- The motive for investment in research should shift away from that of immediate profit.
- The government should formulate a policy ensuring that a small percentage of the industry's profit is spent on R&D.
- The government should give incentives for collaborative research programs (e.g., tax incentives and tax-free import of research equipment).
- The government should allow firms to deduct 0.5% or more from their annual taxable income for expenditures on R&D.
- Academics should be seconded to industries for short periods.
- The university and industry should set up a staff-exchange program.
- Universities should sensitize potential users to the need for research and the use of available research results.
- Joint university–industry research-appraisal panels should be set up.
- The universities should continually invite industrialists to seminars and other town-and-gown meetings.

Policy issues

The policy implications of this study should be highlighted. For university-based R&D to have an impact on the productive sector, a virile link should be established between the two. Ways should be sought to overcome the constraints. Appropriate policy initiatives must be put in place. Furthermore, Nigerian universities should realize that their function extends beyond that of carrying out R&D to that of transfer of the knowledge and technology. This should be given the same care as teaching and research. In fact, teaching, research, and diffusion need to exist in a synergistic balance.

Recommendations

In conclusion, a number of recommendation may be made on the basis of this study:

1. The productive sector should increase its efforts to market university research. Such efforts should involve establishment of such structures as university offices for technology transfer or the novel idea of centres for innovative technology. Such structures should be devoid of any bureaucratic obstacles.
2. University researchers should seek out problems confronting particular industries and make their research relevant to these problems to avoid wasting time and resources.
3. The subsectors of the productive sector should be involved in decisions about proposed research. This will help the universities identify worthwhile research and establish positive links between the productive sector and the university.
4. The quality of R&D at the universities should be enhanced through increased funding.
5. A policy instrument is needed to compel or encourage all companies (indigenous or multinational) to set up R&D units in Nigeria and collaborate closely with appropriate departments at Nigerian universities. Such a policy would encourage the productive sector to intensify their interaction with the universities within a set time frame and, hence, play a more significant role in generating innovations for the Nigerian economy.

6. Further studies should be made to identify and develop effective means for arousing the interest of the productive sector in university research.

Clear policies and strategies to establish university–industry linkages in Nigeria are imperative for technical progress. As this study shows, Nigeria’s productive sector does want to explore linkages with the research community at the universities, but the absence of enabling policies and mechanisms remains an obstacle.

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CHAPTER 18

Technical Change in the Nigerian Cement Industry

Akin O. Esubiyi

Introduction

In broad terms, the aim of this study was to examine the policies guiding the acquisition of technology in a sector of the Nigerian manufacturing industry. A case-study approach was adopted in a firm-level study of the cement industry, within the context of the dynamics of technology acquisition, technical-capabilities accumulation, and technical change in the wider chemical and petrochemical sector of the Nigerian economy.

Objectives

The objectives of the project were the following:

- to appraise of the nature and level of technical change in the cement sector, with a view to identifying elements of technology transfer from foreign vendors of technology;
- to identify the process of human resources development in the industry, with a view to identifying technical and organizational learning efforts;
- to determine and analyze past and present trends in the growth of the selected firms in the Nigerian environment;
- to appraise firm-level machinery for evidence of acquisition of technology; and
- to draw lessons for those formulating policies for the development of the chemical and petrochemical sector.

Methodology

The conceptualization and analysis of the project took the form of a case study. The results of my analysis were then used as the basis for recommendations for national policies on science and technology (S&T) and on industry.

The methodology can be divided into the following phases of activities, which were not necessarily sequential:

- desk research;
- interviews and field trips in Nigeria;
- study and consultation at the Science Policy Research Unit (SPRU) of the University of Sussex; and
- overseas trip to the United Kingdom to see the research and development (R&D) and overseas divisions of Blue Circle Industries (BCI).

Desk research

The desk research focused primarily on the examination of available literature on technological acquisition and technical change in the Third World, especially Nigeria. I also gathered information on cement manufacturing (e.g., materials, processes, and production technologies) and on the Nigerian cement industry.

Interviews and field trips in Nigeria

The interviews and field trips formed the bulk of the work. Cement manufacturing is a relatively successful industry, mainly because of its continuity of production and profit margin. The company studied was the West African Portland Cement Company (WAPCO), Lagos. Visits were made to various policy-making institutions and manufacturing associations:

- the Federal Ministry of Industries, Abuja;
- the Federal Ministry of Science and Technology, Lagos;
- the Nigerian Institute of Social and Economic Research;
- the National Institute for Policy and Strategic Studies, Kuru (near Jos);
- the Nigerian Industrial Development Bank;
- the Cement Manufacturers Association of Nigeria (CMAN); and
- the Manufacturers Association of Nigeria.

Manufacturing ordinary Portland cement

Raw materials

The main raw materials for manufacturing ordinary Portland cement (OPC) are limestone or chalk, shale or clays, minor or corrective components, fuel, gypsum, and extenders. OPC clinkers are composed mainly of lime, silica, alumina, and iron compounds. Each of these components is found in the various minerals that are the raw materials for OPC. Lime is the principal constituent of limestone or chalk (calcareous components). The other components, silica, alumina, and iron compounds, are present in various proportions in shale or clays (argillaceous components). Marls and other materials containing significant proportions of all the four oxides (i.e., lime, silica, alumina, and iron compounds) are frequently used. Some minor components, like magnesia, zinc, copper, fluoride, and phosphate, are also introduced through the calcareous components.

In some cases, corrective components are added with the raw materials to compensate for defects. Such components may include sand (to increase the silica), iron oxide or bauxite (to increase the alumina, especially in special types of cement), and china clay (to minimize the iron in white cement). Calcium fluoride and calcium sulphate are useful in lowering the temperature required for a given combination of raw materials and may yield an improved quality. Gypsum is added to retard setting in the finished product. Powdered blast-furnace slag may be used as an extender to reduce fuel consumption in the manufacturing process.

The fuel needed for OPC manufacture is coal, gas, or oil. The choice depends on economics and the process used. Colliery waste, oil shales, domestic refuse, used tires, rice husks, and sewage sludge have also been tried as novel fuels to supplement to the conventional ones.

The manufacturing of OPC consists of three major unit operations: raw-meal preparation, heat treatment, and cement milling.

Raw-meal preparation

After the limestone has been removed from the quarry, it is crushed twice to reduce it to a size suitable for grinding. The crushed limestone is stockpiled to reduce day-to-day variation in the chemical characteristics of the raw material and also to provide buffer stock (about 1 week's kiln feed, to be used between intermittent quarrying and crushing operations) to maintain continuous raw milling. Another step in the stockpiling stage is to blend two or more materials to obtain a desired characteristic.

After stockpiling is the raw-milling stage, in which the raw material is ground to a powder fine enough ($\leq 15\%$ residue captured on a 90 mm sieve) to burn in the kiln. The raw materials plus any composition-correcting additives are dried and intermittently mixed during the raw-milling stage. There are several raw-milling systems, the choice of which is dictated by the moisture content of the raw material:

1. The air-swept ball mill dries material with $\leq 8\%$ moisture content. It uses hot kiln-exhaust gases and the heat generated during grinding, along with auxiliary furnace heat for moister materials.
2. The semi-air-swept centre-discharge mill dries material in an attached chamber and can handle materials with $\leq 12\%$ moisture content.
3. The non-air-swept ball mill dries material in the separator but is unsuitable for materials with $> 15\%$ moisture content.
4. The Taden hammer-ball mill dries raw materials with $\leq 12\%$ moisture content. The drying occurs in the hammer mill. Hot exhaust gases from the kiln or an auxiliary furnace are used.
5. The vertical-spindle or ring-roller mill can handle raw materials ≤ 125 mm, with 15% moisture content.

Heat treatment

The blending of the raw materials is followed by heat treatment in a kiln (sometimes the materials pass through a preheater first). There are four classes of treatment involving kilns: dry, wet, semiwet, and semidry.

The kiln is cylindrical and slightly inclined horizontally, and it rotates at about 1–4 rpm. The solid material rolls down the kiln and is blown about by cyclones of combustion exhaust from a gas, oil, or pulverized-coal flame at the lower end. The kiln is generally refractory, lined throughout its hot zones with a variety of bricks for insulation. The back end of the chain zone in a wet-process kiln is usually unlined. The processes occurring in the kiln are the evaporation of any water; the thermal decomposition of clay minerals (at 300–650°C) and calcite (800–950°C); the formation of some liquid (at about 1250°C); and, finally, the formation of clinker (at $> 1400^\circ\text{C}$). The clinker emerges from the kiln and passes into a cooler, where convective air flow cools it to a level suitable for subsequent handling and milling. The heat is reclaimed and recycled to the kiln as secondary combustion air. Other gases reclaimed from the suspension preheater (SP) and precalcinator systems (discussed in the dry process), along with the coolers, are used as primary combustion air in the kiln; excess air from the cooler is cleaned and exhausted into the atmosphere.

The whole assembly of precalcinator, SP, rotary kiln, and cooler is usually air sealed, as it operates under a slight vacuum. The sealant helps to prevent air infiltration (which lowers the efficiency of the system) and dust emission.

The dry process

The dry process is probably the best. The powdered, blended meal, with about 0.5% moisture content, is fed initially into the SP, a system of cyclones or similar devices, where it is recirculated and heated by a mixture of countercurrent and cocurrent flows of the kiln-exhaust gases. This system contains one to five bands of cyclones, depending on the energy-balance calculations at the design stage. Temperature gradients of the inlet solid feed and exit gas are 50–70°C (for the solids) and 350–1200°C (for the gas).

When about half or more of the total fuel is burned in or below the SP system and outside the kiln proper, the arrangement is referred to as a precalcinator; in this case, the temperature of the feed entering the kiln may be >900°C. The precalcinator results in the decarbonation of a major portion of the calcium carbonate in the raw mill before the kiln stage. The kiln completes the decarbonation and heat treatment. This whole process takes less time than the wet process.

The wet process

The material fed to the kiln in a wet process usually has about 30–40% moisture content and contains deflocculants to ease pumping. The slurry feed is pumped directly to the upper, or back, end of the kiln, which is usually about 6 m in diameter and about 200 m in length. Steel chains are hung in the dry zone near the back end of the kiln to transfer heat from the hot gases to the moist slurry feed. Toward the end of the chain system, the slurry feed forms nodules, and these are sent out from the zone, dried, and partly decarbonated. Farther down the kiln, the feed is further decarbonated and then clinkered before it leaves the kiln and enters the cooler system.

The semiwet and semidry processes

The semiwet process is a modification of the wet process. The slurry is dehydrated in a filter press to form a cake with about 20% moisture content before being broken and fed directly into either a long, chained kiln or a preheater, such as a moving Lepol grate or disintegrator cyclone system, and, thence, to a short kiln.

In the Lepol, or semidry process, the raw materials are pretreated as in the dry process. The powder is nodulized to approximately 15 mm spheres, with about 12% moisture content, in an inclined rotating dish or drum. The nodules are then fed onto a moving grate, where some drying, preheating, and partial decarbonation take place prior to the kiln stage. Subsequent treatment is similar to that in the dry process.

Cement milling

Cement is produced by grinding the cooled clinker with gypsum (hydrated calcium carbonate). The grinding usually takes place in a tubular mill, partly filled with steel balls. There are two basic cement-milling systems: open circuit and closed circuit. The open-circuit system is the older of the two and is usually found in the old works (plants). In this system, the mill diameters are a maximum of 2.5 m. There is a single pass of material through the mill.

Newer mills tend to be closed-circuit systems and are generally bigger than the open-circuit type. Diameters as large as 4.5 m are not uncommon. In the closed-circuit system, the product is split to provide a coarse-reject stream (which is recycled in the mill for regrinding) and a fine-product stream.

Ball milling generally produces heat, so a fan may be used. Alternatively, a cement-cooling system may be introduced in the closed-circuit operation, outside the mill, and internal water sprays may be used at the mill inlet and outlet.

The ground cement is stored in large silos until packaging and distribution.

Blue Circle Industries

BCI is the largest cement producer in the United Kingdom. The group has about 12 plants, scattered all over the United Kingdom, and claims that these plants are some of the most modern in Europe. BCI manufactures cement and other building materials, such as ready-mix concrete, aggregates, and bricks.

BCI ranks very highly in the UK economy, consistently in the top 120 industries. Its turnover is about 1 billion GBP per annum (in 1995, 0.63 pounds sterling [GBP] = 1 United States dollar [USD]). BCI also enjoys a huge financial profit on its investments at home and abroad.

The activities of BCI are not limited to the UK market. In fact, it has tentacles all over the world. In the United States, BCI has investments in cement manufacturing, cement and allied-products sales, building materials, and the soft construction market. In Chile and Mexico, BCI has similar investments in cement manufacturing and allied products. In Africa, the group has investments in South Africa, Nigeria, Kenya, and Zimbabwe. The multinational also has investments in Asia.

To oversee its considerable overseas investments, BCI created the Blue Circle Overseas (BCO) Division. BCO is located at the Portland House, London, the corporate headquarters of BCI. Within BCO, there is a department responsible for the coordination of the transfer of technical know-how to the overseas plants. This division helps ensure the optimal performance of the plants through the technical services it provides. It also uses other instruments, such as technical-services agreements (TSAs), expatriate placements, management-services agreements, project management, and training.

BCO contracts for technical person-hours as a form of assistance to overseas companies; these are worth as much as about 1 million GBP per annum. This is to implement the TSA schemes, whereby overseas companies gain access to all BCI technical know-how in the form of technical literature, R&D reports, technical information, etc. The TSA is usually independent of BCI's level of investment in the host economy. Also within the framework of the TSA, a two-person project team periodically visits and makes a report, a copy of which is forwarded to the client. Future repair or refurbishment projects on the works are planned on the basis of this report.

BCO also assists by arranging for the placement of expatriates in overseas companies within the group. This schedule is independent of the TSA, and the mode of payment to the expatriates varies from country to country, depending on prevailing conditions.

BCI is the technical partner to two Nigerian cement-manufacturing companies: Ashaka Cement Company, based in Bauchi, and WAPCO, based in Lagos. Some of the specific elements of the TSA between BCO and WAPCO include

- testing the calibration of equipment and measuring instruments;
- advancing milling (i.e. by carrying out grained ability tests on samples);
- designing major items of equipment when needed (e.g., the quarry conveyor system at Shagamu Works); and
- training, in the form of a cement technology course in the United Kingdom.

The Nigerian industrial sector

General overview

A policy of import substitution dominated postindependence Nigeria's industrial development. This policy was pursued vigorously via the national development plans,

which resulted in the commissioning of various industrial projects. An example is given in Table 1. As the economy benefited from the oil boom of the 1970s, the projects became more ambitious and expensive. In the same period, private-sector investment in manufacturing grew as a result of various incentives, such as the Pioneer Status and Approved Users schemes put in place by the government.

Table 1. Major federal government manufacturing programs and projects (Third National Development Plan, 1975–1980).

Project title	Estimated total 5 year expenditure (million NGN)	Total first-year expenditure (million NGN)	%	Expected project completion
Blast furnace complex	461	—	0	1980
Direct-reduction iron and steel	250	—	0	1982
Expansion of existing cement factories	78	n.a.	n.a.	—
New cement factories (Ashaka, Benue, Shagamu)	85	n.a.	n.a.	1978
Commercial vehicle assembly	12	1.40	11.8	—
Pulp and paper car- ryover projects (Jebba, Calabar, Iwopin)	200	12.41	6.2	1980
New pulp and paper projects	72	—	0	—
Pulp-wood plantation	58	11.00	19.0	—
Fish trawling and distribution	19	3.16	16.6	—
Combined fish and shrimp project	6	0.65	10.8	—
Integrated sugar (sava- nnah, Sunti Lafiagi)	280	10.00	3.6	1980
Other sugar projects	40	—	0	—
Petrochemical complex	300	0.88	0.3	1978
Nitrogen fertilizer	70	0.40	0.1	1977
Oil refineries (2)	350	23.38	0.1	1980
Export refineries (2)	376	—	0	—
NNG plants (2)	1 260	0.12	0	1978
Large-scale carbon- ization of coal	29	0.07	0.2	1980

NOTE: In 1995, 78.5 Nigerian naira (NGN) = 1 United States dollar (USD).

However, by the late 1970s, serious structural defects in the manufacturing sector started to emerge, and the diagnosis was that the sector was characterized by high geographic concentration and high production costs, low value added, serious underutilization of capacity, a high import content in industrial output, and a low level of foreign investment in manufacturing. The situation worsened as the foreign earnings from oil started to decline significantly in the 1980s. By this time, the government had invested heavily in a diversified portfolio of industrial projects, including salt, cement, iron, steel, and sugar. The poor returns from these projects, the low capacity utilization, and various other compounding factors helped to plunge the economy into recession. It is against the background of this poor economy that the government embarked on the Structural Adjustment Programme (SAP) in July 1986. SAP aimed to ameliorate the economic situation, to increase local value added and capacity utilization in the industrial sector, and to create sustainable industrial development.

The elements of SAP included fiscal and monetary restraints and measures to

- diversify the export structure through the encouragement of nonoil exports;
- reduce the import dependence of the economy, especially in the manufacturing sector, by encouraging the local sourcing of raw materials;
- restructure and broaden the production base of the economy and reduce its dependence on the oil sector;
- eliminate administrative controls, especially import licencing, and allow market forces to play a greater role in resource allocation;
- achieve appropriate pricing through removal of subsidies, especially for petroleum products;
- rationalize public enterprises through commercialization and privatization;
- reduce the external debt burden through debt rescheduling and debt–equity swap strategies, as well as encouraging capital inflow;
- correct gross overvaluation of the exchange rate, by setting up a foreign-exchange market; and
- rationalize and restructure the tariff system to assist and promote industrial diversification and enhance industrial growth.

Within the framework of SAP, the industrial-sector policy of the country acquired a radical new direction and orientation. The government reappraised the regulatory environment for investment, the structure of the projection for local industries, and the package of incentives available for setting up new projects. In this context, the new industrial policy was recently formulated by the federal Ministry of Trade and Industries, with the following objectives:

- providing more employment opportunities;
- increasing the export of manufactured goods;
- improving the technological skills and capabilities in the country;
- increasing local content of industrial output;
- attracting foreign capital; and
- increasing private-sector participation in manufacturing.

To achieve these objectives, new institutional frameworks in the financial, fiscal, social, and economic environments were set up.

The Nigerian cement industry

Growth

The first cement manufacturing firm in Nigeria was established at the initiative of the Nigerian government. In 1950, the colonial government invited the Associated Portland Cement Manufacturers (APCM), later renamed Blue Circle Industries, to establish a plant in Nigeria. APCM spent about 2 years surveying Nigeria's limestone deposits but then decided not to go ahead with the plant.

In 1954, the government convinced the Danish cement-equipment manufacturer, F.L. Smidth, and the firm's British associate, Tinnel Portland Cement Company, to enter a joint venture to build a cement-manufacturing plant in Nigeria. In 1957, the plant was built in Nkalagu, in eastern Nigeria, and the company was named the Nigerian Cement Company (NIGERCEM). About a month later, APCM, in partnership with the United Africa Company and the Western Nigerian Development Corporation, formed WAPCO. The plant commenced production at Ewekoro in 1959.

A few years after the formation of WAPCO, a clinker plant was set up to grind imported clinker and gypsum. It had an installed capacity of $0.6 \times 10^6 \text{ t a}^{-1}$, but closed down within 3 weeks because of a lack of a technical expertise. Between 1963 and 1964, three other grinding and milling plants opened: two at Lagos and one at Koko.

After independence in 1961, federal and regional government participation in industry and manufacturing became more pronounced because it was considered politically expedient to participate in the ownership of industrial enterprises. In 1962, the northern regional government commissioned a German firm, Ferrostahl A.G., to install an integrated cement plant at Sokoto; in 1964, the eastern regional government commissioned a cement plant at Calabar; and in 1965, the midwestern region (now Bendel State) commissioned Continho Caro for the construction of a cement plant at Unkpilla. This pattern continued with the establishment of Ashaka Cement Company and Benue Cement Company. By 1978, there were seven cement-manufacturing companies in Nigeria.

In 1978, at the peak of the oil boom, the federal government went into a joint venture with Benin Republic to build a cement plant at Onigbolo in Benin. The philosophy behind this international collaboration was that some of the cement produced would be sold in Nigeria, which has a large market for it.

Table 2 shows the profile of the industry (and also includes the Onigbolo joint venture with the Benin Republic).

Table 2. Profile of the Nigerian cement industry.

Company (location)	Est.	Partner (nationality)	Major machinery supplier
Nkalagu (Anambra)	1954	F.L. Smidth (Danish)	F.L. Smidth
WAPCO: Ewekoro (Ogun)	1959	APCM (British)	Wickers-Armstrong Polysius
Sokoto (Sokoto)	1962	Ferrostahl A.G. (German)	MIAG
Unkpilla (Bendel)	1965	Continho Caro (Austrian)	Krupp/Polysius
Calabar (Cross River)	1964	Polysius (German)	MIAG
WAPCO: Shagamu (Ogun)	1975	APCM (British)	Assorted
Benue (Gboko)	1975	Cementia (Swiss)	Polysius
Ashaka (Bauchi)	1975	APCM (British)	Assorted
Onigbolo (Benin) ^a	1978	F.L. Smidth (Danish)	F.L. Smidth

Source: Nigerian Institute of Social and Economic Research — ICD, Lagos.

Note: APCM, Associated Portland Cement Manufacturers (later known as Blue Circle Industries); est., established.

^a Joint venture with Benin Republic.

Employment

Employment categories in the cement industry range from the professional grades (the works, mechanical, production, electrical, and process engineers), to the skilled grades (the machinists, plant mechanics, pipefitters and welders, kiln mechanics, and kiln burners), to administrative staff, to unskilled labour.

All the cement-manufacturing firms in operation in Nigeria were set up with a foreign technical partner. These partners furnished the initial expertise needed for operations, so the proportion of expatriate personnel in most of the cement companies was initially high. However, with the implementation of the Nigeria Enterprises Promotion Decrees of 1972 and 1977 and determined efforts to train Nigerians, the cement industry now has many Nigerians in its management and professional cadres.

The present estimated number of staff at the seven firms in the cement industry is 9000. About 10% of these people are in the professional and management categories. The rest are supervisory, clerical, and other junior workers. The expatriate staff constitute about 2% of the total work force.

Input

The primary input for the production of cement is limestone. Secondary materials are gypsum, shale or clay, and fuel oil or coal. More than 95% of the sector's materials are obtained locally (most companies import the gypsum). One company now operates with 100% locally sourced materials, and CMAN is making efforts to ensure the local sourcing of all materials.

Nkalagu Cement and Ashaka Cement Company have captive plants dedicated to satisfying their paper-bag needs. However, the Nigerian Paper Mill in Jebba is the main supplier. The bag manufacturers have a total installed capacity of 230×10^6 bags per annum, and the seven main cement producers require 104×10^6 bags per annum. There is, therefore, an excess capacity of 55% in the bag-manufacturing industry.

Output

Although there have been seven cement companies operating in Nigeria since 1978, there are eight cement works (WAPCO has two, at Ewekoro and Shagamu). The combined installed capacity of the cement factories is about $5.3 \times 10^6 \text{ t a}^{-1}$. Table 3 shows the local production of cement by the individual companies in Nigeria from 1981 to 1990 and gives the capacity utilization for the industry as a whole. The output in 1990 was estimated at $3.05 \times 10^6 \text{ t}$, representing 61% capacity utilization. The industry's advantage in local sourcing has led to a fairly stable trend in the level of capacity utilization, so the capacity underutilization shown in the table must be attributed to other factors.

Another output of the industry is decorative products, on which WAPCO has monopoly. Portland Paints and Products Division (PPPD) was established in 1972, when WAPCO acquired Cement Paints Nigeria. At inception, the division manufactured only cement-based decorative products, known as Snowcem, Cemwash, and Colorcrete. Between 1974 and 1979, Sandtex products, manufactured in the United Kingdom by BCI, were introduced by PPPD. In 1980, the division commenced the local manufacture (under licence) of Sandtex trowel, Sandtex matt, and Sandtex textured. Other PPPD products has introduced to the Nigerian market include a roller-textured decorative coating (Bluetex) and a high-quality emulsion paint (vinyl matt emulsion).

Table 3. Local production of cement in Nigeria (1981–1990).

	Production (t)							Total (t)	Total capacity (t)	Capacity utilization (%)
	Ashaka	Unkpilla	Benue	Calabar	Nkalagu	Sokoto	WAPCO			
1981	664 191	192 651	388 561	58 756	145 104	—	1 394 960	2 844 223	4 870 000	58.40
1982	711 816	212 956	749 249	50 444	—	31 000	1 506 590	3 262 055	4 870 000	66.98
1983	593 817	182 364	716 500	19 162	—	54 691	1 374 637	2 941 171	4 870 000	60.39
1984	619 952	40 368	665 260	8 500	123 172	42 249	1 499 502	3 006 003	4 920 000	61.10
1985	691 657	106 636	806 788	57 295	180 685	91 257	1 404 930	3 339 266	5 420 000	61.61
1986	676 733	92 946	689 793	62 035	263 811	308 183	1 403 015	3 496 516	5 420 000	64.51
1987	736 975	131 467	553 996	56 312	236 547	229 474	1 437 305	3 382 076	5 240 000	64.42
1988	848 877	120 270	588 550	25 690	191 314	221 771	1 407 243	3 403 715	5 250 000	64.83
1989	844 013	68 059	485 359	28 652	165 886	230 575	1 141 868	2 964 412	5 150 000	57.56
1990	820 657	493 789	493 789	46 843	127 051	243 697	1 214 018	3 053 776	5 000 000	61.08

Accumulation of technological capabilities at WAPCO

WAPCO has its corporate headquarters in Lagos. Its current ownership is BCI, 33%; Odua Investments, 26%; Federal Government of Nigeria, 12%; UAC, 6%; and the Nigerian public, 23%.

The work force at WAPCO is about 2500 (including staff for training schools and repair shops); 21 of these workers are expatriates.

WAPCO commissioned its second plant, at Shagamu, in 1978, and expanded it in 1981/82. At commissioning, it was a two-kiln plant with a capacity to produce $0.65 \times 10^6 \text{ t a}^{-1}$. In 1986, it achieved a record of $1 \times 10^6 \text{ t}$ using the wet process. The present total installed capacity of the Shagamu and Ewekoro works is $1.69 \times 10^6 \text{ t a}^{-1}$, and actual production is about $1.5 \times 10^6 \text{ t a}^{-1}$. This represents about 50% of the total cement produced in Nigeria.

WAPCO has plans for plant extension, to be phased in over the next 10 years, depending on how the national economy performs. One plan is to add another kiln at Shagamu Works, thus increasing capacity by $0.45 \times 10^6 \text{ t a}^{-1}$. It is meant to generate funds for the redevelopment of the nearly obsolete Ewekoro Works.

Table 4 shows WAPCO's turnover and profits between 1979 and 1988.

Table 4. Turnover and profit levels of WAPCO (1979–1988).

	Turnover (1000 NGN)	Profit (1000 NGN)	After tax (1000 NGN)
1979	74 800	10 280	10 280
1980	75 400	10 520	10 520
1981	95 100	10 100	10 100
1982	110 500	14 300	9 900
1983	120 400	21 000	12 600
1984	127 200	29 000	16 000
1985	122 100	30 000	20 700
1986	189 300	35 000	26 300
1987	273 800	46 900	28 200
1988	333 800	68 000	40 500

Source: Various WAPCO annual reports and audited accounts (1979–1988).

NOTE: In 1995, 78.5 Nigerian naira (NGN) = 1 United States dollar (USD).

Besides PPPD, which manufactures special decorative products, WAPCO has the Portland Electrical Repairs Division (PERD), which provides electrical repair services like repairing, rewinding, and refurbishing electrical motors, transformers, and alternators.

Technical management

WAPCO's employment of 21 expatriates, including the technical director of the company, is a result of an agreement between WAPCO and BCI. Generally, the company operates through divisions, the divisions have departments, and the departments have sections. The Technical Division coordinates jobs or projects that are technical. Reporting to the technical director are the company engineering manager and the planning and development manager, who handles the project needs.

At the plant level, the chief executive is a general works manager (GWM). At

the time of this report, the two GWMs were Nigerians. The GWM is invariably a chemical engineer with about 10 years' experience in cement manufacturing, partly spent working or training at BCI cement plants in the United Kingdom, usually rising through the ranks of management and becoming versed in the intricacies of WAPCO operations. The GWM is mostly devoted to long-range planning and reports directly to the deputy managing director, who is an expatriate. Reporting to the GWM is the deputy general works manager, who handles the coordination of plant administration, personnel, accounting, stores and purchasing, etc., on behalf of the GWM.

There is usually a daily meeting of the technical management team, which consists of the department heads. At these, meetings, usually chaired by the GWM, the constraints and problems are discussed. At this level, and also at the technical director's level, the various development and refurbishment projects are identified. When projects have been identified, managers consider various factors to determine the projects' order of priority, almost invariably using a critical path analysis. A project team is then established, and a project leader is appointed to direct and coordinate the project. The role of the project leader can go either to a Nigerian or to an expatriate. The project leader has the power to draw from the personnel and use available skills at the works to successfully complete the project. The project leader also arranges for the procurement of the spare parts needed for the project. Table 5 depicts the level of Nigerian involvement.

Table 5. Nigerian involvement in technical activities in WAPCO cement works.

Level	Project type	Involvement of Nigerian and foreign staff
A	Routine day-to-day works operation	Local staff (Nigerians and expatriates)
B	Minor repair and refurbishment projects	Local staff with foreign technical backup (for design parameters, etc.)
C	More complex projects (e.g., building a new works or kiln)	Foreign experts

Improvement of imported technology

WAPCO commissioned its first works at Ewekoro in 1960/61, when the first kilns were built. Subsequent kilns followed until the full complement of three kilns at Ewekoro and two kilns at Shagamu was reached. Both works operate with the relatively old wet-process technology, although two of the kilns at Ewekoro were converted in 1981 to the semiwet process. Over the years, major refurbishment and improvement projects have been carried out at both works.

Ewekoro Works is one of the oldest successfully operating cement works in the world. Because of its obsolescence, it has a high maintenance-demand factor and a more complex mix of machinery and equipment than its sister works at Shagamu. It has a complete quarry unit; five 12 HP raw mills (1 HP = about 745 W); five cement mills; a set of silos for ground clinker and cement; a filter press for the two semiwet kilns; and three kilns.

Over the years, Ewekoro has had many improvement and refurbishment projects: rebuilding of the grate cooler structure; conversion of the long wet kiln to the semiwet process by the introduction of the filter press unit and the Lepol grate; refurbishment of the electrostatic precipitator unit to reduce dust loss and improve the environment; complete change of the chain system in the kiln; civil engineering works on the preheater system; and repairs and refurbishment of the back-end kiln-seal

system.

Shagamu Works was designed with the benefit of the experience gained at Ewekoro and is newer and more robust. It also is less complex; it has a big quarry; two big crushers (for rocks); three raw mills (3000 HP each); two wet kilns (60 t h^{-1} each); two cement mills (each with 3000 HP and a cement capacity of 100 t h^{-1}); and two cement-packing units (about 100 t h^{-1}).

The major refurbishment projects at Shagamu include the improvement of fuel-consumption efficiency; and dust insufflation to minimize dust-loss problems.

Case 1: Improvement to the Davies preheater system

At commissioning, Ewekoro Works consisted of three long kilns using the wet process. However, in the late 1970s, a conversion of the works was carried out so that two of the kilns could use the semiwet process. Concomitant with this conversion was a change in the process technology. The slurry is now subjected to further processing before it is let into the kiln proper. The slurry is first filtered in a reactor, where the moisture content of the slurry is drastically reduced. The slurry exits from the filter in a cake form. The cake material then passes to the nodulizer, which is essentially a horizontal plate rotating and vibrating on its axis. The effect of the movement of the nodulizer is to turn the cake into neat spherical balls.

The nodules then pass to the Davies preheater, where, as the name implies, they are preheated before they pass into the kiln. Passing the nodules through the Davies preheater reduces energy consumption. In the Davies preheater, nearly all the moisture in the nodules evaporates before they go into the kiln, where calcination takes place to produce the cement clinker.

The Davies preheater is a patented technology, introduced to WAPCO by BCI. It consists of three main parts: the dome, the bowl, and the floor. Surrounding the floor are two slanting coaxial cylinders. The outer one (the bowl) is mounted to a stationary, rigid steel frame so that it can rotate independently on its axis, which is a shaft connected to a bearing arrangement at the top. At the bottom of the dome there is space above the floor to give clearance.

These cylinders (i.e., the bowl and the dome) are sealed at the outer and inner edges with an annular top cover and hood, respectively, which confine the nodules between the cylinders but leave open to the atmosphere the upper side of a roof that spans and closes the dome. The underside of the roof slopes upward and inward and remains static. It has an inlet through which the nodules are fed and an outlet for exhausting gas.

The dome, bowl, and floor rotate independently about their respective axes. Only the floor is power driven, and this is by an auxiliary motor. There are no mechanical links between the bowl, dome, or floor. The rotation of the bowl and dome is due to the friction of the nodules. The nodules move through the annulus to the floor chamber and then exit into the front end of the kiln. Going counter to the flow of the nodules is hot air from the kiln, which preheats the nodules while they are in the preheater.

Water seals are used to keep the whole arrangement air tight. There are three water seals: the bottom seal and the inner and outer top seals. However, after the preheater was in operation for some time at Ewekoro, problems were encountered. There were leaks in the top seals, allowing water into the nodules. Furthermore, the water leakage caused frequent seizures of the whole unit.

A project team, set up to study the problem, came up with a solution: converting the wet seal to a dry seal at the top level. The seal chamber was given a heat-resistant rubber-*teflon* seal. A spring was also mounted so that the constant

motion of the parts helped to reinforce the seal. This solution was arrived at after much experimentation.

Case 2: Improvement to the cooler-drive system

The clinker exits at the back end of the kiln at a temperature of $>200^{\circ}\text{C}$. In this state, it cannot be fed into the mills for grinding. A cooler is, therefore, incorporated at the end of the kiln. In the original cooler assembly at Ewekoro, the cooler drive is mounted at the front end. The power to drive the cooler is transmitted via a V-belt pulley to a gear box, then to the drive shaft of the cooler. Thus, the drive is eccentric to the cooler. However, the machinery and components were too compact, making access for maintenance very difficult.

In 1985, the staff improved this unit by mounting the drive on the side. This arrangement was similar to the original, but the drive was mounted at the centre of the moving frame of the cooler, rather than being eccentric.

Case 3: Improvement to the cement-milling system

After cooling, the next unit operation in cement manufacture is milling. At this stage, the clinker, dosed with gypsum, enters the mill, where it is ground. Cement emerges at the end of this operation. The milled material is sent to the separator, where it is discharged onto a vibrating, electrically controlled screen. Coarse rejects fall off the surface of the screen, and the fine dust is sent to the silos for storage. The pumping unit, submerged in a pit, pumps the cement up against gravity to the silos. The vibrating screen is also at underground level, in the pump pit. However, water logging of the pit, especially during rainy seasons, hampered production and made maintenance more difficult.

The screening mechanization is now a mechanically driven rotary screen, which rotates at the same speed as the mill. As well, the pump was brought up to ground level, eliminating all the problems.

Diffusion of technology

The original driving force for the creation of WAPCO was not so that Nigerians could acquire technology but that the foreign merchants could realize a profit and develop an overseas market. However, over the years, Nigerian involvement in transfer, acquisition, and management of technology began to be emphasized. The main area of Nigerian involvement at Ewekoro was in the preinvestment and construction phases, particularly in infrastructure and civil works. The Nigerians involved were building contractors and bricklayers, etc. However, Nigerians were not involved in feasibility studies, geological surveys, engineering designs, or equipment fabrication.

By the time Shagamu came on stream, in 1979, a core of Nigerian engineers had emerged with experience gained in operating the old Ewekoro Works. The engineers had also been seconded to similar cement works in the United Kingdom for training in daily-routine management.

Nigerians were still not involved in the core of technological activities, but they were involved at the plant or works level after commissioning of the plants, in other words, at the level of production capability. In this phase, a considerable amount of technical change occurred. The Ewekoro conversion and most of the cases discussed above demonstrate this.

A degree of diffusion of technology took place. This was not dictated by a conscious or deliberate effort to acquire technology but by market forces. In 1972, WAPCO established the PPPD to manufacture cement-based decorative products. The division was incorporated in 1985 as a limited liability company. The technological

capability acquired within WAPCO was diffused to the host economy in the form of the know-how at PPPD. The general manager of PPPD is a Nigerian, as is a large percentage of its work force.

PERD was established in 1982. The creation of the division was motivated by the need to conserve foreign exchange and by the dearth of electrical repair services in the host economy. PERD has grown to such an extent that it now offers its services to the local petroleum, steel, and brewing industries. The division will soon commission its compressor-motor rewinding and testing workshop, which will specialize in refurbishing burnt-out hermetically sealed compressor motors for air conditioners, refrigerators, and freezers. PERD now has the capacity to rewind and repair large motors ranging from 3.3 to 11 kV. The division has satellite workshops at Warri to cater to the eastern market and at Kaduna to cater to the northern market. One workshop of the division is now managed successfully by a Nigerian.

SAP has generated some corporate responses from the OPC industry, which diffuses technology in the host economy. In WAPCO's case, such responses have included local machining, casting, and fabrication of spare parts.

WAPCO has some interaction with local universities, which provide consultancy services, environmental-impact assessment studies, energy audits, and so on. The WAPCO offices and works, for their part, provide industrial training for management and engineering undergraduates. Lecturers from Nigerian universities sometimes spend their sabbatical leave at WAPCO because it is a corporate member of the Nigerian Society of Chemical Engineers.

Training and development of human resources

WAPCO operates local and in-plant training programs for the development of human resources needed to manage the imported technology. These programs could be categorized as *in-plant* and external training. The local training revolves around the Training Centre at Ewekoro Works. The Training Centre was established in 1968 with a staff of five: the principal, a training officer, and three instructors. The primary aim of the centre then was to retrain newly recruited technical college graduates whose previous training experience was not entirely relevant to the factory. The first few students took a 1 year brush-up course in three main trades: mechanical, electrical, and process-control engineering. Later, automobile engineering was added to the curriculum.

With the opening of the second works, at Shagamu, the need to increase the number of trained personnel and the scope of training became apparent. The activities of the Training Centre, therefore, had to be expanded. In 1971, the first apprentices were admitted from forms III and IV of secondary school to undergo a 4 year program in the relevant trades.

With the high labour turnover, the company had to substantially increase its apprenticeship intake, from about 12 people to 24, and it established a department to train and develop staff.

In 1978, as an experiment, the company took on some production trainees. The initial intake of six candidates had credits in chemistry, mathematics, and English. The experiment was extremely successful, and some of these people now hold very responsible positions at the company.

Analysis of results

Microlevel

Successful acquisition of technology follows the path of project preparation, project execution, and the final stages of industrial engineering and transfer of technology for

particular needs. This means that the importing firm has to acquire the necessary skills to function without any (or very much) technical assistance from its overseas partner.

WAPCO had a mixture of successes and failures in its efforts to acquire and accumulate technical know-how. It was evident from the start of this study that WAPCO was extremely successful in the Nigerian context. It has consistently been returning respectable annual dividends to its shareholders, and it has achieved more capacity utilization over the years than its competitors. In managing technical change, however, the outcome is not so clear. In an effort to modify the imported equipment and machinery, WAPCO set up the Technical Division. It would be difficult, though, to sustain such skills without the help of resident foreign experts, especially the BCI engineers, who have been part and parcel of WAPCO. However, the changes at the works were accomplished with a considerable amount of Nigerian participation, and the Nigerian engineers become more confident as their participation became more meaningful.

One method for assessing the diffusion of an imported technology is to examine the linkages between the technology and the local economy. A major raw material in cement manufacture is gypsum, and BCO imports the mineral into Nigeria for WAPCO, despite reported occurrences of the mineral in Nigeria. Claims have been made that the local gypsum is of inferior quality and that the local deposit is not commercially exploitable. These claims have yet to be proven with surveys and reports. It seems that WAPCO and, indeed, the cement industry in Nigeria, do not use the local gypsum because there is no enabling environment to encourage them to do so. In other areas of diffusion, WAPCO has scored well, particularly in the diversification into decorative products. The multiplier effect of this move was obvious, and such a venture was unique in the Nigeria cement industry.

WAPCO's technical training program for lower and middle management is a step in the right direction. In fact, the training and development of human resources could be partly responsible for the measure of success achieved at WAPCO. However, the company cannot really claim to have the technical capability to carry out investments in new projects to create new units of production without the assistance of BCI.

The seeds for achieving this capability are present in the Training Centre and the orientation of management toward problem solving, but these initiatives need to be consciously strengthened to achieve the objective of complete technological capability. The interviews, especially those conducted at BCI's R&D Division in Kent, revealed that BCI is willing to help WAPCO achieve this objective. Indeed, BCI would encourage this to ensure it receives its dividends from WAPCO.

Macrolevel

In 1986, as part of SAP, the federal government put in place a set of fiscal and economic policy measures to restructure the Nigerian economy and put it on a path to sustained growth. However, the effect of SAP on the Nigerian economy, in general, and the cement industry, in particular, has been traumatic and far reaching. SAP-induced perturbations in the capital market have drastically increased the cost of capital. The cement industry is not working at full capacity and is not able to make new investments in expansion.

The federal government formulates policies to encourage optimal performance of the industry and the R&D institutions and makes plans for setting up industrial firms and funding universities, but it fails to create a dynamic link between all those responsible for technological-capability accumulation. No aspect of policy addresses the ways industrial firms develop and accumulate their own technological capabilities

or use R&D results to solve specific industrial problems and select, manage, and assimilate imported technology. This was very evident from the case of WAPCO: technical changes at the WAPCO works were really dictated by the profit motive, and there was hardly any awareness of the government's S&T policy in WAPCO's day-to-day activities. WAPCO has no incentive to develop technological capacity.

Recommendations

Based on this study, the following recommendations are made:

1. Government should develop an incentive system to encourage entrepreneurs to invest in more foundries, forges, machine shops, etc., as these provide inputs to large firms and are the "missing link" in the Nigerian industrial sector.
2. The government and the cement manufacturers should together make efforts to establish local sourcing of gypsum.
3. The Training Centre at WAPCO should be used as a model for other training centres in the Nigerian industrial sector.
4. Government should provide a dynamic link between national R&D institutions and industry, thus ensuring a sustained generation of technical change.
5. Government should realize the close relationship between its industrial-development policies and its S&T policies. Closer ties should be forced between the various national S&T institutions and those concerned with industrial development.

CHAPTER 19

Institutions Supporting Technical Change in Nigeria: The Role of Industrial Development Centres

I.E.S. Amdi

Introduction

In many developing countries, much of the technological capability that has been built up slowly over the years is in the small-scale industries in the informal sector. The pace of technical change within the informal sector has been accelerated because of the supportive role of various institutions, such as the United Nations Industrial Development Organization (UNIDO); the private sector; and national governments, which assist through industrial development centres (IDCs). Essentially, the IDCs try to promote technical change in the small-scale enterprises. In this area, the IDCs have received considerably more attention than similar institutions.

Technical change arises through an evolutionary process or by revolutionary breakthroughs. Although the innovation may be small, the development of a technological base through incremental technical knowledge "can further refurbish the pace of technical process" (Lall 1982, p. 82).

What is important in the small-scale enterprises is the acquisition of technological know-how that can generate changes in the process of diffusion, imitation, and adaptation. The acquisition of knowledge in the informal sector can be brought about in Nigeria with the assistance of public institutions. Indeed, institutions like IDCs can "play a pump-priming role and assume primary responsibility for . . . managing techno-economic and techno-management services and facilities for small-scale enterprises" (Oguntoye 1974, p. 2).

The major requirements of the small-scale entrepreneurs are twofold: (1) push and incentive from the government, through bodies such as the IDCs; and (2) the capability to translate the inputs (technical knowledge) into reality and thus improve the quantity and quality of products for the market.

The IDCs established by the federal government of Nigeria operate within the framework outlined in the government's industrial policy guidelines. The third and fourth national development plans stressed the role of the metal-working sector as pertinent to the overall pace of industrial development and technical change in Nigeria. The planners hoped that promoting small-scale enterprises would generate substantial employment opportunities for thousands of unemployed youths, stimulate indigenous entrepreneurship, and mobilize local resources, capital, and skill. The major focus was the development of technological capacity in indigenous entrepreneurship. The government was aware of the inadequacies of the small-scale industrial sector, which include a paucity of technical know-how, a shortage of managerial ability, and inadequate linkages among entrepreneurs. This is why the sector was to be given a "credit scheme and infrastructural facilities and incentives" (Federal Republic of Nigeria 1981 p. 170).

Since the early 1970s the government has emphasized its interest in the development of small-scale industries and, indeed, has believed that it can act as the springboard to industrialization. The government's policy has been to create opportunities for local industries. The expansion of employment has immense advantages, not only for unemployed graduates, but also for rural dwellers.

Several agencies help with the promotion of the small-scale industries: the federal Ministry of Trade and Industry, the state ministries, and the IDCs at Zaria, Owerri, and Oshogbo.

This article examines the institutional efforts to help the small-scale metal-working sector accumulate technological capability and identifies the strategies the IDCs use to improve the technological capability of the small-scale entrepreneurs.

A history of the industrial development centres

The emergence of the IDCs was a result of the Nigerian government's request to the United States to help development and strengthen Nigerian private small-scale industries. Experts carried out feasibility studies and recommended that the government concentrate on five areas: wood working, metal working, automobile repair, textiles, and leather working.

The experts recommended establishing three IDCs: at Zaria (established in 1969), to serve the north; at Owerri (established in 1965), to serve the east; and at Oshogbo (established in 1976), to serve the west. Initially, these centres were to be used for demonstration, training, and seminars. Entrepreneurs were expected to learn about new production techniques, new types of machinery, record keeping, and small-scale business management. The IDC at Owerri enjoyed immense assistance from the Ford Foundation, and the one at Zaria had assistance from China. The aid to the IDC at Oshogbo came from UNIDO. Initially, it was thought that these centres would be sufficient, but more were needed, so additional centres were established in 1978. These were at Maiduguri, Benin City, Uyo, Sokoto, and Abeokuta. By 1981, there were also centres at Bauchi, Akure, Kano, Ilorin, and Port Harcourt. It must be stressed, however, that only the oldest three — at Zaria, Owerri, and Oshogbo — have been very effective.

Organization and functions of the industrial development centres

The IDCs provide the institutional machinery to solve the main financial and technical obstacles facing small-scale industries. The centres are organized and managed by the federal Ministry of Trade and Industry. Each centre has three divisions: a technical services division, under the control of a principal technical officer; a management division, providing management, support, marketing, counselling, training, and feasibility studies; and an administrative division, coordinating the services of the centre. The IDCs provide industrial extension services to the proprietors of small-scale industries, appraise loan applications, train entrepreneurs, and undertake applied research on industrial products. The centres give advice on the choice and purchase of equipment. They can also adapt some of the equipment to suit the Nigerian environment.

The IDCs at Zaria, Owerri, and Oshogbo have assisted in the promotion and development of small industries in many states. They cooperate with the state governments in the granting of loans and supervision of projects for the entrepreneurs. The small-scale industrialists apply for loans through the state ministries of trade and industry. These in turn forward the applications to the IDC for evaluation and appraisal.

The staff at the Ministry of Trade and Industry works with the staff at the centre to identify and assess the project. In the evaluation of a project, the following factors are considered:

- a feasibility study, considering the industrial potential of the project;
- the future markets for the product;
- the management expertise of the proprietor;
- the labour force; and
- the likelihood of that the owner would be able to carry on if faced with inadequacy of capital or unavailability of raw materials.

The secretary to the Small-Scale Industry Division of the Ministry of Trade and Industry and the IDC officials then accept or disqualify the applicant. The IDC makes conclusive recommendations to the ministry. The IDC representative has the dominant role on the committee because he or she determines whether the project is worthwhile and whether the proprietor of the business has the capacity to run it. The IDC is also responsible for the disbursement of the loans. According to officials from the IDC, cheques are normally issued by the officials of the state governments and forwarded to the centre.

The IDCs have three major operational drawbacks: (1) They are organized as integral parts of a government department. Because the rules that govern the ministry also apply to them, requests have to be processed using bureaucratic procedures, and, therefore, delays are inevitable. This limits flexibility and the freedom required for successful operations. (2) They lack inadequate equipment, such as machinery and vehicles. (3) They lack competent technical staff.

Methodology

About 50 entrepreneurs in the metal-working sector were interviewed, as were IDC staff. A case study of the small-scale metal shops in Benue State was undertaken to demonstrate the extent to which IDCs have been able to generate technical change in the fabrication and sheet-metal workshops. The analysis was based on the in-depth case study.

Assistance to the metal-working sector

Evidence from the fieldwork shows that the IDCs at Zaria, Owerri, and Oshogbo often provide technical, financial, management, and consultancy services, either at the insistence of the IDC and the ministry or at the request of the proprietors in the metal-working sector.

Table 1 shows the nature of the services provided by the IDCs and the levels of satisfaction expressed by 24 proprietors of fabrication workshops in the metal-working sector. Most of the entrepreneurs were satisfied or very satisfied with the government's provision of management services and training. The metal-working entrepreneurs were less satisfied, though, with the IDCs' technical services. For instance, almost 80% of the sample expressed dissatisfaction with the technical advice to improve the design and quality of products, which implies something about the nature of the technical services provided and the technical change introduced by the IDCs.

The technomanagerial competence acquired by the metal-working sector is the most important issue. Although management services are important, the indigenous small-scale industries require technical knowledge. Evidently, a rethinking of policy

Table 1. Quality of management and technical services provided by industrial development centres as perceived by 24 proprietors of fabrication workshops in the metal-working industry.

	VS		S		NS	
	(%)	(n)	(%)	(n)	(%)	(n)
Management division						
Training of proprietors in modern management	29.2	7	45.8	11	25.0	6
Guidance and advice in the workshop for better planning and organization to improve productivity and reduce costs	25.0	6	54.2	13	20.8	5
Marketing course in pricing, sales strategy, and marketing methods	41.7	10	41.7	10	16.7	4
Help with record keeping	33.3	8	50.0	12	16.7	4
Help with work simplification	41.7	10	37.5	9	20.8	5
Technical services division						
Technical advice on selection of management	25.0	6	50.0	12	25.0	6
On-the-job training of artisans	12.5	3	29.2	7	58.3	14
Undertaking of repairs and maintenance of machinery at centre workshop	16.7	4	16.7	4	66.7	16
Advice and assistance to solve operational problems in the workshop	33.3	8	16.7	4	50.0	12
Advice to improve design and quality of products	12.5	3	8.3	2	79.2	19

Source: Field research work based on the study of 24 enterprises in Benue State.

Notes: VS, very satisfactory; S, satisfactory; NS, not satisfactory.

by government is required to begin to strengthen the technical competence of the entrepreneurs in the fabrication subsector.

Some efforts were made by the IDCs and the Ministry of Trade and Industry to assist in the sheet-metal industry, which manufactures metal boxes, stoves, and water tanks. Many of the respondents indicated that government assistance in the area of management service was satisfactory. However, like the fabricators, the sheet-metal entrepreneurs indicated that the technical services provided by the IDCs were unimpressive. The quality of the training offered appears more satisfactory: 61.5% of the respondents were satisfied with this service. Although the management and consultancy services may be an important prerequisite for the expansion of technological capability, the respondents' dissatisfaction with technical services suggests that the IDCs and the ministry emphasized management at the expense of technical knowledge, which the entrepreneurs require more than anything else.

The neglect of technical services may be attributed to the fact that technical staff were in short supply, as indicated by interviews conducted with the staff of the metal division of the IDCs. The IDCs also complained about a lack of vehicles to

convey their staff to the metal-working sites. The IDCs also lacked the finances to meet accommodation costs, which limits the time IDC staff can spend at the industry workshops. Because of this, the proprietors often have to travel to the IDC office when they need technical services.

Financial assistance from the government

When Benue State was created in 1976, its government recognized the importance of the small-scale industries in the overall development of the state and tried to help them by providing loans with soft terms. The federal government's policy was to contribute 50% of whatever was disbursed by a state government to the proprietors. The Small-Scale Industry Credit Scheme was set up to aid the manufacturing and processing industries. Between 1977 and 1986, the scheme loaned a total of 2 706 000 NGN to about 194 proprietors in Benue State. The loans were provided at no more than a 5% rate of interest and repayable in instalments for 5–8 years. Many of the beneficiaries misused the money. Officials at the Ministry of Trade and Industry revealed that substantial amounts have not been repaid, and, indeed, many of the proprietors have disappeared.

Table 2 lists the beneficiaries according to type of industry. The metal-working industry received 20.6% of the loans, which is quite high. Between 1977 and 1985, metal workers were busy, and many applied for loans. The high proportion of funds allocated to metal working can also be attributed to the proximity of the Igbo states, Anambra and Imo (the Igbos dominate this trade). We found out, however, that the government officials were reluctant to aid proprietors who were not Benue State indigenes; political interests seemed to have determined who could get the loans.

The effectiveness of the Benue State ministries and the industrial development centres

It is important to appraise the extension services rendered by various government bodies to the metal-working industry in Benue to bring out the value of IDC support in promoting technical change. The government institutions assigned the responsibility for promoting small-scale industry in Benue are the federal Ministry of Trade and Industry, the federal Ministry of Science and Technology, the Benue State Ministry of Trade and Industry, and the IDCs.

Federal ministries of Trade and Industry and Science and Technology

The federal government, through the ministries of Trade and Industry and Science and Technology, formulates policies and makes decisions relating to the structure and activities of the small-scale industries. The two ministries recently had to work together to provide policy guidelines. To some extent, it can be argued that the efforts of the ministries have expanded the base for the takeoff of the metal-working industry. But evidence shows clearly that the resources available to the proprietors and their workshops are inadequate. The bureaucratic control of the process very often affects the speed with which the IDCs can work. Some measure of devolution of power to the IDCs and the state ministries has become inevitable.

Benue State Ministry of Trade and Industry

Although the Benue State Ministry of Trade and Industry has made some contribution to the expansion of the metal-working industry in Benue, evidence has shown that officials' involvement with the proprietors is minimal. Findings also indicated that the

Table 2. Government loans to proprietors by type of industrial activity in Benue State.

Type of project supported	Borrowers (n)	Amount (NGN)
Printing	8	113 000
Shoemaking	4	36 400
Poultry	24	215 420
Laundry	3	20 000
Bakery	21	101 760
Gari processing	9	39 000
Sawmilling	6	166 000
Automobile parts	8	22 845
Block making	20	256 000
Piggery	2	41 176
Rice milling	9	46 473
Knitting	2	7 000
Garments	4	24 490
Electrical works	2	15 856
Popcorn	4	14 222
Photocopying	1	8 000
Weaving	5	27 403
Leather works	5	27 000
Tailoring	3	12 000
Automobile servicing	5	128 000
Coffee milling	2	11 000
Metal work	40	358 082
Stone crushing	2	72 782
Wood turning	1	700
Yam flour	1	1 200
Soap making	2	8 000
Total	194	1 783 809

Sources: Proprietors; staff of IDC Zaria; Ministry of Trade and Industry, Makurdi, Small-Scale Industry Credit Scheme annual reports.

Note: In 1995, 78.5 Nigerian naira (NGN) = 1 United States dollar (USD).

ministry discriminates between nonindigenes and state indigenes in the distribution and processing of loans.

Industrial officers should involve themselves more with the proprietors, particularly in the area of management skills, but some officials at the ministry had a lukewarm attitude because (they argued) nonindigenes dominate the metal-working industry. This argument, however, has little basis: the investigation showed that the indigenes are not predisposed to this line of business, and regardless of where the proprietors come from, their activities in the industry contribute to the development of the state.

Furthermore, the contribution of the state ministry is hampered by scarcity of funds. But very often, even when funds are available, the state diverts these to other needs. This is most likely tied to the low level of commitment of the officials to the small-scale industrial sector.

The industrial development centres

The investigation showed that the entrepreneurs derived substantial benefits from IDC guidance and advice about workshop management. In addition, record keeping

improved and workshop tools were simplified. The adaptations improved the products and showed that the entrepreneurs had reacted positively to the government's encouragement. The success of the government's management service is not unconnected with the fact that this service costs less than the technical services. Moreover, the input required for the management services (advice and counselling) is far less complex than the input required for the technical services.

The appraisal of the IDC technical assistance to the metal-working industry must take into account the technical background of the proprietors. The government designed a healthy policy for the small-scale industries, but as a major policy instrument, the IDCs have inadequate technical staff and equipment to provide the services needed by the proprietors in their workshops.

A cursory examination of the IDCs' technical advice for selecting a manufacturing process, undertaking repairs, and improving operations reveals their inadequacy. The successful improvement of a design or introduction of an incremental innovation in any workshop depends on the proprietor's ingenuity, but the IDC, as a government organization, must step in when required to support the process. The results of our findings indicated that the IDC officials' level of motivation was not high enough. The reason, in part, for the low level of commitment and productivity of the IDC staff is excessive government control through bureaucratic processes. As a civil service instrument, the IDC is, thus, unable to perform its role effectively.

Conclusion

This article has highlighted the various ways that government agencies have helped to promote the growth and development of the metal-working sector, particularly the fabrication and sheet-metal subsectors. Ordinarily, such assistance would be expected to promote the accumulation of technological capability of the metal-working sector; however, we conclude that much is still required from the IDCs.

The inability of the IDCs to adequately promote the small-scale entrepreneurial activities required for creative technical change and innovation in the process of production further limits the capacity of the industry. This is because indigenous technological development cannot be generated simply by wholesale importation of foreign technology. Technical change has to do with the creation of the skills needed to innovate. The IDCs appear to lack the capacity to effect deep changes in indigenous small-scale entrepreneurship. The implication is that the small-scale entrepreneur, who is a major player in technological development, may remain stymied without better state support.

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CHAPTER 20

Technological Change and Project Execution in Nigeria: The Case of Ajaokuta Steel Plant

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Introduction

This work examines industrial development as it is reflected in the importation, adaptation, and assimilation of technology. Studies have established that mastery of technology can be brought about only by deployment of resources in a systematic and sustained manner. Although developing countries introducing a new technology with the complexity of an integrated steel plant do not have to master the basis of the technology, they will face formidable technomanagerial challenges without that mastery.

Nigeria is a late starter; technologically, it is behind South Korea, Brazil, and India, as is reflected in the research literature. Whereas research in the more advanced developing countries deals with innovative changes in the mature industries (steel, capital goods, etc.), the effort in the present study and in most related research in Nigeria is limited to examining the introduction of technology and the mastery of production technology.

Specifically, this study

- reviews the literature on the transfer of technology in, and the development of, the steel industry in Nigeria;
- undertakes a case study of the Ajaokuta Steel Co. Ltd (ASCL), examining the planning (including feasibility studies and other documentation);
- evaluates the contractual relationships between ASCL and the external suppliers of technology to determine the extent to which a continuing reliance on external participation is assumed; and
- examines ASCL's training and other efforts to develop human resources, concentrating especially on the use and maintenance of transferred technologies.

Steel production in developing countries increased from 1.5% of the world total in 1950 to ~11% in 1983, on a per-person basis (UNIDO 1986). This is equivalent to 30–36 kg per person, whereas the corresponding figure for developed countries is 400–600 kg. Africa's production is abysmal — about 8 kg per person. The countries that have established integrated steel plants in Africa, Asia, and Latin America are few, and the degree of self-sufficiency, that is, percentage of demand provided by local production, varies markedly by region: Latin America, 73%; Asia, 56%; Middle East, 12%; and Africa, 7%.

Practically all projects under implementation in sub-Saharan Africa, with the exception of the Ajaokuta plant in Nigeria, have been either abandoned or frozen. Similarly, with the exception of SICARTA, in Mexico, and ACOMINAS, COSIGUA, and

some other minor projects in Brazil, all steel projects in Latin America have been either frozen or cancelled. In contrast, China, South Korea, and Taiwan have displayed dynamism, have enjoyed healthy project financing, and have installed capacities at low costs, emerging generally strong in steel technology.

The most common cause of delays and cancellation is shortage of funds. The extensive infrastructures normally required to support steel-making projects in developing countries contribute significantly to the total cost, and few countries can make the investments without securing loans. The external debt carried by developing countries is already so great that creditors have been reluctant to provide additional loans, especially as most developing countries have experienced serious difficulties servicing their debts. Also, the nature and source of financing strongly influence project implementation — projects with a high percentage of local equity, as in South Korea, rarely suffer project delay (UNIDO 1986).

Steel development demands a high level of skills, technical and organizational capability, and systematic sophistication (supply of capital goods and technical services). These components are available (partially or wholly) in most of the Asian nations, whereas they must be imported by African countries and paid for in foreign currency. Lack of financing, therefore, is a sign of more fundamental problems.

Because of the large, diverse, and specialized nature of steel-making equipment, investment in just the technology, especially for integrated plants, is thousands of millions of United States dollars (USD). The cost per unit of installed capacity has risen over time (an average 350 USD t⁻¹ in 1965 and 1700 USD t⁻¹ in 1980) and varies markedly between regions (UNIDO 1986). The costs are still rising so fast that time overruns are very expensive, and the increase in costs from delays sometimes makes project completion impossible.

The large capital requirements limit ownership in developing countries to government and, usually, joint ventures (Maxwell 1982). Other characteristics of steel making contribute to the profound effects investments in it have on the economy. According to Maxwell, these characteristics are the indivisibility of the steel plant equipment, the long gestation, the irreversible nature and widespread implications of the process chosen, the idiosyncrasies of each plant, and the complexity of the process. For example, because of the indivisibility of the equipment, the designers (initially or during expansion) prefer to build in extra capacity in units like rolling mills. Overall capacity can later be expanded without unduly large investment in new plant units. These add-ons, which are temporarily (and indefinitely) unproductive, can be a dilemma for steel-plant designers.

Long gestation

A long gestation is inextricably linked with inflated costs: the bigger the project, the higher the cost of delay, manifested in contractual escalation costs, production losses, and prolonged paybacks, with attendant interest payments on borrowed money. Public exasperation with the steel projects in Nigeria has been largely due to expansion in the costs caused by the long delays in finishing the plants, as well as the huge sums of money invested. The repercussions on the economy as a whole are so widespread and debilitating that an investigation of the sources and causes of long gestation is almost essential for a study such as this one.

Projects like the creation of steel plant are a process: a series of inter-connecting actions — past, present, and future — not “phased,” or discrete, periods of development. Past actions and outcomes largely influence current and future actions and discussions. In other words, the evolution of a project such as the Ajaokuta steel

plant in Nigeria is affected as much today by discussions at its conception as it is by, for example, a decision to add a new slab caster. In fact, the decisions made 15 years ago may have compelled the action taken today. Nevertheless, classifying decisions and events into phases, or categories, simplifies analysis and discussion. Gestation, as understood by Maxwell (1982), comprises all the events from preinvestment through to construction and from start-up to operation.

Preinvestment starts when the company that will build, own, and operate the plant is legally constituted. In this period, planning, feasibility studies, and financial negotiations are undertaken. Political sanctions are also obtained.

Construction begins when preinvestment effectively ends, consisting of civil engineering works, procurement and construction of structural and infrastructural facilities, erection and installation of process plants, dry testing, and commissioning. Detailed engineering and fabrication of equipment may predate this phase. Start-up of steel making is taken to mark the end of the construction period, although other sections of the plant may begin operations later.

Start-up, according to Maxwell (1982), lasts "from the beginning . . . of production . . . till the achievement of annual output, which corresponds to . . . nominal production capacity." Some plants (especially in developing countries) remain in the start-up phase indefinitely, without achieving anything near their nominal capacity, because of a myriad of constraints (management problems, inadequate raw materials, power outages, and absence of ancillary facilities). Maxwell subdivided start-up, defining *technical start-up* as the period from the start of production until staff learn to operate the plant. Implementation is the sum of time involved in construction and start-up.

The literature on Latin American steel plants indicates that a long gestation period for greenfield plants is the rule, rather than the exception. The time involved ranges from 3 to 19 years, with an average of 10–11 years for both greenfield plants and major expansions. The average is 3–4 years each for preinvestment, construction, and start-up.

A look at Indian plants reveals a similar pattern. Bokāro Steel Ltd was incorporated in 1964; commissioning was scheduled for 1971. Actual commissioning was in 1976. Implementation took 2 years. An expansion, scheduled for completion in 1977, was actually completed in 1984. The first stage of the Bhilai steel plant had a modest time overrun of 2 years, but two expansions had an 8 year overrun.

In the case of Ajaokuta, 12 years passed (1971–1983) between the incorporation of a formal body to oversee steel development in Nigeria to the commissioning of the finishing mills (wire-rod mill and light-section mill). A rescheduling took place in 1985, and 23 years slipped by (1971–1994) without the full integration of the plant. This record compares with the longest gestation documented in recent literature — the expansion of the Acerias Paz del Rio plant (19 years) and the establishment of the Chimbote (18 years) and Somisa plants (16 years).

The reasons for such long gestation periods are relatively few. Preinvestment is delayed by either a shortage of funds for the capital-intensive operation or a political intervention — usually government's planning of the steel industry. The main reasons for long gestation in construction include suspensions of foreign-exchange remittance by the central bank, delays involved in securing financing for equipment from suppliers, equipment-delivery delays, and organizational problems. Start-up seems to be bedeviled by conceptual errors in the design of the overall plant or some of its facilities; weaknesses or defects in equipment fabrication or plant construction; inadequate preparation of the plant's work force; shortages in supply of key raw materials, such as iron ore and coal; shortages in the supply of key services, such as

electricity; and overoptimistic demand forecasts.

One of the key problems is building on a greenfield location — virgin lands in developing countries, which need 75% more spending than an industrialized site and 35% more than a site with some infrastructure (UNIDO 1983). This is demonstrated clearly in Maxwell's study (1982, p. 107):

In the Paz del Rio plant, the lack of availability on time of the planned electrified railway to haul ore and coal from nearby mines to the plant led to some shortages in these raw materials during the startup period . . . while lack of sufficient electricity supply slowed . . . production in Paz del Rio and Chimbote greenfields plants.

These examples run disturbingly parallel to the pattern our study has documented for the Ajaokuta steel plant. *African Business* (May 1986) reported comments by the Minister for Steel Development, T. David-West:

It would have made more sense to have given priority to . . . iron ore mining at Itakpe in Kwara State and should logically have started five years before the Ajaokuta works were commissioned.

The former minister also remarked that it was "important to synchronize the development of the mine with the completion of the Ajaokuta blast furnace." These observations were poignant because of the serious lags between the development of the mines (as well as other infrastructure) and that of the steel plant.

The problems can be grouped not only by phase but by focus:

- finance — shortages of foreign exchange, high indebtedness, and total or almost total importation of capital goods, technology, and engineering services;
- planning and management — inexperience, low levels of technological and organizational skills, and lack of precedents;
- politics — control, bureaucratic interference, and shifting government policies;
- execution — behaviour of the contractor involved in project implementation;
- infrastructure — available and required;
- design — concept, fabrication, and modifications;
- supply — lack of critical inputs such as raw materials, spare parts and consumables, power supply; and
- personnel — inexperience, particularly of the start-up team.

How much damage was incurred with any one of these problems is determined directly by the size, complexity, and nature of the project.

The seeds of long gestation are planted long before the effects are noticed; current, as well as future, actions and decisions could be enriched by a careful look at decisions taken *ex ante*. This demands a review of the evolution of steel making in Nigeria.

The evolution of steel making in Nigeria

Soon after independence, the Nigerian government sought to build an iron and steel industry as the core of its industrial infrastructure. The availability of cheap steel in various forms (bars, sheets, and plates) is considered a key to the development of nations because iron and steel form more than 80% (by weight) of all metals in

general use. Production of steel would, therefore, quicken industrial development and encourage local manufacture of capital goods. Early suggestions were to establish rolling mills using imported steel ingots; miniature steel plants to recycle steel scrap were also considered.

Feasibility studies were commissioned, and their results were examined. However, the discovery of iron ore deposits at Udi and Agbaja and coal at Enugu, along with the potential for electricity from the Kainji dam project, then approaching completion, made a case for the establishment of an integrated iron and steel complex.

Broadly, the two steel-making processes involve either mini steel facilities or integrated plants. Integrated plants typically use a conventional blast furnace – open-hearth furnace (BF–OHF) or a direct-reduction electric-arc furnace (DR–EAF). Mini steel facilities are characterized by low economies of scale; low investment per tonne of installed capacity; rapid construction and, thus, reduced time and cost overruns; relatively fast and simple buildup of production; low energy consumption, especially for scrap; and negligible associated environmental pollution. The main disadvantages are a restricted product mix; an expensive main energy source (electricity); and vulnerability to price fluctuation and availability of scrap. Integrated plants have an advantage where markets are large, annually producing up to 10×10^6 t of steel in diverse shapes and items; also they can combine different sources of energy. However, they require large capital outlays, often incur cost and time overruns during construction, experience a slow production buildup, require an extensive infrastructure and organization, and pollute the environment.

Between 1961 and 1965, several firms were invited to submit proposals for the construction of an integrated iron and steel complex in Nigeria. These firms, all of Western origin, were of the opinion that available raw materials could not economically support an integrated steel work with the available technology. A proposal, which was seriously examined, was to build a plant using the “strategic Udy process,” which was then at the pilot-plant stage, under development in the United States. The government founded the Nigerian Steel Associates, a joint venture with Westinghouse and Koppers. The project did not, however, take off, as the process did not pass commercial-scale testing.

In 1967, a UNIDO study cited Nigeria as a potential market for steel. A team of Soviet steel experts visited Nigeria the same year to conduct a feasibility study for an integrated iron and steel works. Their study recommended the blast furnace – basic oxygen route to iron and steel making. The study admitted that the local ores were of poor quality and recommended further geological surveys. In 1970, a contract was awarded to Technoexport of the Soviet Union to determine the quality and quantity of the deposits of iron ore, coking coal, limestone, dolomite, and refractory clays available in Nigeria for the operation of an iron and steel complex.

In 1971, the Nigerian Steel Development Authority (NSDA) was formed. The authority was responsible for the planning, construction, and operation of steel plants in the country, as well as carrying out the necessary geological surveys and metallurgical research. The authority also examined various processes, including direct reduction with natural gas, even though this process required high-grade iron ore not known to be available in the country. In 1973, NSDA commissioned Tiajpromexport (TPE) to prepare a preliminary project report for the proposed steel plant.

The report recommended that the plant produce 1.3×10^6 t of long (rods, bars, and light structures) and flat products. The plant was to be sited at Ajaokuta and would use iron ore from Itakpe. NSDA accepted the report’s recommendation in 1975, with a few modifications, mainly to produce 1.3×10^6 t of long products in the first phase and 2.6×10^6 t (an added 1.3×10^6 t) of flat steel sheets as soon as expansion

was feasible.

In the same year, TPE was commissioned to prepare a detailed project report based on the earlier recommendations. This report recommended an integrated steel works, the first phase of which would include the following:

- a plant with two batteries of 49 coke ovens each (9×10^5 t a⁻¹ total capacity);
- a plant to process the by-products of the coke ovens and produce dehydrated tar, ammonium sulfate, etc;
- a plant with two sintering machines (2.64×10^6 t a⁻¹ total capacity);
- a plant with a blast furnace to produce pig iron (1.355×10^6 t a⁻¹ capacity);
- a plant to produce lime (9.1×10^4 t a⁻¹ capacity);
- a plant for steel making, with two LD converters (135 t capacity each) and three four-strand continuous-casting machines; and
- a complex with a billet mill (7.9×10^5 t a⁻¹ capacity), a medium-section structural mill (5.6×10^5 t a⁻¹ capacity), a light-section mill and bar mill (4×10^5 t a⁻¹ capacity) and wire-rod mill (1.3×10^5 t a⁻¹ capacity).

Also, the report suggested there might be early expansion to a steel-producing capacity of 2.6×10^6 t a⁻¹, half of which would be flat products. The final expansion would be to 5.2×10^6 t a⁻¹. At this stage, more flats, as well as heavy sections, would be produced. The report was submitted in September 1977 and accepted in 1978, with several modifications. The plant layout was broadly specified, and a tentative master schedule for completion of the plant was included with the plan.

A series of protracted negotiations regarding the construction of the plant then started between NSDA and TPE. Negotiations were frequently deadlocked, and a final contract emerged only after a high-level delegation (led by the Chief of Staff, Supreme Headquarters, General Musa Yar'Adua, then the de facto Vice President under the military government of General Obasanjo) undertook a journey to the Soviet Union and met with high-level Kremlin officials. Finally, in July 1979, a contract was signed with TPE for the preparation of working drawings, supply and installation of equipment, and construction of special steel works for the Ajaokuta steel project.

In 1979, NSDA was broken up into various organizations, including ASCL. In 1980, a contract for civil engineering was signed with Western firms: Wimpey was to build a metallurgical training complex and a river port; and project management was awarded to Pan African Consultancy Services Ltd (PACS) and Metallurgical Engineering Consultants (MECON) of India. Construction work began the next year, but within 2 years it came to a virtual standstill, and the partners began to negotiate and attempt to reactivate civil works and set up a more realistic contract.

Other steel projects

Ajaokuta was not the only one of the government's steel projects. In 1975, the federal government was advised of the potential for direct-reduction production of steel, with the fuel being some of the natural gas that was being flared at the time.

A delegation from Nigeria toured various countries to see the types of direct-reduction plants in operation and assess their performance. Following this, the government decided to establish two direct-reduction plants: one at Port Harcourt and the other at Warri, each with a capacity of 5×10^5 t a⁻¹. One of the plants was finally shelved, and in October 1977, an agreement was reached between the federal government and a consortium of 10 German and Austrian firms to construct a plant

to produce liquid steel at a capacity of $1.0 \times 10^6 \text{ t a}^{-1}$. Part of the steel would be finished in the plant's $3 \times 10^5 \text{ t a}^{-1}$ light-section mill, and the remaining steel would be rolled in major market centres in the country.

In 1979, contracts were signed for three rolling mills, to be built at Katsina, Jos, and Oshogbo. The Katsina plant was constructed by Kobe of Japan, and the Oshogbo and Jos plants were constructed by German companies. Each of the plants was designed to produce bars and wire rods at a capacity of $2.1 \times 10^5 \text{ t a}^{-1}$. These were to be rolled from billets produced at Aladja.

The Delta steel plant was commissioned 29 January 1982, and the rolling mills were completed on a turnkey basis.

The 1981–1985 development plans also included the following:

- a flat-products plant (capacity, $1.5\text{--}2.0 \times 10^6 \text{ t a}^{-1}$) to produce steel to be formed into sheets, plates, coils, thin plates, and welded pipes;
- an alloy and special steels plant (capacity, $8\text{--}18 \times 10^4 \text{ t a}^{-1}$);
- an iron and steel foundry complex; and
- an aluminum smelter.

The contract required TPE to supply and install plant units. NSDA was to arrange for the civil works of the plant and the erection base and build a river port.

The strategies and sequence adopted may be examined with the benefit of hindsight. The initial options can be summarized as the establishment of mini steel mills using scrap and an electric-arc furnace; rolling mills; and an integrated steel works.

The proposal for mini steel mills was questionable because the local supply of good scrap was poor and the infrastructure couldn't support steel making by an electric-arc furnace. However, as such plants usually have a low capacity, the experience gained in establishing and operating them could be expected to offset some of the costs resulting from a lack of economic feasibility.

The rolling mills were scheduled for completion up to 3 years before the primary plants, and when they were completed, they would have to operate at less than 20% capacity because of the lack of steel available to roll. The total capacity for long products was to be $2.36 \times 10^6 \text{ t}$ (including private rerollers), although projected demand (Project Review Committee 1981) for long products was $7.5 \times 10^5 \text{ t a}^{-1}$ and for flat products was $8 \times 10^5 \text{ t a}^{-1}$.

The long gestation period and huge escalation in costs for these overly ambitious projects turned the steel dream into a nightmare. Today, the federal government of Nigeria owns two integrated steel plants: Ajaokuta, using the conventional BF–BOF process, and Delta, using the DR–EAF technology, with a combined installed capacity of $2 \times 10^6 \text{ t a}^{-1}$. The government also has three inland rolling mills, with a total capacity of $6.3 \times 10^5 \text{ t a}^{-1}$; the raw materials for production are to be billets from the uncompleted integrated plants. The rolling mills compete with the private steel mills (Table 1). Even if finances had not dried up and all projects had been completed as planned, the available labour force capable of the requisite managerial and technical-support functions were too few to absorb the technology.

Factors deserving more consideration during the planning stages included the following:

- the stage of technological advancement and all available options in the field;
- the pool of trainable or usable personnel;

Table 1. Location and installed capacity of privately owned rolling mills in Nigeria.

Firm	Location	Capacity (10^4 t a ⁻¹)
Qua Steel	Eket	10
Universal Steel	Ikeja	8
Continental Iron and Steel	Ikeja	15
Sels Metal	Ikeja	10
Federated Mills	Ofa	14
Allied Steel	Onitsha	10
General Steel Mill	Asaba	5
Nigerian-Spanish Engineering	Kano	19
Mayor Engineering	Ikorodu	29
Oro Steel	Ilorin	??
Kwara Commercial Metal and Chemical Industry	Ilorin	4
Union Steel	Ilorin	??
Asiatic Manjarin Industries	Ikorodu	6
Niger Steel	Enugu	3
Metcom (Nigeria) Ltd	Owerri	3
Others (estimated)		2

- the demands and limitations of the market to be served by the product;
- the effects of the gestation period and the economic climate;
- the scale, complexity, and nature of the processes; and
- the availability of raw materials and infrastructure (Table 2).

The nature, quality, and availability of raw materials used in steel plants affect decisions on technology. In fact, input materials and the choice of technique are more or less inseparable. For example, whereas natural gas is the dominant energy source in the DR-EAF process, it finds only an auxiliary use in the BF-BOF process, which uses coking coal as the major fuel. Nigeria has fairly large deposits of iron ore but a paucity of coking coal. The coal available is riddled with ash and sulfur. The available iron ore can be beneficiated fairly cheaply to meet the requirements of Ajaokuta's blast furnace, but Delta's direct-reduction plant demands a high ferrous content (about 66%) and requires ore with an iron content of 38%. The cost is high. Imported ore may be cheaper than local ore because of the expensive beneficiation and imported coking coal. The fuel for Delta's direct-reduction plant is natural gas, which is so abundant in Nigeria that large portions of the associated reserves (gas that occupies oil wells) are still being flared. The main reserves are practically untouched. Thus, on one hand, the plant that is operable with a cheap fuel may have to rely on imported iron ore; on the other hand, the plant this is operable with local ore is doomed to using imported fuel (coal). The raw materials are about four times the value of the product, and Ajaokuta alone would have to process more than 5.0×10^6 t a⁻¹ raw materials for its production of 1.3×10^6 t a⁻¹.

Nigerian iron ore falls into two categories. The first is hematite-magnetite iron ore, which has been the most explored. A reserve at Itakpe, 66 km from Ajaokuta, is estimated to have 300×10^6 t, with an average iron content of 38%, which can be beneficiated relatively cheaply to about 63% ferrous iron. The iron ore at Ajabanoko, Chokockoko, and Agbaja is similar to Itakpe ore, with a reserve of 150×10^6 t. The second category is an oolitic sedimentary type. A deposit estimated at about $3000 \times$

10⁶; is located in the Agbaja–Lokoja–Koton–Karifi area. It contains high levels of phosphorus and zinc and has been investigated very little, beyond initial feasibility reports.

Table 2. Raw materials for the development of the steel industry in Nigeria.

Raw materials ^a	Source	Role	Requirements (10 ³ t a ⁻¹)	
			Delta	Ajaokuta
Iron ore	Itakpe Hill, Ajaba Noko, Shoko-shoko, and Agbaja	Sinter; sent to blast furnace to produce pig and molten iron	1 550	2 200
Coal	Enugu, Lafia, and imported	Carbonized in coke ovens; powers furnace	—	1 300
Limestone	Jakura, Mfamosing, and Ubo	Used in sintering and heating of iron ore	130	690
Scrap	Recycled and imported	Melted in electric-arc furnace; used as coolant in the steel-making shop	250	293
Bauxite	Imported	Used to maintain slag fluidity	??	13
Dolomite	Osara and Burum	Low grade used as flux in iron making; high grade used in brick refractories	??	250
Refractory clay	Onibode, Oshiele, and Ozubulu (Irno)	Used to produce bricks in aluminosilicate plant	??	??
Manganese ^b	Imported	Used to control quality of metal in blast furnace	??	85
Water ^c	Widespread	Used for cooling	83	120
Natural gas ^c	Widespread	Powers furnace	2 000	370 000

^a Except oil, all other materials, including iron alloys, aluminum, sulfur, caustic soda, and tar, are imported.

^b Manganese is indicated in t a⁻¹.

^c Water and natural gas are indicated in 10³ m³ h⁻¹.

The two known coal deposits in Nigeria are the Enugu and Lafia–Obi coal fields. The Lafia–Obi coal has coking properties but is high in ash and sulfur, and the deposit has structural problems. The coal in the Enugu deposit, on the other hand, is reasonably free of impurities but is noncoking. Thus, it was decided that, initially, the coking coal would be imported. However, technologies exist to make at least 20% of a fuel blend from Enugu coal. The savings would be significant. Another deposit, at Okaba, has coal with high ash content and low tar yield, and this coal disintegrates on carbonization, although its use in the production of steel has not been ruled out.

Limestone is supplied to Delta Steel by Cross River Limestone at Mfamosing. Delta has equity in the deposit. A deposit at Jakura has been proposed for Ajaokuta because of its proximity to the plant, but Jakura limestone would have to be formed into briquettes. The government has not taken a definitive stand on the use of coal and

most of the other materials and is still deciding whether to award contracts for the supply of briquetting machines.

Deposits of dolomite (4×10^6 t) in Burum, near the federal capital, are also not far from the plant site. Both deposits need to be fully explored, and the issues of ownership and mining rights need to be resolved. Refractory deposits are found in Oshiele-Onibode (very far from Ajaokuta) and in Ozubule, Imo.

Both bauxite and ferric alloys are to be imported, although low-grade manganese (2×10^6 t) has been reported in Tundun Kudi, northern Nigeria, and bauxite has been reported in Oju, Benue.

The Ajaokuta dream

The operations at Ajaokuta are straightforward. The raw-materials section of the plant consists mainly of open yards and silos to store the ores, coal, lime, etc., and a plethora of separators, crushers, and sieves to remove unwanted foreign matter, size the output, and segregate the materials before they are sent to processing units.

To prepare coke, the plant has 49 ovens for each of two oven batteries (5.5 m high, with a useful volume of 30.3 m^3). The capacity of the batteries is $9.0 \times 10^5 \text{ t a}^{-1}$. The sintering plant has two machines that produce 100% self-fluxed sinter. The plant is designed to use iron ore from the Itakpe mines.

Iron making is done by a single blast furnace, with $2.0 \times 10^3 \text{ m}^3$ capacity. It has been adapted for natural-gas injection, to reduce coke consumption. The pig iron produced ($1.5 \times 10^5 \text{ t a}^{-1}$) is used in foundries; the remaining molten iron is sent to the steel shop; and the slag produced as by-product ($5 \times 10^5 \text{ t a}^{-1}$) is used in cement making.

The steel-making shop consists of two LD converters with 130 t capacity each, three two-strand continuous machines, and the lime shop. There are four rolling mills: a 320 mm light-section mill; a 700 mm medium-section structural mill, a 900/630 billet mill, and a 150 mm wire-rod mill.

The green-field nature of the plant, the unreliability of public utilities, and the dearth of small-scale suppliers in the immediate vicinity plant meant that the development of the steel works had to include special provisions for spare-parts manufacturing facilities and power plants, etc. Among the facilities needed for Ajaokuta were a comprehensive repair complex, with its own foundry, forge shop, and heat-treatment and hard-surfacing shop; a thermal power plant and turbo blower station; an oxygen plant; refractory shops and a lime plant; and laboratories and transportation facilities.

Also needed were external infrastructure, such as railways, roads, ports, and electric-power systems. For example, there was a proposal to construct a line from Onne port through Port Harcourt to Ajaokuta, although it was shelved for financial reasons. A line between Itakpe and Ajaokuta was to carry iron ore, and the line running from Lafia-Obi and Makurdi was to carry local coal. Onne port was to be built to handle imported raw materials and finished products for Ajaokuta, but with the cancellation of the rail program, the use of Onne port was questionable. Electric-power facilities included a 330 kV double-circuit transmission line, from Benin to Ajaokuta, and the captive electric-power system at the plant site in Ajaokuta.

Planning the plant at Ajaokuta

To understand the setup at Ajaokuta, one needs to look closely at the planning and subsequent actions of the decision-makers in government. The selection of the site for the plant deserves mention. NSDA predicated its choice of location for the Ajaokuta

steel project primarily on the source of iron ore. The location study, contained in the preliminary project report, contained a detailed technoeconomic analysis based on scenarios in which local or imported ores were used (Table 3).

Table 3. Estimated capital and operating costs for steel plants at three possible sites in Nigeria (1984).

Ore supply	Capital costs (10 ⁶ NGN)				Operating costs (10 ⁶ NGN)
	A	B	C	Total	
Imported and local					
Warri	504	182	142	828	187
Onitsha	341	142	126	609	143
Local					
Ajaokuta	359	231	158	748	201
Onitsha	331	142	126	599	163

Source: NSDA (1974).

Notes: A, transport, water, electricity, and gas; B, substructure work, site leveling, construction of plant; and C, construction of township for the main contractor and the Nigerian personnel. In 1995, 78.5 Nigerian naira (NGN) = 1 United States dollar (USD).

Two suitable zones were defined: the coastal zone, stretching for about 100 km between Forcados and Port Harcourt; and the central zone of the country, along the banks of River Niger, south of Lokoja, for 50 km to Onitsha.

Eleven possible locations in these areas were distilled down to three: Warri, Onitsha, and Ajaokuta. The report recommended Onitsha, on the premise that the use of local ores would save precious foreign exchange.

Political factors outweighed the economic considerations, although the reasons for this are a matter of conjecture. The preliminary report was submitted for consideration in 1974. This was 3 years after a civil war, when the eastern zone of the country (with Onitsha its trading capital) attempted to break away and set up a separate nation. With the memories of the war and its scars still fresh, the authorities might have hesitated to choose to site a project of such huge cost at Onitsha: they would be unable to guarantee the security of government property or the safety of workers from other regions of the country. In other words, the decision was economically suboptimal but, perhaps, politically justifiable. We suggest that it is no use pretending that noneconomic factors are irrelevant. In fact, they tend to be decisive in developing countries, so policy analysts must seek to accommodate them.

In contrast, the choice of technology seemed economically sound. The main groups involved in this decision were the main contractor (TPE of the Soviet Union), the Nigerian engineers (from NSDA), and the consultants to NSDA (SOFRESID of France). The preliminary report by the Soviets considered two options for the iron-making plants: two blast furnaces, with an effective volume of 1003 m³ each, and a single blast furnace with an effective volume of 2000 m³.

SOFRESID and NSDA engineers agreed that either option would meet the requirements for hot-metal production. The preliminary report pointed out that labour efficiency with a single furnace is higher by about 30%, and the prime cost per tonne of hot metal was about the same for the two options.

Nevertheless, the report favoured the two blast furnaces, to avoid complete shutdowns when repairs were needed. SOFRESID observed that the equipment proposed in the report was obsolete, by Western standards, and recommended areas for improvement.

The final decision was in favour of a single 2000 m³ blast furnace, capable of producing 1.355×10^6 t a⁻¹ of hot metal and incorporating high top pressures, as well as auxiliary fuel injection. Some of the arguments that favoured the single, large furnace cited an expanding market for steel products, constraints on the amount of available land, and a high rate of capacity utilization. A major drawback of the equipment chosen was its need for 100% sinter as raw material. Small furnaces are more tolerant of poor-quality raw materials (i.e., more local coal could have been incorporated in the coal blend) and are easier for inexperienced operators to manage. Mistakes are easier to correct, and reliance on instrumentation and controls is less critical. In the Nigerian environment, pure scale effects constitute a less valid reason than furnace availability and operability.

NSDA engineers made their decision without the benefit of hindsight or the technical skills that accumulate from operating such plants. The engineers believed the national economy would remain buoyant enough to finance an expansion in capacity immediately after the completion of the first phase, and they also felt that the blast furnace of the first phase would be a training ground for the subsequent phases.

However, the economy collapsed and the expected growth in demand for steel products evaporated. Clearly, decision-makers must build in some allowance for uncertainty and change. ASCL probably cannot finance even the coke it requires (150 million USD a⁻¹), under present economic conditions.

Uncertainty derives not only from the economy but also from the technological environment, particularly the weak capability to maintain equipment on a sustained basis and the lack of local supplies of spare parts and machines. Learning was taken for granted and was not given serious attention in decision-making. The project's evaluators made no attempt to analyze the potential opportunities for gains in technical know-how offered by the two options, and few if any long-term social objectives were considered in the decisions.

The steel-making shop proposed in the preliminary report consisted of two oxygen converters, each with a 130 t capacity. This proposal was accepted because the concept of oxygen steel making was well established. Less clear cut was the decision about the process for casting. Traditionally, molten steel is poured into ingot moulds, allowed to cool, and then reheated and shaped. A more recent technique — continuous casting, or concasting — casts the molten steel directly into blooms (typically, 260 mm × 260 mm or 335 mm × 6 m), billets (100–150 mm² × 12 m), or slabs. Concasting increases the yield of cast and has great advantages in productivity, material handling, and fuel costs.

The preliminary report recommended the use of concasting, and SOFRESID agreed. However, the consultants did not agree on the product. The Soviets recommended blooms (with later reduction to billets in a mill) and slabs. SOFRESID suggested casting billets directly because it offered a reduction in capital and operating costs. It is not clear why the Soviets recommended a bloom caster, but it is suspected that the technology of billet casting was still new to Soviet steel-plant designers; hence, there would not have been a manufacturer from the Soviet Union to supply the plant.

The Soviet proposal had following advantages:

- It is easier to cast blooms than billets.
- It is possible to produce variable sizes of billets in a mill, thereby increasing flexibility for sales (a billet mill is a simple rolling mill with few stands and, thus, is not likely to create a production bottleneck).
- Natural gas for the operation of reheating furnaces is locally available, so

costs for converting blooms to billets would be a local expenditure (except for imported rolls and accessories).

The evidence indicates that the Nigerian engineers carefully considered the technical and economic factors and decided in favour of bloom casting. Casting the billets directly would have been preferable, as this would have resulted in some standardization in the rolling mills and would have eliminated the need for a billet mill. The decision of the NSDA engineers could have been influenced by their training in Indian steel plants, where continuous casting facilities were not yet available.

For the rolling mills, the preliminary report proposed a product mix consisting of equal amounts of flat and long products, a total of $1.3 \times 10^6 \text{ t a}^{-1}$. This was based on the current demand. However, at the time, the national economy was booming, and the construction industry was enjoying higher growth than the manufacturing sector. Large office blocks, industrial complexes, and long bridges were being built, and the government had plans for heavy industrial investment in liquefied natural gas, petrochemical plants, and fertilizer plants. All of these would require large amounts of steel sections, mainly long products. This led to the decision that the first stage of the plant would be devoted to long products, and the second stage — an expansion to $2.6 \times 10^6 \text{ t}$, which was expected immediately — would be devoted to slabs that could be rolled into flat sheets.

The preliminary report recommended

- an 800 mm billet mill,
- a 450 mm medium-section structural mill,
- a 250 mm light-section and wire-rod mill,
- a 1700 mm hot strip mill,
- a cold rolling mill,
- a corrugated-sheet mill,
- a hot-rolled coil-cutting unit,
- an electrolytic tinning unit,
- a pipe spiral-welding plant, and
- a pipe electric-resistance-welding plant

These proposals were based on the recommendation that the plant produce equal amounts of long and flat products. The steel concasting plant would be made up of one bloom caster and two slab casters. The bloom casts would be further reduced in billet mills, then finished in 450 and 250 mm mills. The slabs would be reduced first in the hot strip mill and the cold rolling mill, then finished as corrugated sheets, electrotinned sheets, spiral-welded pipes, and electric-resistance-welded pipes.

Hindsight shows that the change of the original concept of the plant was a grievous error. The overall interest of the country would have been served best by a mixture of flat and long products. Today, Nigeria is flooded with long products, and every industrial concern voices the demand for flat products. The refrain has led the government to adopt what it calls “accelerated phase of expansion — flat products stream.” What it proposes is to add a slab caster, a hot mill, and a cold rolling complex, with associated auxiliary facilities, to produce hot-rolled and cold-rolled products. The new setup would take about half the molten steel from the units of the first phase.

Optimism about future economic growth was probably also to blame for the inclusion of a medium-section structural mill, which was done at the suggestion of NSDA. The contractor noted that demand for medium sections was low and recom-

mended, instead, a section forming unit. A forming unit offers higher efficiency and lower capital cost than a medium-section mill. It is, however, slower and not amenable to high-tonnage production.

The NSDA engineers decided in favour of a high-capacity, medium-section structural mill to anticipate growth in demand for its products from heavy industry, including the plant itself. At advanced stages of project execution, the final design of the rolling mill was further modified, after the detailed project report, to incorporate production of rails.

The maintenance philosophy put forward in the preliminary report, at the suggestion of Nigerian engineers, was a central system of repair facilities. Thus, the report contained elaborate provisions for machining new spare parts and consumable equipment in departmental workshops. Provision was also made for large repairs — an iron and steel foundry, forge and fabrication shop, machine shop, and a shop for heat treatment and hard surfacing. SOFRESID questioned the rationale for such enormous facilities, saying that (1) these provisions were excessive for a steel plant, by usual standards; and (2) the plan featured duplication and overequipping of the departmental shops.

The shop featured excessively large cranes. The repair shops for power equipment would be able to repair of 13 000 electrical items annually. The estimated requirements for spares at the facilities were astronomical by any standards (Table 4). Also featured were a rubberizing workshop, an equipment storage and charging station, a block of workshops dedicated to the steel-making plant, a workshop for the rolling mills, and a workshop for the coke-oven and by-product plant.

Table 4. Estimated requirements for spare parts in repair shops.^a

	Requirement (10 ³ t a ⁻¹)	In-plant production (10 ³ t a ⁻¹)	To be bought (10 ³ t a ⁻¹)
Iron castings	4.33	4.23	0.10
Steel castings	4.58	4.48	0.10
Nonferrous castings	0.19	0.19	—
Forgings	4.48	2.28	2.20
Long products	2.10	—	2.10
Steel structures	2.50	2.20	0.30
Cast-iron rolls	0.86	—	0.86
Steel rolls	1.60	—	1.60
Copper plates	0.17	—	0.17
Machining of new parts and consumable equipment	8.36	8.29	0.07
Remachining for reclaiming and rehabilitation	1.43	1.43	—

^a Plant design capacity with a two-shift operation.

Repair shops were to supply 67% of the spare parts, although some were to be specialized products that could be economically produced outside dedicated plants. That the work, according to the report, represented a two-shift operation suggested

that a 50% increase would be possible with three shifts.

In engineering circles, Soviet equipment is regarded as generous in its allowance for capacity. It is large and electronically unsophisticated. The Soviets make allowances for weak industrial cultures by building in extra capacity. For example, a Soviet contractor will supply a 2500 t day⁻¹ furnace to a developing country, labeling the equipment as a 2000 t day⁻¹ furnace. This is safe for the contractor, as it is then easy to demonstrate the guaranteed performance, and plant operators are able to meet design capacity easily. This practice has endeared Soviet technology to several developing countries, where most steel plants have remained wholly government owned.

Overdesign is not necessarily negative. It may serve as the basis for growth and minor innovations. For example, Maxwell (1982) observed the preponderance of overdesign in some Latin American steel plants and noted that initial imbalances removed the need for investment in new capacities during expansion.

The elaborate provision for spare-parts manufacturing was aimed at developing a local capability for repair and replacement of worn parts and manufacture of whole machines, where necessary. Developing the capability to effectively use these plants would lead to the independence of the plants from outside suppliers and would be a base for manufacturing parts (in case the contractors' equipment needed to be amended to adapt to specific local conditions or to increase the productive capacity).

What, in an economist's view, is overcapacity could, in the long run, provide the financial buffer that enables the steel plant to break even. The facilities already have received a deluge of manufacturing orders from outside firms.

Dahlman et al. (1978) documented how the repair shop at the USIMINAS steel plant in Brazil grew into a successful manufacturing concern through systematic investment in human and material resources. USIMEC (the machine-making subsidiary) designs and builds all the capital goods USIMINAS needs and also serves outside consumers. What USIMEC is doing for USIMINAS, the Growth Shop is doing for Tata Iron and Steel Co. in India.

Such commercial endeavours are possible because local suppliers cannot support industry, which is underlined by the experience at the Delta steel plant. Six years after commissioning, Delta (which is nearer than Ajaokuta to an established industrial environment) still cannot obtain rudimentary spare parts and consumables locally. Great foresight was not displayed in the design of the repair facilities. The Soviets favoured and adopted the repair-shop approach, probably because of their experience in supplying steel plants to developing countries, whereas SOFRESID, the French consultants, found the facilities superfluous. In France, it may not be cost effective for a firm to be unburdened with such provisions, which in themselves may pose organizational problems.

Thermal power plant

The process equipment of the steel plant can be categorized on the basis of its tolerance to power interruptions. Equipment that may create a danger to operating personnel or sustain severe damage is usually regarded as critical equipment and must be supplied power from at least two feeders. In most developing countries, the prime source of power is the national grid; this is supported by a by-product power generator in the steel plant. A minimum of 30% of the peak power demand should be generated within the plant for security reasons, even if the plant can purchase all its power requirements.

The preliminary report recommended three 55 MW generators, fueled by oil

or natural gas. SOFRESID recommended an alternative: three 110 MW generators that would generate even more electricity than the national grid system and would make the steel plant independent of the grid. The NSDA engineers opted for two 55 MW generators. The peak power demand is 220 MW. The in-plant power generation was based on the available by-product fuel and the minimum power needed to carry the critical equipment in the plant.

The two independent sources of power are a technical requirement, although some agencies contend that both sources could come from the National Electric Power Authority (NEPA). This argument is flawed by the fact that NEPA has never been reliable.

However, running a full-size 110 MW power plant places a heavy load on the technical and organizational management of the steel plant. The organization has to cope with power generation (a large, complex plant) a spare-parts-manufacturing complex, and large waterworks, as well as the integrated steel complex. Such diverse activities require a very able technical administration. The integrated plant includes facilities with different technical characteristics. For example, the coke-oven by-product plant is like a petrochemical complex and miniature fertilizer plant; the links among iron making, steel making, and continuous casting are sensitive to, and intolerant of, poor planning and sloppy management. Because of the managerial competence required, some form of goal-oriented decentralization seems appropriate, although that may also be a source of problems. Where government allocation of finances to projects can be affected by pressure groups and rapidly changing priorities (because of political instability), one section of a project may proceed smoothly while another essential component under a separate management organization experiences delay.

A good example is the development of the Itakpe mines: the contracts for the ore beneficiation plant and the Ajaokuta-Itakpe rail line were not awarded until 1987, 4 years after the blast furnaces at Ajaokuta should have been commissioned, and the contracts required a minimum execution time of 22 months. How developing countries, with their limited resources, can avoid such incongruencies is unclear. The choice seems to be either one large organization, with complex and diverse technical arms under a single umbrella, or a number of independent smaller organizations, trading services with each other but having a central coordinating agency.

Major actors and their roles in the Ajaokuta project

The actors — their activities, management capabilities, and strategic conceptions — strongly influenced the events and shaped the evolution of the firm. The Ajaokuta project involved three main actors:

1. The development contractor was TPE, the Soviet company that supplied working drawings and structures and installed the process units.
2. The owner, or client, was ASCL, which acted as proxy for the federal government of Nigeria.
3. The contractors for civil engineering work were primarily Fougerolle Nigeria Ltd – Fougerolle SA; Bilfinger and Berger Bauaktiengesellschaft – Julius Berger Nigeria Ltd; and Dumez Nigeria Ltd – Dumez Africa. George Wimpey was awarded a contract for the training school complex; Boskalis was contracted for the river port; and two of the civil works contractors (Julius Berger Nigeria Ltd and Fougerolle Nigeria Ltd) were given contracts for infrastructure.

Most capital-intensive enterprises in developing countries are totally or partially owned by government. Therefore, ultimately the government's control of, or influence on, the project implementation and subsequent running of the firms is significant and fashions the path of development for the enterprise. Nigeria is no exception. This feature of firms in developing countries, as opposed to those in industrialized countries, is crucial.

The major obligations of TPE, the development contractor in the Ajaokuta project, were the following:

- preparation of working drawings for all the construction, erection, and special civil works;
- delivery of the equipment, steel structures, refractories, rolled stock, pipes, and other articles and materials required to carry out the erection and special civil works at the plant units and the erection base;
- erection and special civil works at the plant units and the erection base, as well as training of Nigerian workers to master the erection specialities;
- supervision of start-up and commissioning of plant units;
- provision of technical assistance during the operation of the plant, as spelled out in a supplementary contract; and
- training of Nigerian personnel to operate the plant.

ASCL's main obligations for the execution of works were the following:

- preparing the units and the site for erection, including readying storage areas for equipment, steel structures, pipe, and refractories, etc;
- undertaking civil works for the construction of the erection base;
- ensuring availability of river and sea ports and river-port facilities;
- building upland and lowland canals;
- providing offset water supply, sewage treatment, rail and roads, and natural gas pipelines;
- ensuring availability of national and international communication facilities;
- establishing the township for the main contractor and Nigerian personnel;
- investigating further sources of raw materials (coal, limestone, dolomite, refractory clays, and iron-ore concentrate) and submitting the results to the contractor at a stipulated time (to be determined later);
- coordinating, managing, and supervising construction of all facilities in cooperation with the Soviet experts who were supervising the civil works to guarantee quality of work; and
- providing local personnel for erection work.

Perhaps the most critical of ASCL's obligations was civil works, without which the site could not be made ready for installation of plants and equipment. This component of construction turned out to be the rate-determining step in the evolution of Ajaokuta — and its Achilles heel.

Details of the civil contract were finalized in September 1980. The broad schedules for construction of civil works and erection of steel structures and equipment were agreed on by ASCL and TPE during a series of meetings in Moscow, lasting from December 1980 to February 1981.

Delays

For the main civil contractors, the plant site was divided into three lots (Table 5). By the middle of 1981, all the contractors had overcome the problems of site access and had their work forces fully mobilized. The tempo of work built gradually and continued for almost 2 years. The first signal of a major disruption was in July 1983, when Dumez and Fougerolle started slowing their pace. By December 1983, Dumez had completely stopped work. In August 1984, Fougerolle limited work to minor finishing touches. Bilfinger and Berger continued work and by the third quarter of 1986 had almost fulfilled its obligations, as well as picking up work left undone by the other two contractors. For example, work abandoned by Dumez and required for the commissioning of the mill and the power plant was transferred to Bilfinger and Berger in January 1985; this extra work was to complete the water recirculation system, the mechanical repair shop, the forge and fabrication shops, and the power-equipment repair shop. The transfer has enabled these units to reach an advanced stage of completion.

Table 5. Division of lots for civil works contracts in the Ajaokuta steel plant project.

Lot	Contractor	Civil works
I	Fougerolle Nigeria Ltd – Fougerolle SA: joint venture	Raw material plants, coke ovens, blast furnace, thermal power plant
II	Bilfinger and Berger Bauktiengesellschaft – Julius Berger Nigeria Ltd	Steel-making shop, rolling mills
III	Dumez Nigeria Ltd – Dumez Africa: joint venture	Auxillary shops, lime and refractory plants

The major reason for the civil contractors' deceleration and eventual demobilization was that funds earmarked for the project were exhausted. When the contract was negotiated, it was anticipated that the economic landscape would be unstable, and a cost escalation factor was included in the agreement. However, wages and salaries were based on prices in 1981, and no allowance for increases was made. Sociopolitical and economic forces were already at work to make a mess of the calculations. A new civilian administration was voted into power at the end of 1979. As part of the new government's economic program, it revoked the system of "zooming," whereby skilled, semiskilled, and unskilled labour were paid at different rates. As a result, wages increased 196–384% in some categories of labour.

The world economic recession, with its concomitant effect on the Nigerian economy, led the government to introduce the *Economic Stabilization Act*, which caused sharp escalations in the cost of raw materials (both local and imported), transportation, and services. The civil contractors used enormous amounts of cement and steel structures purchased locally and abroad and hauled large quantities of these materials over great distances, which seriously affected their costs.

Also, the March 1980 call for tenders for civil contracts left out main units and off-site facilities needed for the general operation of the plant; for example, the permanent water-supply intake, water-treatment plant, general-purpose drinking-water supply, sewage-treatment plant, sludge disposal system, and plant boundary wall were not included because the design date and specifications were inadequate. Similarly, construction of low-cost housing for the civil contractors and of site facilities

subsequently added to the cost of civil works. Also not included in the 1980 call for tenders were the river port and the metallurgical-training complex. These eventually ballooned costs.

During construction, changes are usually made: equipment is added to strengthen the original designs; excavations and earth fillings deviate from original estimates; and design errors compel modifications and, therefore, substantial cost revisions. Some examples from Ajaokuta are the following:

- the transfer of work from Dumez to Bilfinger and Berger;
- the decision of the federal government to modify the medium-section structural mill to make it produce rails; and
- modifications to the 17 m × 17 m × 1.5 m foundation of the blast furnace (the foundation required continuous pouring of concrete for more than 36 h).

The final stoppage of civil works came with the formal demand from the contractors for an activation of the contractual formula for price fluctuations. The fluctuations demanded by the contractors were 1.9 for Dumez (the first to abandon work) and 1.6 for Fougerolle. However, consultants had previously pointed out anomalies in the price fluctuation formula (as contained in the contract), especially in the ways the formula affected wages.

By March 1983, the government was directing ASCL to negotiate with the contractors to arrive at a realistic and equitable formula for price fluctuation. Protracted negotiations followed, and after more than 2 years, a formula of 1.5 was fixed. For further escalation in costs of material and labour, a system of basic rates was fashioned, with the base rate being the one arrived at in April 1984. The standstill and the negotiations saved the project about 125 million NGN, but the costs in time overruns and lack of production cannot be easily calculated (in 1995, 79.5 Nigerian naira [NGN] = 1 United States dollar [USD]).

The civil works were expected to take 54 months from November 1980. More than 70 months elapsed, and much still remained to be done. Meanwhile, the new agreement, estimated at 838 million NGN, catapulted to 1484 million NGN.

After the new agreements and new commissioning dates were established for the plant units, other external threats — the shackles created by bureaucracy and the uncertainties in the economic climate — emerged to make the new timetable unrealistic. The new commissioning dates were predicated on the assumption that import licences for the contractors (for the 1985/86 financial year) would be available by August 1985. In fact, the licences were not in place for more than a year. The civil contractors, who were expected to resume work once the deadlock was broken, had not done so by late 1986, partly because the new mode of payment for the civil works was being processed through the bureaucracy and partly because the import licences had not materialized.

The contractors resumed work towards the close of 1986, but before the end of first quarter of 1987 new problems relating to the mode of payment had brought the work to a standstill once again. Paradoxically, the abrupt halt to progress on the civil works made little difference overall. Infrastructural facilities, external to the plant, are meant to supply, process, and convey raw materials to the plant. Even if the steel plant itself had been constructed on schedule, delays in the installation of these facilities would have rendered it inoperable. The most important delays occurred in the following:

- the Itakpe iron-ore mine, which produces the concentrates to feed the Ajaokuta plant, 56 km away;

- the railway link between Itakpe and Ajaokuta to transport iron ore, the contract for which was awarded only in 1987;
- the development of mines or quarries for limestone, dolomite, and refractory clay and of transport facilities to convey the raw materials to Ajaokuta; and
- the development of a bulk transportation system to carry imported raw materials, like coal, from Onne port to Ajaokuta.

These major links in the network of supply facilities (mines, power, ports, rail lines, and roads) were in a sorry state. The lack of coordination between institutional subsystems responsible for these facilities and the final user (the ASCL) had delayed the development of the facilities, as had the precarious state of the economy. The most obvious effect of the delays was the need to set new dates for commissioning the plants. Originally, the steel-making plant, the last shop to be commissioned, was to have begun operations in March 1985. In August 1985 a new schedule was agreed on at a meeting of a Soviet delegation of technical experts and their Nigerian counterparts.

The direct and indirect costs of delay were many:

- Capital was tied up in half-completed civil works, partially installed equipment and plant units, uninstalled structures and equipment, and idle tools and equipment for erection.
- Workers were demobilized and remobilized.
- Equipment needed refurbishing. With time, conservants like grease and oils that protect equipment from rust lose their potency; of about 1.8×10^5 t of equipment, half is expected to need reconsevation.
- Installed but idle plant units needed protection from a hostile environment.
- Completed but idle units depreciated in value.
- Supplies for plants and equipment, erection, and commissioning were deferred (if ASCL could not supply the requisite materials, it would be required to pay highly for the time the contractor's personnel were idle on the job).
- Interest accrued on unproductive loans (100% of the civil-works contracts were externally financed, and the bulk of the money was to be paid back in foreign exchange).
- Prices escalated.
- Workers were idle, and morale was low. There was a large turnover of skilled and unskilled workers waiting for the plant to come on stream (in some instances they waited for more than a decade after their formal training in steel-plant operations). The firm lost several experienced engineers and administrators for political reasons (mass purging); others left for better pay in the private sector or out of sheer frustration).
- Output and revenue were unrealized; the plant failed to contribute to the economy of the country.
- Technical assistance was required.

The major factors causing delays were the nature and complexity of the project. The decisions made and their subsequent implementation demanded unusual technomanagerial capabilities. Because of the paucity of these kinds of capabilities in Nigeria, it is not surprising that the project faltered.

Practically all the capital goods — structures, columns vessels, and reactors — had been made abroad, the products of detailed knowledge acquired from many years of design and fabrication. Not being a party to the design and fabrication is an operator's first major handicap. Understanding the technical basis for a design limits guesswork and enhances the operator's ability to make judgments about use and maintenance. Clearly, the project demanded massive investment in training and development.

Personnel training and development

At an early stage (primarily during preinvestment, when the detailed project report was being discussed), the need to fill the yawning gap between the knowledge of NSDA staff and that of the Soviet specialists was acutely felt. To make discussions with the Soviets meaningful and to contribute more to the detailed reports, NSDA staff embarked in preliminary training in steel-plant design and operations. Training was provided in several countries: the Soviet Union (Zaparozyhe and Cherepo vetse), Italy (Italsider—Taranto), Canada (Stelco), United States (US Steel), Japan (Nippon Steel), France (SOFRESID), and Britain (BSC—Corby).

Training was mainly ad hoc, lasting from 3 to 9 months, and NSDA simply took what was offered. The contents of the courses varied and were usually pre-designed. Participants supplemented these learning opportunities by regularly reading journal articles on iron and steel (NSDA maintained an up-to-date library on steel manufacturing). Some of the ad hoc arrangements continued until 1974, when several senior staff of NSDA were sent to MECON (India) to study general layout and transport, civil engineering design, structural and project engineering, and so on.

Training in India

The first program, in 1974, was initiated with Steel Authority of India Ltd (SAIL). At that time, the Indians offered the most economical training, and the major contractor handling Ajaokuta, TPE, had been involved in the construction and operation of two integrated steel plants in India: Bhilai and Bokāro. The success of Bhilai, a publicly owned steel plant, undoubtedly influenced the decision to study in India.

The training program was designed entirely by SAIL, with each trainee spending 9 months on specialized work and 9 months participating in shift work. The contract between SAIL and NSDA was valid for 4 years, starting August 1974, and the scheme involved mainly executive and engineering staff. The experience of early trainees resulted in two major amendments: the period was reduced to a total of 12 months, and training in the use of some critical equipment, like cranes, was included. The intention was to equip executives and engineers with skills that would enable them to keep vital operations going and to judge the performance of workers.

The training of steel-plant personnel was conducted at the Bhilai, Bokāro, and Raurkela steel plants, Coal India, and the National Mineral Development Corporation, among others. Some design training took place at MECON's design office in Rānchī.

The trainee's program was divided roughly into three phases: (1) general training, (2) specialist training, and (3) management training.

In the first phase, the trainee was taken through all the activities of the steel plant, from raw material receiving, handling, and preparation to the finishing end, in this case, the rolling mills. In the second phase, the trainee then spent some time interacting with the engineers, technicians, and shop hands in specific operations or maintenance. Next, the training focused on, for example, coke ovens, by-products, or steel making. Shift work was mandatory. The third phase, the general management course, lasted 2 weeks. The course was designed to familiarize trainees with basic

accounting; project implementation; production, materiel, and personnel management; marketing; and safety.

Another contract with MECON proposed training another 636 engineers, staff operators, and nonexecutives, but this never got off the ground.

Training in the Soviet Union

As part of its contract with NSDA, the Soviet Union was committed to providing Nigerians with scholarships to Soviet technical colleges and institutes to be educated for the various professions required for the effective operation of the Ajaokuta iron and steel plants. The main fields of study were metallurgy and mining, mechanical, civil, electrical, and electronics engineering. Selected personnel from the company travelled to the Soviet Union for the courses, which lasted 5–6 years. The contract and its revisions provided for the training of almost 2000 Nigerians.

The program started in 1981. The first Nigerians trained in the Soviet Union were mostly trained for the priority rolling mills (light-section and wire-rod mills), as well as for the operation of the thermal power plant, the gas facility, and the electric power facility.

A new schedule calls for training fewer people abroad; only those needed for the most critical categories will be sent. A “cascade” approach is now planned: those already trained will be expected to impart their knowledge to others in Nigeria, mainly at the technician–operatives level.

According to the original contract, training was to be carried out “in conformity with the training programmes prepared by the establishments where training will take place.” This seems to reflect the climate of the time, a time when NSDA did not have the personnel, the confidence, or the capability to plan such a venture. The direct experiences of the NSDA students resulted in revisions to the contract, such as shortening the length of training and focusing on training in critical equipment.

There was a tendency to leave the content of the courses up to the Soviets. For example, the contractor was to assign trainees “to the various establishments taking into account the relevance of these establishments to the training programmes, the similarity of the available equipment to that to be supplied to purchase.”

The contract stipulated that “industrial and technical training of trainees shall be conducted in the Russian language. However, to ensure more efficient training, PURCHASER’S trainees shall, *prior to coming to the USSR* [emphasis ours] for industrial and technical training, study the required minimum of the Russian language in PURCHASER’S country.”

The obligation to ensure that trainees have a knowledge of the Russian language has been treated with levity. When trainees get to the Soviet Union, a language program, not exceeding 3 months, is normally arranged, along with the specialized training. Not surprisingly, most trainees never really understand the language. This imposes serious constraints on learning. As most texts are printed in the Russian language, trainees who wish to explore technical books and journals find it is a barrier as much at the library as on the shop floor. Invariably, they misinterpret technical information, as do the interpreters, who are language specialists, rather than technical specialists. The communication gap sometimes leads to long, unproductive periods of clarification and repetition — time that could be used more productively.

Training in Nigeria

The technical and vocational group is the largest category of personnel running the plant. According to the detailed project report, 7757 nonexecutive personnel will be

needed to run the plant. This prediction is in line with UNIDO (1984) world estimates.

To meet this requirement, the metallurgical-training complex was to be built to train about 200 at a time, in 25 different trades and skills. Graduates would number about 900 annually. Fully equipped classrooms and workshops for practical training, as well as hostel facilities, were to be provided. The current complement of staff at Ajaokuta comprises 666 engineers and technicians and 1163 other workers (Table 6).

Table 6. Personnel working in various departments of the Ajaokuta steel plant (1987).

Department	Engineers and technicians	Other workers
Coke oven	18	4
Steel-making plant	21	79
Iron-making plant (including blast furnace)	18	29
Maintenance (including lime plant, refractories)	95	190
Power and utilities	173	205
Central repair-shop complex	108	76
Research and quality control	47	14
Production, planning, and control	17	3
Light-section mill	50	200
Wire-rod mill	49	208
Billet mill	70	155

However, the thinking that impelled an investment in a massive training institution made no provisions for the future, when the knowledge gap will have been narrowed. A survey carried out in 1973 (and updated in 1976) indicated that certain skills simply could not be met by educational programs in the country. At that time, metallurgy, metallurgical engineering, mining, refractory technology, and instrumentation and control were not taught in any Nigerian institution. These findings prompted the initiation of a postgraduate diploma course and a master's degree program at the University of Lagos. The aim was to give chemical engineers, chemists, and mechanical engineers the basic concepts of metallurgy, with emphasis on physical and extraction metallurgy.

Two of the rolling mills are now in operation and are overstaffed by engineers and technicians and critically short of other kinds of workers (UNIDO 1984). As a result, personnel trained to run the coke oven and steel shop have been converted overnight to mill operators. At the coke-oven plant and steel-making shop, on the other hand, there is a shortfall of engineers who have received their local and Soviet training. Both the coke-oven plant and the steel-making shop have yet to go through the commissioning stage, a stage when staff participate in equipment start-up and dry test runs. The familiarity staff would develop with plant equipment prior to commencement of commercial operations could be crucial to the efficient operation and development of a no-nonsense maintenance crew. At present, engineers are underemployed, and many have already left.

The strategy of cross-posting of trained personnel from plants under construction to completed plants arose mainly for financial reasons (and, partly, for reasons of organizational politics). The main point is that when the financial resources committed to large projects of this nature start to dwindle, training is the first program to suffer. This has a crippling effect, leading to the prolonged infancy of the firm.

Some other shops in the plant are fully constructed, yet they too are constrained by shortages of trained personnel. The most striking example is the central

repair-shop complex. We can judge from the experience of other plants, such as USIMINAS (Brazil), that this complex should be fully exploited to serve potential customers. The shop requires 115 engineers, but no one has been formally trained. This shop is incontrovertibly the most complex and best equipped in sub-Saharan Africa. It has a projected staff of 1677, of which 702 are expected to be highly skilled workers (Table 7). To date, few of these workers have been recruited, although more than 200 machine tools have been fully installed and the shop has been commissioned.

Table 7. Full complement of personnel required for the central repair-shop complex of the Ajaokuta steel plant.

Shop	Engineering staff	Skilled workers	Semiskilled workers	Unskilled workers	Service staff
Foundry	17	78	48	57	17
Forge and fabrication	12	53	34	38	10
Mechanical repair	40	254	145	37	15
Building repair	20	67	82	93	9
Power equipment	26	250	152	106	17

The statistics are one measure of the deficiencies. Close observation of the system, as well as direct interviews with various personnel, enabled us to deliver an analysis that goes beyond the statistics. We have several observations.

The recruitment, training, and development of personnel have been inadequate. The numbers of personnel lag seriously the required numbers for both commissioned units and those under construction; it would seem that the plant will face a personnel crisis.

Key units are being commissioned without the participation of carefully prepared, well-trained teams. For large technological complexes, such as the Ajaokuta steel plant, semipermanent working teams should be set up to ensure continuity in the technology acquisition. Included on these teams should be people from the enabling system (government in this case) the ASCL board of directors, and the various departments of the firm).

Political instability — with frequent changes in the leadership of government ministries and in the portfolios of directors, general managers, and senior management staff — makes continuity almost impossible. For example, since 1979, when ASCL was set up, it has had three general managers, not counting the project manager, who retired at the start of construction. For half of this period, ASCL was under direct ministerial control, as there was no board of directors while a new government took the time identifying and appointing its own people. The other half of the time, the management of the firm was shared by two boards of directors. The major disadvantages of direct ministerial control are the bureaucratic delays and the lack of the flexibility needed to efficiently run a corporate manufacturing enterprise.

No one stays in any position or manages any portfolio long enough to sufficiently appreciate the importance of the roles of people in technology acquisition. Under such conditions, it is impossible for people to accumulate the required technomanagerial skills on the job (learning from past errors). Yet, this is the basis for an enduring technomanagerial buildup. This situation is by no means peculiar to Nigeria. Perhaps the way to seek continuity is to assume a system that insulates large technological projects from the weak political culture of developing countries.

One of the prerequisites for the smooth transfer of knowledge is a shared language, yet no serious effort has been made to ensure that language is not a barrier.

Interpreters can never substitute for direct communication.

With the advantage of hindsight, we can say it is doubtful the project would have achieved its objective, given Nigeria's recent entry into the steel-producing league, its shortage of experience, and its low level of technological capability. It is also doubtful that a team of the type needed to cope with a plant of the size and complexity of Ajaokuta could have been raised under the circumstances. The project never had the industrial-behaviour pattern or the level of organizational discipline it needed, nor did it have the time needed to achieve these. It may be that there were misconceptions about the technical and managerial know-how available in the country.

The major factors causing time and cost overruns also contributed to the unhealthy state of the training program. A delay in implementation tends to justify (on the surface) shifts in the training program — Why train people when there is such uncertainty about completion date? The learning process, however, is suboptimal and cannot be otherwise when staff's education in the technology does not include textbooks. However, despite an unpreventable atrophy of their knowledge and skills, the staff whose training took place a long time ago form the bulk of management and, by all accounts, have a better appreciation of the issues than those who are completely uninitiated into plant practices.

The requirements for certain basic qualifications, especially those of skilled and unskilled workers, have not always informed the selection process. For parochial and political reasons, personnel have been installed whose abilities are inadequate. Conscious steps should have been taken to ensure that a project of this nature attracted and trained the best and the brightest graduates of the universities and polytechnical institutes. This could have been achieved by open and preemptive recruitment. For example, although the company experiences critical shortages of certain personnel (electrical and electronics engineers and electrical technicians), college graduates are roaming the streets elsewhere in the country, looking for employment.

The chain of learning is broken when newly trained personnel leave for higher paying jobs; yet, the company pays the lowest salaries in the manufacturing industry, and this is a training ground. The accumulation of the required technological skills is clearly impossible under these conditions.

Nontechnical staff in operations and maintenance receive some training, but those in stores management, inventory control, finance, and the training unit receive little or none, although they need a technical understanding of their disciplines.

A lack of confidence has emerged in the firm: this has resulted from overreliance on consultants for tasks that Nigerians have proven themselves capable of doing. For example, the Soviets have delayed handing over the bulk of spare parts and consumables to ASCL officers, with the result that the plant sometimes must wait for parts that were delivered years ago but are locked up in the stores to be documented.

There are no computer facilities to handle the 200 000 drawings and 20 000 t of spare parts, and the study of information storage and retrieval problems has hardly begun. The company realizes the need for computer facilities but has been denied funds or has been caught in bureaucratic delays while continuing to strain under a problem that will require years of expert labour to solve. In the company archives (which stores drawings and various operation and maintenance manuals), there are only a few people with a modicum of training on documentation and registration. The company library — a centre for intellectual activity when the detailed project report was submitted — is now a storage room for old books.

The gradual decline in the calibre of managers responsible for the firm's

training program may reflect the true place of training in the management priorities of the firm. At one time, the training managers were highly trained engineers, who were deeply committed to the project and appreciated the role of training in the acquisition of technological capability. Training no longer headed by an engineer: it has been relegated to a small unit that has little role in the scheme of things.

Other crucial segments in the acquisition of knowledge, such as periodic programs for engineers and managers, do not receive adequate attention. Intermediate-level personnel rise to senior management levels without being trained. There is no clear vision of how training and development should be related to appointments and promotions. The unit cannot be so isolated from the system. The role of training in skills acquisition has to be kept in view.

The main functions and roles of a training team are the recruitment and selection of candidates; the intensive and extensive study of the basic-training program contents; the comprehensive study and maintenance of up-to-date information on the human resources of the firm; control of, and accessibility to, facilities required for training and development; monitoring of the training program (basic, in-plant, and post-training or operational-phase performance); and subsequent development and upgrading of personnel as they change roles or get promoted.

The training team currently does not have the ability to manage these tasks, which are essential to systematic accumulation of know-how.

Conclusions

To meet the objectives of this study, we examined the different phases of a process to create a steel plant in a developing country. One conclusion of this work is that past events continue to interact with more recent ones (the evolutionary nature of the project cycle) — earlier decisions impinge on, and critically shape, today's events. Although the process is continuous, the compartmentalization of events simplifies the analysis. Thus, we divided the process into preinvestment, construction, start-up, and post-start-up, or operation. Only the first two fall within our scope; however, the activities carried out in the construction phase affected the succeeding phases. In addition, we examined training and development, as well as general issues concerning project implementation (particularly the effects of long gestation).

Preinvestment was characterized by the sharing of functions among major contractors (suppliers of equipment), the client, and other participants. The major contractor was commissioned to provide a preliminary report; this was followed by detailed discussions with Nigerian engineers, before the final reports emerged. Events demonstrated clearly that project formulation and execution are complex and multifaceted, demanding an in-depth knowledge of technology and a team of skilful people.

The many issues that called for attention showed how little prepared we were to undertake the project. The sheer magnitude of the problems relating to raw materials and plant infrastructure belied the initial optimism and exposed the fragility of the inchoate organization that was expected to produce steel for Nigeria.

The elements in the project's formulation that shaped the way the project moved were finance (supply and services) and the scheme for implementation.

The civil-works contractors (who were also the suppliers of external credit) dictated the pace of the project. ASCL was expected to survey and explore for all the raw materials, provide port facilities, construct rail and road networks, and so on. A critical assessment of the relative management capabilities, experience, and human resources of the organization should have been made at a very early stage. Our

findings suggest that the magnitude of work, given the resources available, was thoroughly understood. There seems to have been no concise plan for moving forward in the assigned roles; in consequence, precious years meant for planning and action were frittered away while participants bickered because the responsibilities for crucial activities were not clearly and concisely defined.

The sources and nature of the financing seriously limited Nigerian control and imposed penalties in the long run. The supply of technology and equipment and the erection of facilities were done by one firm (the Soviet firm, TPE). The execution of civil works, on the other hand, was mainly done by three contractors from Western countries. The financing of TPE and the Western contractors was through export credit. No major problems in this matter have arisen between TPE and ASCL. The delays and cost overruns have stemmed from the actions of the civil-works contractors, who have exercised total control over the rate of progress — without civil works, no erection of plants can take place. Therefore, the long gestation and cost overruns could be said to have arisen from four situations:

- the ambiguous nature of the terms and methods of payment set out in the contracts, particularly the anomalies in price-fluctuation formula (more than 2 years were lost in negotiations before an acceptable formula emerged);
- the lack of financial provisions for future escalations (no provisions were made, and so none was available when the need arose);
- the contractors' absolute control of the sources of financing; and
- the world economic situation (exchange-rate fluctuations added to the final cost of the project).

During execution, two major issues arose:

- the choice of self-administration (departmental execution) rather than a turnkey approach; and
- contracting of the civil works to three different firms.

Laudable and nationalistic as the effort to self-administer the project was, the decision to do this was inappropriate. Proof can be found in the recent action by the government (advised by experts from the firm) to contract out the modification of the first stage (under the so-called accelerated flats production) on a turnkey basis.

Everything, from the market survey to the preparation of technical documents, had been done by either the Indian consultants or TPE. Although Nigerians can competently handle major aspects, there is dependence on consultants. This reliance on outsiders easily translates into a mistrust of the abilities of local staff. This malaise started from a lack of serious effort to organize a team for each of the critical areas around which the future plant could be built. One finds pockets of excellence scattered all over. They are not just badly organized — no organization is evident. The perception is that Nigerian engineers within the firm cannot possibly handle serious design work, despite evidence to the contrary. The need for teams is paramount for future modifications and expansions if the assimilation of technology is an objective. Umbrella units, like the "design bureau," could be used; this is a congregation of design engineering specialists who find solutions to technical problems.

When blessed by continuity, coherence, and excellence in composition, as well as by careful and systematic training in critical areas, teams have a chance of giving high returns. A team-building effort has, unfortunately, not been observed in the firm. It is essential, however, if the firm is ever to be free from reliance on foreign suppliers and consultants.

Because the planners were unable to appreciate the magnitude of the work,

they failed to make the extra preparations needed to meet the challenges of the project. Grafting steel-making technology onto Nigeria — particularly at the scale attempted — represents a Gestalt shift. The complexity of the technology does not end when the hardware is installed; mastery of technology rests with the crucial supply of human elements. This dimension has not been given sufficient attention.

The experience with the civil works belied the idea that one can get the best value when contracts are shared among competing firms. When problems arose, ASCL was always forced to negotiate on three different fronts. This made the task arduous, unwieldy, and time consuming and may explain why negotiations to revise the price-fluctuation formula took such a long time. Financial arrangements that are acceptable to one firm may not suit another. Also, organizing the technological capabilities of the three firms added to the difficulties.

Nigerians may have been too optimistic in allocating to themselves such a magnitude of work, which in the long run affected the quality of planning. The quality of planning has come to haunt the project in several ways, and the “breathing space” provided by a long gestation was not usefully used in organizing to meet the future.

Additional causes of the long gestation include overruns before commissioning, as well as extra time spent trying to attain nominal plant capacity. It is not difficult to see the close correlation between the scheme of execution and the rate of progress — poor planning inevitably shows up in delays during project execution. What’s more, the absence of teams with sufficient technical exposure will make an early start-up difficult. A realistic stocktaking of capabilities should precede the choice of implementation strategy. When the costs are added and compared with the benefits, one may find not only that time overruns have taken their toll in financial losses but that valuable skilled personnel have been lost during the long years of waiting.

As a guarantor of finance capital, the state was seriously disturbed by influences and powers external to it. This has been demonstrated clearly by the long delays in this project. The project’s financing and Nigeria’s inability to sustain foreign credit exposed the weakness and fragility of the state’s financing power.

From the lessons learned, it is clear that the firm should try to ensure that it gets projects off the ground as speedily as possible and avoids harmful delays, and it should pursue the acquisition of technology so that it can rely on its own efforts.

Technology acquisition is a desirable social objective, but, to achieve it, firms must be able to shield themselves from the environment. They must garner sufficient technological capability to adapt strategically to environmental constraints. Aggressive pursuit of technical capacity and the attendant maturation forge for a firm a new image in the public eye. Then, a firm can chart technological growth that fulfils its objectives and its ideals. Clearly, to avoid falling prey to the lack of raw materials, inadequate infrastructure, and lack of local suppliers of parts, a firm must erect protective armour and then begin to set strategic goals.

Recommendations

Based on this analysis, we make the following recommendations:

1. Government should prepare adequately (through training) before attempting to execute a project with the ramifications of the Ajaokuta steel plant.
2. Decision-makers should make allowance for the acquisition of technology through two critical components: embodied knowledge (residing in humans and cumulatively acquired) and disembodied knowledge (exemplified in capital goods and all other physical manifestations of technology).
3. Efforts should be made to keep abreast of the state of the art in technology,

innovative activities, and the strengths and shortcomings of suppliers and technical partners. This would ensure an optimum return on investment.

4. Steel-making projects and similar endeavours should be conceived as taking place within the context of the country. Practically all the capital goods for implementation of the Ajaokuta plant were imported. This state of affairs suggests that steel production was conceived of in isolation. The steel industry supplies the basic materials for the capital-goods sector, and the capital-goods sector supplies the machinery and equipment needed to erect plants for the steel industry. Industrial policy should articulate this symbiotic relationship, and a link should be actively promoted to ease the pain of project execution and promote indigenous manufacturing. It is difficult to see a truly indigenous technological effort taking root without a dynamic capital-goods sector.
5. The steel plant's facilities, such as the machine tools in ASCL's repair-shop complex, should be used to satisfy demands outside the steel plant. This would not only contribute to the economy but also help develop an indigenous technological capability and enhance adaptive abilities.
6. A rigorous inventory of resources should be taken of the raw materials needed in steel making. However, the technomanagerial abilities of the various institutions concerned with this would have to be upgraded first.
7. A study should examine the present status of the industrial sector and the adequacies or inadequacies of the institutional arrangements for finding, exploiting, and allocating resources and of those responsible for providing infrastructures.
8. Those making financial arrangements for projects should seriously consider the nature and source of funds. Indigenous equity financing and the encouragement of local capital financing would reduce the risk of the costly foreign-credit squeeze that has been the bane of this project's execution.
9. Rethinking is needed to correct the present anomalies in institutional coordination and to strengthen future organizations responsible for implementation.

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CHAPTER 21

Adaptive Responses to Modern Technology: Kitui Farmers in the Semiarid Regions of Eastern Kenya

Wilhelmina Oduol

Introduction

During the last three decades, development and implementation of modern agricultural technology in Africa have been shaped and moulded by modernistic approaches. Agricultural researchers, planners, implementers, and extension agents have developed and transmitted agricultural information on the assumption that farmers' indigenous knowledge systems, strategies, and capacities are limited and unsuitable for a fast changing market-oriented economy (Moore 1963; Inkeles 1973; Hyden 1983).

Farmers are usually perceived as uneducated, conservative, superstitious, and illogical people who need instruction in effective farm management for increased agricultural production. Extension agents adopt the role of expert advisers, and breeders develop and release hybrid seed varieties without considering the farmer's seed-selection practices or other local knowledge of production systems. Dependency theories have been propounded to explain the reasons for this arrogant superimposition of the international community and, by implication, their agents (scientists, planners, and implementers) on peripheral peoples. These theories, however, portray local people as passive recipients unable to resist attempts by the core to obliterate local cultural practices and impose their supposedly advanced forms of social organization and technological development (Dos Santos 1969; Bernstein 1973; Todaro 1977).

What modernists fail to realize is that no society wholly denies its cultural values or environmental orientation to fully embrace the values, norms, technological innovations, and social institutions of another culture. This fact was aptly summarized by Apter (1965, p. 8), who noted that "cultures never give way completely to the new, no matter how ruthless the impact of innovation."

Many traditional societies draw insights from the knowledge, cultural values, practices, and perceptions learned and passed on through the generations (Thrupp 1989). They selectively adopt innovations, according to their needs, while adapting or rejecting those that do not fit into their cultural orientation (Rogers 1983; Thrupp 1989). Indeed, contemporary anthropological studies argue that the farmer's so-called conservative or backward practices are often rational responses to local conditions and are logical adaptations to perceived risks, based on practical experience.

This study examines the adaptation of new agricultural technology by a subsistence-oriented rural community in the semiarid regions of Kenya. The implications of the national Sorghum and Millet Improvement Programme (SMIP) for the Akamba community of Kitui District, in Eastern Province, and its seed-selection and seed-adoption practices are analyzed. Emphasis is placed on the farmers' adaptive responses to the program, which result from a combination of indigenous knowledge and selective adoption of innovation to suit their environment and particular

sociocultural and economic circumstances.

Theoretical assumptions

This study is guided by two theoretical assumptions. The first assumption is that technology is not a deterministic force, separate from society and affecting it without being influenced by human decisions. Nor is it an autonomous, immutable, and inevitable force controlling and shaping the lives of a largely unresisting human mass, despite what determinists would have us believe (Ellul 1962; Langdom 1975; Cooley 1987). On the contrary, I argue that technology is a social and cultural phenomenon influencing and being influenced by human, political, economic, and social activities. This contextualization of technology was reinforced by Pfaffenberger (1988, p. 249), who defined technology as a "totally social and cultural phenomenon which marries the material, social and symbolic in a complex web of associations." It is the social construction of nature around us and within us and, therefore, a form of life. In essence, technology is a symbolic reflection of people's values, belief systems, and cultural practices. Hill (1988, p. 27) further stated that

the particular forms of technology that develop and bed into society are shaped by cultural meanings and social negotiations. Equally, the experience of technology and its impact on everyday life are shaped according to cultural meanings that reside within the wider society.

This dialectical relationship is fully realized when one acknowledges the fact that in all technological developments, the motivating factor for creating them originates from the need of human beings to transform the world to their advantage. Technologies are created, adapted, and adopted according to human needs and conditions at the time. These needs are developed and shaped according to cultural meanings and social negotiations. They are culture specific, environmentally tailored, and malleable to socioeconomic and political influences. The humanistic nature of technology is so overwhelming that decisions determining its invention, adoption, adaptation, and rejection rely wholly on people. Just as technology influences human life, therefore, human beings influence the creation and development of technology.

The second assumption is that farmers' reactions to agricultural innovations depend to a large extent on environmental factors. For subsistence farmers, who live in marginal environments characterized by harsh climatic conditions, limited and erratic rainfall, poor soil nutrients, perpetual crop failures, and chronic famine, a bad crop would not imply simply that some land or livestock has to be sold to provide the much needed subsistence. In extreme cases, it would also mean starvation and death (O'Leary 1980). This is consistent with the theory of the "subsistent ethic" of Myint (1969), Scott (1976), and Ellis (1988), who argued that the cost of failure for farmers near the subsistence margin is such that safety and reliability take precedence over long-term profit. The fear of food scarcity provides justification for the farmers' holding on to their traditional practices, rather than gambling with innovations and plunging their families into starvation and death. In the event that they adopt new technologies, they do so cautiously, marrying tradition and modernity and selecting only those items that best suit their circumstances.

Rationale for the project

During the 1970s and 1980s, the Government of Kenya increasingly focused on the problems of the arid and semiarid regions in the country. This emphasis emerged with the realization that with the increasing population pressure on the 19% of high-potential, arable land (Central Bureau of Statistics 1980), food scarcity was becoming

a stark reality. In an attempt to solve the problem, emphasis was placed on evolving well-developed and less risky farming systems in arid areas (constituting 81% of the land mass), to ensure food self-sufficiency not only in these areas but in the whole country. Because these areas receive mean rainfall within the 500–800 mm range and are characterized by seasonal moisture deficiencies, it was felt that the quality of the indigenous drought-resistant food crops could be improved, not only for consumption but also for marketing purposes.

As a result, the Government of Kenya, in collaboration with the Kenya Research Institute and its various research stations, established the national Sorghum and Millet Improvement Programme (SMIP) in 1978. This program developed and released improved sorghum and millet seed varieties for adoption by farmers in the Eastern Province in the early 1980s. The improved seeds were early maturing and drought and pest resistant, had acceptable food-processing qualities, and could withstand fluctuating environmental conditions. The technological package also included complementary methodological procedures, such as improved farming techniques (e.g., row planting, timely weeding, and terracing), use of fertilizers and pesticides, and improved harvesting and post-harvest techniques.

Kitui District, which is one of the areas where the program was implemented, is the largest district in the semiarid zones of Eastern Province. The district has a total land mass of 6030 km² and a population of more than 700 000 (Republic of Kenya 1979–1983). Because most of the district lies within ecological zones IV, V, and VI, which are the areas with the lowest potential in Kenya, it is drier than other semiarid regions in the country. Thus, the other semiarid regions have some choice in the crops they grow, but Kitui District has none — it must grow sorghum, millet, and other dryland crops or face starvation. Agricultural-development implementers, therefore, felt that SMIP would result in an overall increase in food production in the area.

At the time SMIP was implemented, the farming systems of the Akamba community were predominantly subsistence oriented. Emphasis was placed on family labour at the expense of hired labour. Division of labour was based on sex, age, and status. Rudimentary technology, rather than mechanized farming, was used. Traditional farming systems predominated: seed-selection practices, land preparation, planting, weeding, and harvesting were based on indigenous technical knowledge accumulated over generations. Although the community was fully monetized, the farmers usually ignored the neutral and impersonal mechanisms of the money economy, preferring to use kinship networks, reciprocal exchange systems, communal structures, supernatural sanctions, and rituals to organize their production, consumption, and distribution of agricultural products.

SMIP, therefore, aimed at transforming the production system by promoting hybridization, modern farm methods, and the use of farm inputs, which are all components of the green-revolution model. Within this modernistic approach, indigenous knowledge and farmers' experiences and perspectives on the environment were considered obstacles to development and were omitted during the design, planning, and implementation of the program.

Methodology

The data used in this paper were collected between November 1992 and February 1993. A survey questionnaire was administered to 415 respondents from all over the district. This was supplemented with informal interviews, key informant techniques, direct observation, and focus-group discussions to obtain in-depth information on farmers' perceptions, cultural values, and norms. Because of the high rate of male out-

migration (estimated at 40% by an agricultural survey in 1986), more than 70% of the respondents were women. The male interviewees tended to be elderly and had more of a general than a specific knowledge of farm operations. Thus, this information is largely attributed to women farmers' perception of local farming systems.

Farmers' adaptive responses to the program

The survey revealed that both traditional and hybrid sorghum and millet seed were grown by the farmers, with the traditional seed variety being more popular. The hybrid varieties included 2k × 17, locally referred to as *katumilla*, *serena* (*kaserina*), and an undefined agricultural variety called *mutune* (red-brown sorghum). Of the local varieties grown, the most popular were *kaveta*, at 21.2%, and *katengu*, also at 21.2%. Table 1 shows the varieties of sorghum grown by respondents.

Table 1. Sorghum seed varieties grown by respondents.

	Respondents (<i>n</i>)	Rate (%)
Hybrid varieties		
<i>Mutune</i>	50	7.2
<i>Serena</i>	82	11.7
2k × 7	97	13.9
Traditional varieties		
<i>Kaveta</i>	148	21.2
<i>Katengu</i>	148	21.2
Other local varieties	173	24.8
Total ^a	698	100.0

^a There were only 415 respondents, but some grew more than one variety.

From Table 1, it is evident that the traditional sorghum varieties were preferred (67.2%). However, it was difficult to clearly distinguish the adopters of hybrid seed from the nonadopters because all the adopters also grew traditional varieties. Their reason for growing both kinds was that the local varieties and the hybrid varieties had different characteristics, so they would be avoiding the risk of total crop failure (usually caused by lack of rain fall and by other environmental hazards). The choice and use of particular seed varieties largely depended on their compatibility with the existing norms, their environmental adaptability, and the farmers' cultural perception. The farmers considered taste, colour, storability, grain size, processing qualities, weight (whether the flour is filling when eaten), and resistance to pests and drought. These selection criteria led to the continuous use of *katengu*, a traditional sorghum seed that is highly palatable, is easy to prepare, has good processing qualities, and is white, a characteristic that makes it preferable to red sorghum varieties. *Kaveta*, another traditional variety, was mixed with salt and eaten raw. It was also harvested and eaten before it was completely ready. This seemed particularly important in this area, where food scarcity is a chronic problem and alternative foods are rare. It was also believed that the nutritious qualities of *kaveta* increased breast milk in lactating mothers.

The unpopularity of hybrid seeds was due precisely to their lack of the qualities that farmers preferred in traditional varieties. Only 82 of the respondents

adopted serena seed. Despite its high-yielding qualities and resistance to birds, serena seed was largely rejected because of its red colour, which was offensive to the eye, according to the local community, and had a bitter taste as a result of its high tannin content. Those who adopted it did so for marketing purposes rather than for consumption. Adopting it for marketing would appear rational to modernists and agricultural scientists, but for many local farmers this was not an option because food scarcity, starvation, and death were prevalent in the area. The first consideration, therefore, was to attain food security; the surplus could be marketed later. In fact, findings reveal that those who grew serena seed in abundance had a higher socioeconomic status and could afford to buy alternative food for consumption.

The only hybrid seed that compared favourably with local varieties was 2k × 17. It was white, palatable, used in a variety of local recipes, early maturing, and drought resistant. It had the additional advantage of producing higher yields than some of the local varieties and, therefore, could be successfully marketed. However, farmers complained about stomach upsets when it was poorly processed. It was also highly susceptible to birds, a common problem with all white varieties of sorghum.

Table 2 shows the millet seed varieties grown by the respondents. The limited adoption of bulrush millet (14.4%) resulted from the farmers' inability to eat it raw, which was due to its spiky covering. It was also more susceptible to weevils when in storage than the local varieties. The local millet seed variety, referred to as *mwee wa kikamba* or *ute wa makova*, was grown for the same cultural reasons as *kaveta*. It was also preferred (69.7%) over the hybrids because it was more pest resistant and could be stored for several years without any pest infestation.

Table 2. Millet seed varieties grown by respondents.

	Rate (%)
<i>Mwanza</i>	7.3
<i>Nguunu</i> (undefined variety)	8.6
Bulrush	14.4
Local variety	69.7
Total	100.0

Questions relating to sources of information about hybrid seed revealed that only 19.9% of the respondents who usually had direct contact with the scientific agents had learned about hybrids from them. The rest obtained information informally from churches, nongovernmental organizations (NGOs) working in the area, friends, or relatives. None of the respondents indicated having had any contact with the Katumani Sorghum and Millet Breeding Research Station, whose area of operation and testing sites covered the district. The farmers indicated no knowledge of collaborative efforts between other farmers and research station or extension staff working locally to produce hybrids for multiplication and distribution. This finding seemed to be consistent with information received through interviews with the staff of the Katumani Sorghum and Millet Breeding Research Station, who indicated that before any seeds are released to farmers for adoption, breeders develop them at the research station. Cluster farmers are then identified in the station's area of operation, and farm trials are undertaken to obtain feedback from these farmers. Once the required characteristics are developed in a seed variety, the Farming Systems Section collaborates with extension staff, who in turn transmit the information to local

farmers. The fact that none of the respondents had had any contact with the breeding station suggests that either they were not cluster farmers or they had not heard of the stations. This meant that the cluster farmers were few and far between or that the rest of the farmers had little contact with extension staff and, therefore, were unaware of research activities relating to seed development, multiplication, and distribution.

For more than 60% of the respondents, the most reliable source of seed was themselves: they selected healthy, untainted seeds from the harvest and preserved them, usually by the smoking method or by applying ash and pepper for pest resistance (Table 3). Seed selection was largely a specialty of the older women, who would gradually teach this to the eldest daughters-in-law, to be used when the elders were either away, too old, or dead.

Cost and availability of the hybrid seed also played a major role in determining farmers' choice and adoption of a particular seed. More than 50% of the respondents could not afford the price of seeds available in the shops; the rest noted that seed was unavailable at the shops and other distributing centres during planting season. Instead, they depended on sporadic sources, such as NGOs working in the area, government personnel, chiefs, churches, neighbours, relatives, and others in the kinship network. Family affiliations and friendships played an important role in ensuring that seeds were available to those who could not get any through the reciprocal-exchange systems. Seed was freely given and received, and many farmers were without any specific reason for planting a specific seed variety, except that it was available or was given to them by a friend, relative, or neighbour. The unavailability of hybrid seeds reduced the choice and encouraged the farmers to continue planting traditional varieties or to replant hybrid varieties.

Table 3. Seed preservation measures.

	Respondents (n)	Rate (%)
Ash and <i>mitaa</i> (traditional herb)	47	11.3
Ash	60	14.5
Nothing	69	16.6
Pesticides	89	21.5
Ash and pepper	150	36.1
Total	415	100.0

Qualitative information obtained from focus-group discussions revealed a curious event, which resulted from repeated replanting of hybrid seeds. Questions about the significant differences between repeatedly replanted hybrids and traditional varieties revealed that traditional varieties retained their original characteristics, but the seed of the hybrids shrank, its stalk grew taller, and its yields decreased. For serena seed, the red colour faded into white, making the seed attractive to birds. The spikes of bulrush millet fell off, also exposing the seed to birds. In time, the farmers saw no difference between their traditional seed and the hybrid seed.

It is clear that seed adoption cannot be encouraged without making the seeds available on a continuous basis and providing adequate information about them. Furthermore, one cannot assume that after the farmers obtained hybrid seed, they would use modern farm methods to plant, weed, and harvest them, which would be needed to ensure increased yields. On the contrary, the type of farm operations chosen, whether traditional or modern, depended on the availability of resources, such

as farm inputs and modern farm equipment, and on the farmers' awareness of modern storage techniques. If the farmers did not have the resources or lacked the scientific knowledge they needed to use modern techniques (as was usually the case), they would broadcast the hybrid seed or plant it in the same hole with traditional seed to minimize the risk of losing both seed crops if the rains failed. Often, they also used traditional weeding methods, pest-control strategies, and storage techniques for hybrid seeds. Obviously, this idiosyncratic use of planned agricultural practices made it difficult to determine the impact of hybrid seeds on overall crop yields. As a matter of fact, the complexities resulting from the interplay between technology and human action made it quite difficult to directly correlate the adoption of hybrid seed with the expected overall yields in the long run.

The mixture of traditional and modern farm operations by the farmer could also be indicative of the weak extension-farmer linkage evident in the area of study. Although 67.2% of the farmers knew that there was an extension agent working in their locality, only 46.3% had met him. However, the majority (60%) had only met him once in 6 months and often in public forums rather than on their farms. The implication here is that many of the farmers who adopted hybrid seed had to rely on information from neighbours, NGOs, friends, and other sources or fall back on the traditional practices used for generations.

Strategies for sustainable agricultural development in arid regions

A major conclusion of the study is that hybrid seed varieties are less popular than traditional varieties because farmers have inadequate contact with the extension agents and especially with the research station scientists, who should have asked the farmers about their preferences and needs before developing hybrid varieties. Indeed, agricultural modernists prioritize scientific knowledge at the expense of the farmers' local knowledge and use a top-down approach to transmitting it.

In Kenya, research directors and their staff typically set up research priorities with the expectation of feedback from farmers through farm trials and extension input. However, as Thairu (1985) and Audi (1985) rightly noted, the research agenda is set by the plant breeders, but rarely in collaboration with the farmers. This weak linkage extends to the interaction between research stations and extension personnel: financial constraints and other logistical problems prevent them from holding regular workshops and other forums of communication for disseminating research findings (Audi 1985). Extension-farmer linkage faces a similar setback because of chronic problems that plague the Kenyan Ministry of Agriculture, such as few extension personnel (estimated at one for every 500 farmers), limited transportation available, lack of incentives for staff, and a bureaucratic structure that stifles staff initiative at the local level (Uma Lele 1975; Chitere 1980; Ogum 1982; Benor and Batter 1984; Oduol 1991).

The obvious way to overcome these weak linkages is to change the agricultural-development approach from one that is top down to one that is bottom up, from centralized standardization to local diversity, and from blueprint to learning process (Chambers 1980). The adoption of the bottom-up approach by planners would require that the research agenda be determined by farmers' preferences, rather than those of the experts. This means that a needs assessment of the farmers' circumstances should be undertaken before hybrid seeds are developed, rather than developing the seed first and then testing it with farm trials. The major advantage of the bottom-up approach is that farmers' local knowledge of crop-development practices and their adaptation of farming practices to ecological and genetic diversity would be harnessed to supplement scientific knowledge for sustainable crop development. Linked with this

is the need to consider farmers' seed-selection criteria and their effectiveness, as well as the sociocultural and economic setting in which farming practices are undertaken. This knowledge becomes particularly important where hybrids are broadly adaptive and uniform but rarely sustainable in the long term, particularly in arid environments (Berg 1993).

Although a lot of indigenous knowledge is presented too generally by social scientists to be of much use to plant breeders, this knowledge can make a big difference in agricultural development if harnessed by a multidisciplinary team of scientists, social scientists, and farmers. Through their combined efforts, they could obtain information on consumer preferences, as well as the sociocultural, economic, and ecological characteristics of the plant environment. Prain (1993) provided the example of an interdisciplinary team that successfully explored ways of collecting and documenting sweet potato germ plasm and associated indigenous knowledge in western Java. Dorp and Rulkens (1993) also described how the combination of a multidisciplinary team, participatory rural appraisals, and villagers with local knowledge of seed-selection criteria provided information that was then integrated into breeding programs in Indonesia. Worede and Mekbib (1993) noted similar experiences in northeastern Shawa and southeastern Walo, where farmers maintain crop diversity and improve genetic performance with the assistance of breeders and other scientists. Such examples clearly illustrate the importance of taking a participatory approach in agricultural development programs in the Third World to ensure sustainability.

The weak extension-farmer linkages could be strengthened if the Kenyan central Ministry of Agriculture extension agents networked with the NGOs working in the rural areas. One advantage of networking with local NGOs and churches is that they already have extension programs and resources that facilitate their interaction with local populations. Because the Ministry of Agriculture lacks precisely those facilities needed for effective work, it could form collaborative networks with NGOs and provide the additional skills, experiences, and expertise that local NGOs may require to strengthen their extension programs. The extension training component of the Kenya Energy and Environmental Organization and the efforts of World Neighbours help to strengthen farmers' capacity to analyze agricultural problems and make appropriate changes (Wellard 1993). As well local farmers chosen by the local community could be trained to provide extension services. The use of local farmers chosen by the community could help alleviate problems with contact farmers, who are isolated by local communities because they are identified with extension personnel and, by implication, with the administration, rather than with the villagers.

The study also revealed that agricultural development is implemented selectively, rather than in an integrated and holistic manner. Although hybrid seeds are developed for adoption, adequate plans are not made to ensure they remain available to farmers, and the purchasing power of the farmers and other economic constraints on farmers' access to seed are not taken into account. This conclusion was reinforced by Oduor (1991), who revealed that most of the improved varieties are unavailable at the Kenya Grain Growers Co-operative Union, one of the main seed-multiplication centres, because most of the projects that used to produce seeds in bulk are no longer operational. Furthermore, the Kenya Seed Company, the major commercial distributor of seeds, may not be stocking the shops and other retail outlets effectively in arid regions because of their remoteness and inaccessibility from cosmopolitan centres (Oduor 1991).

The difficulties agricultural implementers face in seed multiplication and distribution leads us to explore the possibilities of using an important but previously ignored resource — the farmers themselves. Case studies abound with examples of

local communities using available resources to adapt to a quickly changing environment (Brokensha et al. 1980; Chambers 1980; Thrupp 1989). The challenges experienced in difficult environments such as arid regions are usually dealt with through group formations based on kinship affiliations, family networks, friendships, and neighbourhood linkages. Communal linkages are used as moral- and social-support systems in labour camps and in development-project activities, such as road construction, bridge building, and soil conservation. The *Mwethya* groups among the Akamba, the *Saga* among the Luo, and the *Bulala* among the Luyia communities serve to illustrate this point.

The local capacities that have been eroded by interaction between local communities and the international market economy should be rebuilt and strengthened for sustainable agricultural development. Although traditional breeding systems could certainly benefit from scientific input, they need not be wholly replaced by modern technology. Instead, a participatory breeding program, with farmers, plant breeders, and scientists identifying appropriate seed-selection criteria, along with seed development, distribution, and multiplication, would go a long way in empowering local communities to be self-sustaining in seed production. In their study of a participatory approach to breeding for improved varieties, Muarya et al. (1988) recommended a similar adaptation strategy for Zimbabwe. They argued that for small-scale farming systems to become the central source of crop genetic diversity, the systems must incorporate four steps:

1. Selection of germ plasm by breeders in consultation with farmers
2. Preliminary on-station selection, based on criteria identified by farmers, and breeding for improved varieties, with frequent feedback from farmers via agricultural extension agents
3. Release of improved varieties for evaluation and selection by farmers
4. Coordination of farmers' evaluation by agricultural scientists and breeders and use of the farmer-selected material for subsequent trials

It is suggested that for effective multiplication and distribution of seeds, local farmers be mobilized in both formal and informal groups; that plots be obtained through negotiations and consultations with the local people, the NGOs working in the area, and government representatives; and that enough improved seed be planted and distributed among members of the group for planting on their farms and the rest sold to other farmers at affordable prices. This approach would not only solve the seed-scarcity problem but also take into account the economic circumstances of the local people, thus ensuring accessibility of improved seed and its continued availability.

In conclusion, this paper analyzes the adoption strategies developed by Akamba farmers in response to new agricultural technology. The major finding of the study is that farmers largely persist in using traditional seed varieties because agricultural scientists and extension agents hardly consult with them before developing hybrid seeds. The farmers are also not adequately involved in hybrid-seed selection, production, multiplication, and distribution, and this results in low adoption rates.

The conclusions derived from this study are that the deterministic and top-down approach used by agricultural experts to transmit information ignores the fact that farmers also influence technological processes and their development cycle. This omission results in the development of inappropriate technologies and policies during the design, planning, and implementation of agricultural programs. Sustainable agricultural development can only occur if a participatory approach, involving plant breeders, extension agents, social scientists, and farmers, is used in future program activities.

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PART IV

**Gender and Technology
and Technological Capability**

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CHAPTER 22

Technology and Women's Ventures in Nigeria's Urban Informal Sector

Funmi Soetan

Introduction

Female entrepreneurs in Nigeria's urban informal sector (UIS) seem to be invisible, along with their contributions and needs. Despite government programs aimed at reaching small-scale entrepreneurs, women as a group are not considered for assistance. A major reason for this is that most of the enterprises women engage in, such as petty trading, dressmaking, hairdressing, food processing, and small-scale manufacturing, fall outside the Census of Production Surveys. These surveys normally include enterprises employing 10 or more people. However, smaller enterprises are crucial to the survival of women and their families.

Women have limited access to critical resources like education, land, technology, and credit. Hence, they are often excluded from employment in the formal sector. Theoretically, the UIS provides employment for the groups excluded from employment in the formal sector. The notion of the informal sector captures certain peculiarities, such as informality of business organization, use of rudimentary technology, lack of separation of consumption and production, ease of entry and exit, reliance on family labour and apprentices, and small requirements for capital.

This study seeks to enhance the visibility of women's contribution to Nigeria's UIS by examining the role of technological inputs such as sewing machines, milling machines, and hairdressing equipment in employment and income generation for women. Three categories of women's ventures where female participation predominates — dressmaking, hairdressing, and food processing — are considered.

The research problem

The role of women in the UIS merits special attention for various reasons. Women in Nigeria generally have less access to formal education and, hence, have low participation in the formal sector. Therefore, many women take up self-employment in the UIS after apprenticeships in nonagricultural occupations, which are most often in petty business. In addition, the women have limited access to other resources, such as credit and technology. Hence, even within the informal sector, they are confined to microenterprise. This includes trading and technology-related occupations, such as dressmaking, hairdressing, food milling, and small-scale manufacturing.

According to the Economic Commission for Africa (ECA 1991), next to the agricultural sector, the informal sector is the largest employer of women in most African countries. There were an estimated 16 million women in sub-Saharan Africa engaged in the sector in 1990 (ILO 1990). Although the representation of women in the informal sector is higher than that of men (Berger and Byvinie 1989), the participation of women is underestimated. This is because women's activities, which

are often excluded from national Census of Production Surveys, are unaccounted for in the calculation of the gross national product.

Theoretically, women's activities in the UIS enable them to effectively combine their productive and reproductive roles because hours of work are flexible, permitting women to care for their children. Women's increasing participation in the UIS is also due to the current economic hardship in Nigeria and the fallout from the Structural Adjustment Programme (SAP). More than before, women are under increasing pressure to contribute to household income; this is even more true of women whose husbands have been laid off by the formal sector as a result of rationalization, privatization of public enterprises, and cuts in government spending. The number of entrants to the UIS has swelled because of unemployed men and women, as well as those seeking part-time employment to augment their regular income.

SAP policies have led to substantial declines in consumer incomes, resulting in dampened demand for goods and services produced in the UIS. Competition in the UIS has been heightened by these developments, thereby compounding the problems of women, who generally operate small-scale businesses with limited capital.

The literature on technology in women's ventures in the UIS has often focused on the nexus of technology and rural employment, especially agricultural production and processing (Boserup 1970; Ahmed 1985; Adekanye 1985; Stamp 1989). Of note is the emphasis on improved techniques in food processing that save rural women time and labour and give them the higher income-generating opportunities resulting from technological change. In contrast, studies on women in the UIS have tended to focus more on women from the view point of their labour-force participation (Trager 1987; Olkine 1989). However, women in the UIS often operate in a hostile environment and are ignored as far as public policy is concerned. Often, they are seen as illegal traders to be harassed by law-enforcement agents. It is quite evident that women in the UIS generally have limited access to start-up and working capital. Hence, they use simple technology, requiring minimal capital investment.

This study seeks to fill the research gap in this area. It is important to address this issue because of the high labour-absorption capacity of the informal sector and the need to increase the productivity of technological inputs to stimulate urban employment opportunities for women. The study uses the paradigm of employment, productivity, and income generation, which is more suitable for urban studies than for rural (Whitehead 1985).

Objectives

The ultimate objective of the study was to investigate the role of technology in women's enterprises in dressmaking, hairdressing, and food processing. The immediate objectives of the study were

- to inquire into the conditions under which the UIS provides employment and generates income for women using technological inputs;
- to assess the impact of technology on the training of UIS apprentices;
- to identify the constraints faced by the enterprises;
- to identify the linkages (both marketing and technical) between the informal and formal sector, as well as the agricultural sector; and
- to propose strategies and make recommendations to further enhance the accessibility of technology to women and improve their incomes.

Methodology

Three methodological tools were used in the study:

1. *A literature review* — I reviewed the literature on the role of female participants and technology in the UIS. This provided me with a conceptual context for the analysis of the data collected through the survey. In addition, it generated a number of testable hypotheses.
2. *Focus-group discussions* — Sixteen focus-group discussions were held with 7–10 female entrepreneurs in the three business categories in the six survey locations. Open-ended questions were used to elicit information on issues relating to access to machines and equipment, impact of the SAP on the businesses, apprenticeship training, relationships with customers, and entrepreneurs' expectations. The answers to these questions improved the usefulness of the quantitative data. Group discussions were tape recorded.
3. *Questionnaire interviews* — Interviews using structured and semistructured questions were conducted with female business owners and with key informants, who were apprentices, customers, officials of business associations, and suppliers of technological inputs (Table 1). All questionnaires were pretested.

Table 1. Respondents.

Category	Min. selected in each town	Total in all locations	Method of selection
Business owners	130	1006	Stratified sampling
Apprentices	330	2111	Stratified sampling
Customers	34	218	Stratified sampling
Business association officials	6	51	Purposely selected
Suppliers of technological inputs	7	61	Purposely selected
Total number of respondents		3447	

The interviews and focus-group discussions were conducted between July 1992 and January 1993. The fieldwork was initially meant to cover three states and six large urban towns in southwestern Nigeria: Ibadan and Osogbo (Oyo State); Abeokuta and Ijebu-Ode (Ogun State); and Akure and Ondo (Ondo State). However, the fieldwork coincided with the period when a new state, Osur, with Osogbo as its state capital, was carved out of Oyo State. The study, therefore, covered four states. In each state, the state capital and another commercial town of comparative size were chosen. These towns were expected to have a large UIS. They are all within a radius of 500 km of each other. They are inhabited by a major tribe, the Yorubas, but have different ethnic Yoruba groups, such as Oyos, Ijebus, Egbas, Ekitis, and Ondos. Migrants to these towns in search of employment.

The three business categories were selected on the basis of significant female participation and use of technological inputs. The categories (and their technological inputs) were the following:

- hairdressing (hair dryers, hair steamers, trolleys, ring boilers, and electric fans);
- dressmaking (sewing machines, finishing machines, electric irons, and scissors);
- food processing (food-processing mills).

It was difficult to adopt a rigorous random-sampling technique, mainly because of financial constraints and the absence of a sample frame. Instead, I divided each town up into major streets and markets (called UIS blocks) where informal-sector businesses were concentrated. Field staff were trained for 2 weeks to ensure standardization and ensure sensitivity in the interviewing process.

Problems encountered

Several problems were encountered during this study:

1. There was a general lack of information about the UIS, especially that pertaining to its female component.
2. The informal-sector operators were rather suspicious of our motives, despite assurances from the field workers that they were not from the Inland Revenue Department and had not come for tax-assessment purposes.
3. In two survey locations, Ondo and Ijebu-Ode, the members of the Pepper Millers' Association did not cooperate with us on the focus-group discussions.
4. The record-keeping habits of the informal-sector entrepreneurs were very poor, so only approximate figures were obtained.

Findings

The literature

The literature on the UIS has emphasized the dichotomy between the formal and informal sectors and the informal sector's low capital and skills requirements, the flexibility of its operations, and its high labour-absorption capacity and employment-generation potential in developing countries (Mabogunje and Filani 1976; Fapohunda 1978; Sethuraman 1984; Dawson and Oyeyinka 1993). However, the studies have generally neglected the gender-biased inequalities in access to resources within the UIS. Studies on the UIS show that women are confined to the microenterprise end of the UIS. These studies also highlight the importance of the UIS in enabling women to combine their productive and reproductive roles, as well as in providing employment and generating small sums in income for such women (Shields 1980; Trager 1987; Okine 1989; Soetan 1991). However, studies on women in the UIS have generally treated the women as a homogeneous group. This tends to camouflage important factors that would be useful for policy interventions for women in this sector.

The enterprises

Thirty-one percent of the women's enterprises were in hairdressing; 35.1%, in food processing; and 33.9%, in dressmaking. The majority of the enterprises (86.1%) were sole proprietorships. The rest were partnerships, family-owned businesses, or registered private companies. A few had other ownership arrangements.

The peak sales periods for the enterprises are Easter, Christmas, and Muslim festivals. Because record keeping is notoriously poor in the UIS, accurate weekly sales and profits could not be ascertained. However, more than half of the respondents said their weekly sales in the peak periods were ≤ 500 NGN (in 1995, 78.5 Nigerian naira [NGN] = 1 United States dollar [USD]). This indicates that the majority of the women in the UIS have small incomes and their livelihoods are in microenterprises.

At the time of the study, the majority (63.2%) of the enterprises were ≤ 10 years old. More than half (57.5%) of the enterprises operated from rented shops; 15.4%, from the home; 6.9%, from a husband's premises; 5.4%, from sheds or kiosks;

3.1%, from federal or local government stalls; 0.4%, from their father's premises or the family home; and 0.3%, from uncompleted roadside buildings. Many of the enterprises (66%) paid monthly rents of ≤ 100 NGN. Usually, the rent paid depended on the size of the building, so this figure indicates that most of the enterprises operated from small rooms.

When asked about the number of branches they owned, 39.3% of the women said they had no other branches; 22.8% had one or two other branches; and only 0.5% had more than five branches. This confirms that these businesses were small and that their owners had not expanded their businesses.

The presence of electricity, tap water, and telephones in the businesses was also ascertained. A large proportion (85.2%) of these enterprises had electricity. Some could afford electric generators (6.9%), which are important because of the unsteady supply of electricity in Nigeria. Tap water, however, was not as available as electricity: 32.2% had tap water; 32.5% used well water; and 77% obtained water from bore holes. Access to water would be crucial to hairdressers and food millers. Only a small proportion (6.0%) could afford telephones.

The female entrepreneurs

Table 2 shows that many of the women were 41–50 years old; 19.4% were older than 50. Almost half of the women had secondary education; 20.9%, only primary education; 11.4%, no schooling; 5.5%, technical or vocational education; and 4.0%, post-secondary education.

In this survey, single women were in the majority, which emphasizes the employment-generating role of the UIS for young, unmarried women who set up their own businesses after an apprenticeship in the UIS. Because this survey was carried out in southwestern Nigeria, it was not surprising to find women from the southwestern states of Oyo, Osun, Ondo, Ogun, and Lagos predominated among the entrepreneurs.

When asked why they engaged in their present occupations, 68.0% of the women said they were personally interested; 16.5% said they needed a job to survive; and only 5% said their parents influenced their decision.

Apprentices

Most apprentices (94.8%) were ≤ 30 years old (see Table 2). Most of these people had finished either secondary school (59.3%) or primary school (27.4%) and were single (86.2%).

Only four of the apprentices were in the food-processing industry (this occupation requires and offers little or no training). By contrast, 1060 of the apprentices were being trained in hairdressing, and 1139 were being trained in dressmaking. The majority (95.2%) reported that training lasted an average of ≤ 3 years, and only 1.9% said the training period was 4 years.

Parents and close relatives were responsible for placing 79.1% of the apprentices; 3.5% reported that their friends helped in placing them; 2.4% said they were placed through the National Directorate of Employment; and it was interesting to note that 8.4% reported the influence of the mass media, especially television, on their placement decision.

Many apprentices (47.0%) paid their training fee twice a year; 21.7% paid in unspecified instalments; and 18.9% paid annually. A small proportion (3.1%) paid a specified deposit at the start of the training and paid the balance at the end.

Table 2. Demographic characteristics of respondents.

	Business owners (%)	Apprentices (%)	Suppliers of technological inputs (%)	Officials of business association (%)	Customers (%)
<i>Age</i>					
<20	3.1	47.1	3.3	—	2.8
21–30	11.9	47.7	26.2	7.8	63.3
31–40	8.1	0.6	44.3	41.2	18.8
41–50	34.3	0.1	16.4	31.4	2.3
>50	19.4	3.0	9.8	19.6	1.4
No answer	23.2	1.4	—	—	2.3
<i>Sex</i>					
Male	—	6.8	—	52.9	—
Female	100.0	93.2	—	47.1	—
<i>Education</i>					
None	11.4	1.8	1.6	7.8	7.8
Primary	20.9	27.4	11.5	25.5	11.5
G4/modern	—	—	—	23.7	—
Technical/vocational	5.5	1.5	3.3	—	—
Secondary	42.8	59.3	13.1	31.8	35.8
Postsecondary	4.0	1.3	3.3	9.8	39.4
Other	—	4.5	1.6	—	1.8
No answer	15.5	8.1	65.5	—	3.7
<i>Marital status</i>					
Single	21.4	86.2	29.5	3.9	56.4
Married	18.6	10.4	68.9	94.1	42.2
Widowed	8.4	0.1	—	—	1.4
Separated/divorced	7.7	0.5	1.6	—	—
Other	4.2	0.1	—	—	—
No answer	39.8	2.6	—	—	—
<i>Children</i>					
None	—	—	14.8	2.0	2.8
1–4	—	—	23.0	—	32.6
5–7	—	—	4.9	15.7	6.4
8–10	—	—	1.6	60.8	0.5
>10	—	—	16.4	17.6	—
No answer	—	—	23.0	3.9	57.8
<i>Tribe</i>					
Oyo	—	—	—	13.7	17.4
Ijesha	—	—	—	5.9	4.6
Ekiti	—	—	—	9.8	3.2
Egba	—	—	—	15.7	15.2
Ijebu	—	—	—	13.7	13.3
Ondo	—	—	—	17.6	17.0
Other	—	—	—	23.3	28.9
No answer	—	—	—	—	0.5

Notes: Number of business owners, 1006; number of apprentices, 2111; number of customers, 218.

Most of the apprentices (89.8%) reported being allowed to operate the equipment or machines either very frequently or frequently. A large proportion (64.5%) also said the equipment had never broken down while they were using it. The common practice was to share payment for repair of equipment damage among all the apprentices (53.8%); some said this had to be paid for by the apprentice responsible (21.4%); and others said this was paid for by the proprietress (14.3%). The same pattern emerged for payment for stolen or missing equipment.

Many apprentices reported very long hours, with rarely any time off. In addition to the duties directly related to their training, apprentices also assisted their bosses with other duties. They frequently assisted with domestic duties (60.5%), shopping (52.5%), child care (49.4%), or running errands (68.9%).

Most (84.3%) of the apprentices hoped to establish their own businesses.

Customers

Most customers were 21–30 years old (see Table 2). The proportion of those with secondary education was 39.4%; only 7.8% had no schooling; and 11.5% had primary education. Customers were predominantly from the southwestern states, but some belonged to other tribes in Nigeria.

Most customers were married and started patronizing the women's enterprises in the last 10 years. Most customers heard about the business through a friend or another customer, but some heard about the business through other people or saw the signs and started going there. Customers also patronized the businesses because of the good quality of work, prompt service, and proximity. The media (e.g., radio, television, and the local newspaper) were not common sources of information about these enterprises.

In response to a question about the effects of the SAP, 50.4% of the customers thought the pre-SAP prices of goods and services increased only slightly or not at all, but 77.5% reported rapid price increases during SAP.

Officials from business associations

Young people were in the minority among officials of business associations. Most (52.9%) of the officials were men (see Table 2), even though these associations represented predominantly female occupations. Most officials had secondary schooling, and very many (94.1%) were married.

Many of the associations were less than 6 years old at the time of the study. The majority of the officials (92.6%) reported that the associations were established to promote cooperation or unity among members for their mutual benefit.

Meetings of all members in a town were commonly held every month (43.1%), and meetings of members in particular areas or streets within a town were commonly held every 2 weeks (45.1%). Members could be fined for missing meetings.

Suppliers of technological inputs

The demographic data on the suppliers of technological inputs are seen in Table 2. Although not shown in the table, it is especially interesting to note that 45.9% of the suppliers said that their start-up capital came from their personal savings, and 32.8% indicated that it came from friends or relatives. As well, 75.8% of the suppliers had bank accounts. Despite this, 85.2% of these entrepreneurs had never taken out a bank loan. Only 19.7% had taken out loans from informal savings and credit associations.

Analysis of the data

The analysis of the data is based on percentages and simple cross tabulations to explore the relationships between the enterprises and (1) the number of apprentices, (2) the productivity of the enterprises, and (3) customer type.

The informal sector and apprenticeship training

Because 42.1% of the enterprises were younger than 5 years old at the time of the study, it was not surprising to find (Table 3) that some enterprises trained no apprentices. Training apprentices was undertaken more by hairdressers and dressmakers because food processing requires very few skills and is often done by children or other family members. The table shows that apprenticeship training was higher among hairdressers than among dressmakers for the most part.

Table 3. Apprentices trained by the three types of businesses.

	Apprentices trained						
	None	1-5	6-10	11-15	16-20	21-25	>25
Hairdressing (%)	45.8	67.7	70.7	62.5	50.0	12.5	50.0
Food processing (%)	34.6	1.2	2.4	—	—	—	—
Dressmaking (%)	19.6	31.1	26.8	37.5	50.0	87.5	50.0

Productivity of informal-sector enterprises

Enterprises with a high daily productivity (>50 goods or >50 service transactions) were relatively insignificant, representing only 2.1% of the enterprises. This reflects a low daily productivity in the businesses and means that the use of technologies, such as sewing machines, hair dryers, and food mills, did not result in high productivity. Enterprises in the UIS often used family labour or a few apprentices; hence, low productivity could be due to low labour inputs.

Daily productivity was higher among food processors than in the other businesses, and this was especially noticeable as the number of goods and services increased (Table 4). This was not surprising, as it takes less time to process food items (which are often in small quantities) than to sew a dress or to render hair-dressing services.

Table 4. Daily productivity in the three types of businesses.

	Goods produced or service transactions per day				
	1-10	11-20	21-30	31-40	41-50
Hairdressing (%)	35.0	34.8	12.8	12.1	7.7
Food processing (%)	31.6	36.6	53.2	54.5	65.4
Dressmaking (%)	33.4	28.6	34.0	33.3	26.9

Forward and backward linkages

Forward linkages were mainly with individual customers (Table 5). Individual customers represented up to 90% of customers in all categories of enterprise. Linkages with other informal-sector enterprises and government agencies were very weak.

Table 5. Types of customers for the three types of businesses.

	Individuals	Informal-sector enterprises	Larger firms	Government or agencies	All these groups
Hairdressing (%)	82.5	13.1	0.8	3.4	11.7
Food processing (%)	90.1	7.0	0.3	—	2.6
Dressmaking (%)	88.7	1.1	1.1	3.8	5.3

Backward linkages were with suppliers of technological inputs, such as food mills, serving and finishing machines, hair driers, trolleys, and diesel and petrol engines for operating the food mills. Most of these items were imported, but grinding mills were manufactured locally. Some suppliers also stocked spare parts for the equipment or machines they sold.

Effects of SAP on women's ventures in the UIS

The Nigerian government adopted SAP in 1986. Under SAP, the women said, profits have been low and costs of inputs have been very high. These high prices are reflected in the high prices the enterprises charge. Undoubtedly, SAP generated high inflationary pressures, resulting in accelerating prices and declining profits. Okine (1989) and Dawson and Oyeyinka (1993) came to the same conclusion. The women in the focus groups also supported this view. Three female members of the Abeokuta Garment Makers' Association reported that the cost of a sewing machine had increased from 800 NGN in 1989 to 4000 NGN by 1992. Most of these women could not afford to replace their sewing machines. Prices of other inputs, such as threads, needles, and stays, had also increased very rapidly. A wedding dress that cost 700 NGN to make in 1989 cost 3000 NGN in 1992. Food millers had a similar story to tell. Members of the Pepper Millers' Association in Abeokuta reported that a grinding machine that cost 800 NGN before the SAP cost 3000–4000 NGN in 1992. Members of the Hairdressers' Association in Ibadan complained that high costs of inputs and the resulting high prices charged to customers led to greatly reduced patronage.

Requests expressed by the entrepreneurs

Generally, the women wanted governments to assist with controlling inflation so that prices of machines, spare parts, electricity, and other inputs would be reduced. Some of the women also sought credit assistance from the government. In addition, members of a zonal group of the Hairdressers' Association at Oshogbo wanted the government to intervene with their city council, which was harassing the association's members for unpaid taxes, rates, and levies. The women also expressed a need to learn new skills because of technical progress and the new machines on the market. Members of the Hairdressers' Association at Ibadan appealed to government to bring them into the Better Life Program, aimed at assisting women.

Conclusions

The UIS consists of heterogeneous enterprises, even among women's enterprises. These activities provide employment for women who might otherwise be unemployed and enable such women to take care of their children and perform other domestic

duties while carrying out their productive roles. The enterprises also provide employment for young graduates and other youth. These young people undergo apprenticeship training for about 3 years and then establish their own businesses in the UIS.

However, owing to the escalating prices of equipment and spare parts in the highly inflationary environment created by SAP, it has become difficult for the entrepreneurs to replace their equipment. Hence, productivity is low. It is clear that assistance with credit to procure new equipment and training would increase productivity. SAP policies have increased the prices of technological inputs, reduced profits, and made spare parts less available. SAP has also reduced patronage, as real purchasing power within the economy has been greatly reduced.

Retrenchments in the formal sector will likely force more women into the UIS to create their own employment. This can be expected to lead to increased competition for resources and customers within the UIS. This situation will make it even more difficult for the female entrepreneurs, who have less access to resources than their male counterparts. These points have implications for the policy measures needed to remove the constraints experienced by women entrepreneurs in the UIS.

Policy implications

Credit

The government and nongovernmental organizations (NGOs) should provide credit assistance to female entrepreneurs operating in the UIS, as lack of credit is a major constraint. Credit can be channeled through women's associations. No collateral should be required; the association would guarantee the loans and monitor both repayment and the use of the credit. Distinctions should be made between different categories of enterprises, and the specific needs of particular categories of enterprises should be considered. Some enterprises have a greater need for working capital than for investment capital. Hence, a participatory approach should be taken (e.g., getting feedback from the women and asking them about their specific needs) before credit is provided. Linkage strategies that open up access of women's groups to existing credit institutions, such as the peoples' banks and community banks, should also be used to widen women's access to credit. Many women find filling out loan applications both cumbersome and discouraging; either this should be minimized or bank officials should be trained to assist women with such details. One of the recommendations of the recent World Bank Poverty Assessment Workshop, in Lagos, Nigeria, was the establishment of a social fund, financed by both private and public organizations, to channel resources to the poor. These are created outside the government bureaucratic structure to assist local groups with capital.

Training

Although lack of credit was identified as a major constraint by the female entrepreneurs, some of them indicated that lack of technical training was a major factor hindering them from keeping pace with technical progress. The UIS provides training for apprentices, but new ideas are few and far between. As one female entrepreneur put it, reading the instructions that accompany a machine gives one very little understanding of the process of assembling and using it. Concrete assistance is needed from both government and NGOs in the form of on-the-job training or short courses to familiarize the entrepreneurs with new methods, machines, equipment, processes, and management training. UIS entrepreneurs hardly keep records, and this is a major reason for their poor performance. These policy initiatives should incorporate the gender dimension, given the increasing feminization of the UIS. Enhancing the skills

of these female entrepreneurs would increase their productivity and income, both as a group and within different business categories.

Technology

Technology is a major supply-side factor and a key determinant of income, productivity, and employment for the female entrepreneurs. The process of acquisition of technological inputs has been severely constrained in the past 7 years. In addition, suppliers of technological inputs depend mainly on imports and only minimally on local fabrication. Lack of access to credit and to training has also hindered the adoption of new technologies. Structural and institutional imperfections limit productivity and income. Policy intervention is needed to control inflation and make technological inputs more accessible and affordable. Local production of spare parts should also be encouraged.

The SAP

The negative impact of SAP on the UIS and on women as a group needs little elaboration. The informal sector has swelled as a result of retrenchment in the formal sector, which is due to rationalizations and to privatization of government-owned enterprises. Unemployed graduates are also looking for employment in the UIS. Usually, women are disadvantaged in the competition for resources. Inflationary pressures have eroded profits and increased the prices of technological inputs and raw materials, as well as the prices of final products and services. Deregulation has not had any salutary effects on the agricultural sector; hence, migration from the rural areas to the UIS has worsened. Under these circumstances, women will be increasingly marginalized because SAP policies are also gender blind. The appropriate policy approach is both sectoral and gender sensitive, incorporating different budgetary allocations to disadvantaged sectors and groups. Women as a group need to be taken into account in the formulation and implementation of intervention programs.

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CHAPTER 23

Equity and Gender Consequences of Policy for Distribution of Irrigation Technology in Nigeria

B.O. Oramah and Osita M. Ogbu

Introduction

Maximizing agricultural production from available agricultural land has occupied a prominent position in government policies ever since Nigeria became a food-deficit country in the 1970s. During the 1970s and early 1980s, declining domestic food production was supplemented with food imports financed by huge earnings from oil. The food-import bill rose from 1.6 billion United States dollars (USD) to 4.5 billion USD between 1978 and 1983 (FAO 1984).

However, imports to meet the ballooning food needs could no longer be financed because of the crash in the oil market, which sent foreign-exchange earnings tumbling by as much as 50% in 1982. Unpaid trade bills began to accumulate, and foreign suppliers would not honour letters of credit originating in Nigeria (Osuntogun and Oramah 1991a). Food prices shot up. To address this problem, the government introduced the Structural Adjustment Programme (SAP) in 1985.

One of the food-security measures under SAP was to ban imports of rice, maize, and wheat. This was intended to stimulate domestic production. The government also invested in irrigation development, which ensures cropping in dry areas and multiple cropping in wet areas with marked dry and wet seasons.

Irrigation refers to a system of harnessing surface and underground waters to make up for deficiencies in total volume of seasonal precipitation or deficiencies in the distribution of the precipitation over time and space (Balogun 1986). Even though deficiency in total volume of precipitation is a problem in some parts of the country, particularly in the Sahel Savannah area, the distribution of rainfall in time and space and the dependability of the rainfall are the major problems. The seasonal distribution of rainfall does not match the seasonal water requirements of plants. It is this match that irrigation technology attempts to achieve. Thus, irrigation is capable of increasing the total national food production, improving the income of farmers, and creating year-round farm employment.

Out of the country's total land area of 98.3×10^6 ha, about 71.2×10^6 ha is arable, but only 34×10^6 is presently cultivated (Oramah 1991). Of this area, about 100 000 ha is irrigated. Using irrigation technology during the dry season can increase the gross cropped area (net sown area plus area sown more than once) by ensuring multiple cropping in the 34×10^6 ha of net sown area. This is possible because Nigeria's annual surface water is estimated at about 193×10^9 m³ and the volume of groundwater is many times that (Ayimodu 1981).

The government's recent drive is to increase the area under irrigation. The government, together with donor agencies like the World Bank, are making huge investments in surface- and lift-irrigation schemes in all the ecological zones of the

country. The 11 river basin development authorities (RBDAs) in Nigeria have recently been divested of other responsibilities so that they can concentrate on managing the water assets under their control. In Nigeria, as in most of sub-Saharan Africa, female farmers are critical to increased agricultural production and food security. However, policies at increased food production do not recognize the central role that women play. The Nigerian government has demonstrated some seriousness in supporting irrigation technology for improved agricultural production. It is, therefore, necessary to examine the extent to which this policy is gender sensitive.

The problem and the objectives

The problem

The Nigerian government's commitment to improving national food production through irrigation has contributed to the expansion of the area under irrigation, from about 32 000 ha in 1984 to about 100 000 ha at present. The Ministry of Water Resources announced in 1991 its plans to construct about 20 more irrigation schemes.

In addition to the goal of improved national food supply, other goals of irrigation technology are improved income for the farmers and redistribution of income from the rich to the poor (Oramah 1991). It is expected that public expenditure on irrigation technology for the rural poor will be considered a form of income transfer. In the long term, though, the benefits will be shared by urbanites, too, as the irrigation technology shifts the crop supply function to the right. This issue has been discussed extensively by Osuntogun and Oramah (1991b).

Although the potential of irrigation technology for improving welfare and alleviating poverty is usually stated in irrigation plans, experience with extensive irrigation systems in South Asian countries seems to indicate that the welfare aspects of irrigation systems have not been realized. Vyas (1983) argued that

Growth of agricultural production in South-Southeast Asia during the past decade or so has been quite satisfactory. An equally remarkable feature of development during the past decade is that it made very little impact on the effect of poverty in this region.

In the same vein, Sampath (1987) noted that the rural poor in Asia could not have an equitable share in agricultural growth because, as pointed out by Vyas (1983), there was gross inequity in the distribution of benefits arising from the major source of that growth, namely irrigation. Obviously, if the outcome of the policy is measured in output growth alone, poverty can still be an issue even in improved agricultural production. This state of affairs was confirmed by Chambers (1986), who referred to it as the "production thinking" of policy-makers and irrigation authorities, according to which the primary purpose of irrigation is production, almost to the neglect of other stated welfare objectives.

It is, therefore, obvious that the efficiency and speed with which irrigation helps to alleviate poverty and reduce inequality of income in the rural areas will depend on how equitably the scarce resource (water) is distributed among cultivating households (small versus big farmers, women versus men). The overall income-redistribution impact of publicly provided irrigation technology also depends on the tax system and the financial performance of irrigators, which also derives from how equitably water is distributed among cultivating households. That is why equity in irrigation distribution is now commonly adopted by almost all Asian countries and recognized by irrigation professionals as one of the most important objectives (Coward 1980; Bromley 1982).

Despite the wide acceptance of this objective, no major empirical work on equity in irrigation distribution has been done in Africa. The only attempt was that of Osuntogun and Oramah (1991c), but the emphasis was on equity in water pricing in specific irrigation schemes.

At the centre of this equity issue should be a gender consideration. Women's participation in development in Africa has been rated as low. This low participation has also been blamed for the less than satisfactory impact of public investments in development. Moreover, the absence of gender-sensitive policies has made it difficult for women to obtain appropriate technology. This reduces the impact of a given policy. There is further evidence that men tend to push women out of the production of what have traditionally been "women's crops" when these become commercially lucrative.

In view of the potential of irrigation technology for increasing the efficiency of production and the support normally provided by government in such schemes, there is the fear that the best area could be taken up by the government for irrigation activity without ensuring gender fairness in distribution of irrigation plots. This is compounded by the fact that farmers usually do not have a choice about the crops they grow in Nigerian irrigation schemes, which implies that in areas where the government's choice of irrigation crop coincided with the women's crop, the competition from irrigated crops produced by the men would push the women out of business, affecting their income and possibly the nutritional standards of the children at home. It is, thus, important to understand the effects of the provision of irrigation on the gender division of labour and economic opportunities.

It is obvious that to understand inequity in agricultural development across regions and along gender lines, especially in areas where irrigation is crucial for agricultural activities (the northern part of Nigeria, for example), we need to understand how the benefits of irrigation are distributed to these groups. In other words, inequity in agricultural development, especially in areas where irrigation is important, is to a significant extent explained by inequity in irrigation development and distribution. Thus, we need an understanding of equity to judge the outcome of irrigation-distribution policies, especially now that the government is planning about 20 new schemes (Ministry of Agriculture, *New Nigeria*, 16 July 1991). Such an effort would be of immense benefit to policy-planners in determining the participation of different socioeconomic groups in existing and new schemes.

Objectives of the study

The general objective of the study was to determine the equity and gender implications of irrigation distribution in Nigeria.

The specific objectives were

- to estimate the level of inequity (or inequality, as the inequality measure adopted in this study satisfies most equity axioms) in irrigation distribution among cultivating households in different areas distinguished by the extent to which irrigation is needed for agricultural activity (this objective was important to eliminate bias in policy prescriptions that may be introduced by considering states where rainfed agriculture is the norm);
- to determine the relationship that may exist between the extent of farmer participation in the distribution of irrigation and the level of inequality in irrigation distribution among households; and
- to determine the gender implications of irrigation development in Nigeria.

Review of the relevant literature

Equity consequences of irrigation distribution

There has been much confusion in the literature about the use of the words *uniformity*, *equity*, and *equality* in the context of irrigation distribution. Sampath (1987) clarified to a great extent the meaning of these terms. He suggested that the use of *uniformity* in discussing equity and equality in irrigation distribution needs to be dropped. In fact, the term *uniformity* in the discussion of irrigation distribution was originally used in engineering design to refer to the spacing and arrangement of the sprinklers in a sprinkler rotation system (Karmeli et al. 1985). The suggested uniformity measures were purely statistical moments of distribution, with no reference whatsoever to social welfare. Sampath (1987) pointed out that uncritical acceptance of these measures in studying equity in irrigation distribution could result in antiegalitarian policy prescriptions and conclusions.

Inequality, on the other hand, is used to describe statistical properties of the distribution of irrigation water with respect to a given attribute, such as households, farms, or unit command areas. This measure does not incorporate any judgment about the social superiority or inferiority of one distribution over any other. *Inequity* is used whenever some criteria based on certain norms, axioms, or value judgments are applied in ranking or evaluating the given distributions.

It, therefore, follows that perfectly equal distributions are not always perfectly equitable, and vice versa. In fact, equal distributions could sometimes be inequitable. This is because the equity concept of equality in irrigation distribution is a notion of "being equal" that refers to the amount of water received per farm, per hectare, or per person, without reference to moral or ethical justification.

Several measures of inequity have been proposed in the literature (Malhotra et al. 1984; Lenton 1984; Abernathy 1986). Sampath (1987) critically evaluated them and recommended the use of Theil's (1967) information theoretic measure. Few empirical works on inequity have been done, apart from Sampath's study. Osuntogun and Oramah (1991c) attempted to determine inequity levels arising from uniform hectareage water pricing in canal commands with tenant farmers. The dearth of studies on this issue is not unconnected with conceptual and data problems. These, however, should not deter further efforts. It is in recognition of this that this study drew from Sampath's extensive study on the issue and used Theil's information-theoretic approach in estimating inequity in irrigation distribution in Nigeria.

Gender and irrigation development

The last decade has seen a lot of policy debate about the role of gender in development. The central role of gender in the distribution of labour in African agriculture is now widely recognized. Studies indicate that women are key food producers in Africa (Mkandawire 1989). Some studies have gone further to argue that African households are looked on as amorphous units, with no competition for resource control. This has contributed to the less than satisfactory impact of many development programs targeted at the rural households. For this reason, programs should be based on a better understanding of how family structures mediate women's access to resources. The IFPRI (1992) study argued that biases in policies that limit women's economic access need to be replaced by

- providing women with an equitable wage, under their control;
- increasing women's access to and control of productive technologies;
- removing gender segregation in labour markets; and

- ensuring women's access to property and entitlement in their own right (rather than through presumptive family relationships such as spouses, daughters and mothers).

As relevant as the gender issue is, there appears to have been hardly any study of irrigation distribution in Nigeria to evaluate the extent of women's access to irrigation technology or the role women play in the system. These issues are crucial to understanding the performance of the irrigation schemes, especially in alleviating poverty and improving household food security.

The idea that men and women spend income under their control in different ways has figured prominently in studies of intrahousehold resource allocation (Hoddinot 1992). It is widely thought that men spend some of their income on goods for personal consumption — alcohol, cigarettes, status consumer goods, and even “female companionship” have been cited in the literature (Hoddinot 1992). This finding makes nonsense of the standard approach to modeling household behaviour, which appears to be the major plank on which development goods are distributed. That approach assumes the existence of a household utility function that reflects the preferences of all members. Taking household budgets into consideration, a household's effort to maximize its utility function gives rise to demand functions for goods and leisure. It is, thus, assumed that all household resources (capital, labour, and land) are pooled and that all expenditures are made out of this pooled income.

Studies have emerged to disprove these assumptions, and these studies have led to new models departing from the premises that (1) individual members of households have different utility functions and preferences and (2) consensus is arrived at through a bargaining process. These bargaining models agree that the relative strength of the bargaining parties is crucial to determining the division of gains. The party perceived as making a larger contribution can expect to obtain an outcome more favourable to him or her. This brings to the fore the importance of who controls income-generating resources in the household. If the control is equally shared, the models' outcome will indicate that gains are likely to be more fairly shared. If not, marked deviations can emerge. It also follows that the allocation of resources within the household may reveal insights into intrahousehold behaviour and the roles of members within the household. For example, gender division of labour within the household may in the main be a function of unequal bargaining power: the less privileged is perpetually made to remain so by being restricted to having a low income (or, indeed, no income).

The bargaining models, therefore, appear to provide better explanations of why men move into women's crops when economic dynamics make these more profitable. The promotion of women's crops through improved technology may, indeed, affect women adversely if their bargaining position is weaker at the onset.

Irrigation development in Nigeria

Water-resources development in Nigeria can be said to have started in 1908, when a water-level gauge was erected at Jebba for the railway bridge over the River Niger. In 1914, gauges were also laid along the Niger at Baro, Lokoja, Idah, and Onitsha and along the Benue at Yola, Ibi, and Markurdi (NEDECO 1959).

Nwa and Martins (1982) reported that the first recorded survey of irrigation potential in Nigeria was in the early 1900s, when Colonel Collins, a military engineer, undertook work at the Sokoto–Rima and Zamfara valley systems. The first attempts to impound water, in 1918, were later destroyed by floods in 1922. Work on flooding and canalization was reported to have been carried out on the Shella Stream in 1925,

and by 1929, 243 ha had been developed for perennial irrigation. Singh and Maurya (1979) reported that farmers owning land on the scheme could not comply with government requirements for cropping patterns based on cash cropping because they did not find these profitable. The scheme was, however, flooded out in 1946.

The Northern Region Ministry of Agriculture established the first irrigation division in Nigeria in 1949. The division concerned itself with small-scale irrigation schemes. In 1959, a hydrological section was set up in the irrigation division to develop a network of hydrological stations and organize in-field training services.

An FAO report, commissioned by the federal government in 1965, and the *Study Group on Irrigation and Drainage Report* added much impetus to irrigation development in Nigeria. These documents made important contributions to the Third National Development Plan (Nwa and Martins 1982). The third plan period (1975–1980) saw the vigorous formulation and pursuit of a coherent irrigation-development policy in Nigeria. It is not surprising, then, that most of the feasibility reports for the ongoing irrigation projects were drawn up during that period.

The emphasis on irrigation development is understandable because of the wide differential in rainfall distribution in the country. For example, the volume of rainfall in the far north is very low ($<50 \text{ mm a}^{-1}$) and concentrated in 2 or 3 months of the year. In the south, however, a much larger volume of rainfall (sometimes $>200 \text{ mm a}^{-1}$) is obtained, stretching over a longer period, up to 8–10 months. Although rainfall distribution in the north is unimodal, it is bimodal in the south. Thus, almost all parts of the country have a dry season. This extends from November to February in southern Nigeria. There is usually a break (dry spell) in August, and rainfall peaks in June and September. In the north, the dry season stretches from about September to May.

Because of this situation, irrigation becomes important. The effective rainy period for agricultural activity is usually short, even in the southern part of the country. As a result of this short effective rainy season, land clearing, seed-bed preparation, and sowing must be done quickly before the continuous rain to ensure the highest yields possible. Farmers invariably face labour shortages during the limited time they have for these operations. In households where this increased labour demand cannot be met, either planting has to be finished on time by reducing the cropped area or the required operations are completed late. In either case, the productivity of the household is negatively affected. Thus, exclusive reliance on rainfed farming systems hinders increased agricultural production by restricting activity to the rainy season and also by reducing cropped area during the rainy season. This is aggravated by the uncertainty and the intensity of rain, as well as labour shortages.

Irrigation can solve this problem. (1) Farmers can start field operations weeks before the rains. They can, therefore, hire substantial idle labour at that time, at a much reduced cost, to accomplish major production tasks before full wet-season agricultural activities start. (2) Farmers can rely on supplementary irrigation during the wet season to forestall the effects of variations in peak river discharge (where flooding is possible), which could substantially reduce yields. (3) Traditional techniques are well adapted to the conditions that naturally prevail in rainfed farming, but there is a limit to the yields that can be obtained with these techniques. Better results can be obtained using a more efficient irrigation system, with new technologies.

The potential benefits of using irrigation to tackle Nigeria's agricultural problems can be better appreciated by comparing present and potential productions from irrigated farms with those from farms with rainfed agriculture. Fatokun and Ogunlana (1992) estimated that if 25% of the presently identified 2×10^6 ha of

irrigable land was put under irrigation and cropped twice with maize and rice, at least 2×10^6 t of maize and 5×10^6 t of rice would be produced annually, ensuring surplus food production in Nigeria.

The government's past and planned efforts to develop irrigation technology in Nigeria should, therefore, be appreciated. Table 1 shows the extent of this effort so far. Although the data are incomplete, they throw some light on the government's commitment to developing agriculture through irrigation.

The study area and the data

Study area

At the beginning of the study, we felt that broad research would be done, encompassing about four RBDAs in Nigeria: two in the dry north and two in the wet south. However, during the actual progress of the study, we discovered that farm size-class and gender-related information, thought to be readily obtainable from the RBDA officials, was, indeed, difficult to come by. We would have to carry out surveys to supplement the data we could get from the RBDA, so we thought it prudent to scale down the scope of the research to something manageable. We ended up choosing two RBDAs: the Anambra – Imo River Basin Development Authority (AIRBDA), in the south, and the Niger River Basin Development Authority (NRBDA), in the north. We chose these two because their officials were interested in our research.

In AIRBDA, only one irrigation project of significance was highly developed, the Lower Anambra Irrigation Project (LAIP), which covers a potential irrigable area of 8000 ha. Hence, the study concentrated on this project.

The federal government of Nigeria used a 16.9 billion JPY (in 1995, 89 Japanese yen [JPY] = 1 United States dollar [USD]) soft loan from the Japanese government to build the LAIP in the lower Anambra Basin. The project is about 55 km west of Enugu. Its intention was to increase rice production through double cropping, improve the welfare of the farmers, and help the farmers adopt the optimum cropping pattern (AIRBDA 1988). Farmers started farming under the project in 1982, with wet-season rice as the only enterprise. However, in 1985, dry-season rice production was started. The project extends on a gently undulating topography, over an area of more than 5000 ha. The climate is characterized by two distinct seasons, rainy and dry. The water source for the project is the Anambra River at Ifite-Ogwari (drought discharge, $39 \text{ m}^3 \text{ s}^{-1}$). There are four villages in and around the project area: Omor, Umehum, Anaku, and Mgbakwu. The irrigation water is lifted (31 m) at the Ifite-Ogwari pumping station and is gravity fed to the paddy fields through several irrigation canals. Prospective irrigators are normally allocated plots of 0.5 ha each, for which, in 1993, they were paying operation and maintenance charges of 125 NGN per plot (in 1995, 78.5 Nigerian naira [NGN] = 1 United States dollar [USD]) in the rainy season and 250 NGN per plot in the dry season. There were no repayment obligations because all the farmers were tenants with short-term leases. Land-preparation charges, usually charged with the water rates, amounted to 300 NGN ha^{-1} in 1993. Half of the irrigated area was allocated to the villagers, who were former owners of the land, 25% was allocated to farmers from nearby communities, and the other 25% was allocated to outsiders. There were about 4000 farm households in the scheme in 1993.

NRBDA had several relatively small irrigation projects, mainly canal and pump systems. NRBDA covered the area drained by the River Niger, its tributaries, and its confluence with the Ubo River in the south and the Malendo River in the north. It encompassed four states: Niger, Kwara, Kogi, and Kaduna.

Table 1. Extent of irrigation development by river basin development authorities (1993).

RBDA	Potential irrigable land (ha)	Potential water resources (10 ⁶ m ³)	Cultivated (ha)		Rainfed		Irrigated	
			Rainfed	Irrigated	Crop	Yield (t ha ⁻¹)	Crop	Yield (t ha ⁻¹)
Anambra- Imo	111 200		21 500	3 996			Rice	4.5
							Maize	3.0
							Cowpea	2.0
							Veg.	≤20.0
Chad Basin	89 000			23 000			Wheat	2.4
							Rice	3.5
							Cotton	
							Sorghum	
Cross River	550 000		10 000	244	Maize	1.7	Maize	3.5
					Cassava	10.0	Veg.	3.0
					Yam		Cowpea	3.5
					Cowpea		Ginger	4.0
					Veg.		Rice	
					Banana			
					Rice	1.5		
Hadejia- Jama'are	260 000	4 600	229 000	16 920	Sorghum	1.0	Rice	4.0
					Millet	1.0	Wheat	2.5
					Cowpea	0.8	Tomato	25.0
					G/nut	0.8	Maize	2.0
					Rice	1.5	Onion	37.0
					Maize	2.0	Pepper	15.0
					Sesame	0.1		

Table 1 (continued).

RBDA	Potential irrigable land (ha)	Potential water resources (10 ⁶ m ³)	Cultivated (ha)		Rainfed		Irrigated	
			Rainfed	Irrigated	Crop	Yield (t ha ⁻¹)	Crop	Yield (t ha ⁻¹)
Lower Benue	260 000	0.0025	94 670	14 000			Rice	4.0
							Maize	3.5
							Melon	1.0
							Millet	0.5
							Soya bean	1.2
							Yam	10.0
							Cassava	10.0
							S/cane	7.2
							B/seed	0.5
							Irish pot.	8.0
							Bean	0.8
Niger Delta	285 000		53 000	27 000	Rice	5.0	Rice	5.0
					Plantain	20.0	Plantain	20.0
					Cassava	8.0	Cassava	8.0
Niger River	70 000			1 540	Rice		Rice	2.5
					Maize		Maize	2.0
					Wheat		Veg.	1.2
					Veg.		Wheat	1.2

Table 1 (concluded).

RBDA	Potential irrigable land (ha)	Potential water resources (10 ⁶ m ³)	Cultivated (ha)		Rainfed		Irrigated	
			Rainfed	Irrigated	Crop	Yield (t ha ⁻¹)	Crop	Yield (t ha ⁻¹)
Ogun-Oshun	36 593	840	9 104		Rice	2.0	Rice	
					Maize	2.0	Maize	
					Veg.	10.0	Veg.	
					Cowpea	0.8	Cowpea	
					Yam	12.0	Cassava	
					Soya bean	0.8	Soya bean	
Sokoto-Rima	180 000	3 422	80 465	26 600	Millet	1.2	Rice	6.0
					Sorghum	1.5	S/potato	10.0
					Rice	5.0	Cowpea	1.5
					Cotton	1.2	Maize	2.0
					Cowpea	1.0	Wheat	1.5
					G/nut	2.5	Veg. & other	3.0
					Maize	1.5		
					Veg. & other	3.0		
Upper Benue	588 313	645 000	19 050	11 510	Rice	2.5	Rice	8.0
					Maize	1.5	Maize	2.0
					S/cane	30.0	Veg.	20.0
					Sorghum	2.0	S/cane	35.0
					Legume			

Source: Federal Ministry of Agriculture and Water Resources.

Notes: G/nut, groundnut; Irish pot., Irish potato; RBDA, River Basin Development Authority; S/cane, sugar cane; S/potato, sweet potato; Veg., vegetable.

Because of the small and scattered schemes under the NRBDA, data gathering was restricted to one project, the Tungan Kawo project, which covers 800 ha. It is a canal irrigation scheme, with about 290 farmers participating. Water charge in the basin is 500 NGN ha⁻¹, which may reflect the relative scarcity of rain in the area.

Data

We obtained the data for this study from the RBDAs. In the case of LAIP, the officials could not furnish information about farm sizes immediately, so we conducted a sample survey of 500 households, randomly selected. In the case of the Tungan Kawo project, information on irrigated farm size, obtained from the NRBDA office, enabled us to group the data into farm-size classes. We also conducted a small survey, which covered 200 households, randomly selected.

We also interviewed the irrigation authorities. The main purpose of this was to obtain information on gender considerations in irrigated-plot allocation and on the role of women in irrigated agriculture in the areas studied.

Some theoretical issues

Inequity measure

We used Theil's (1967) information-theoretic measure, which fulfils all of Sampath's (1988) relevant equity axioms, as well as being easily amenable for decomposition analysis, which is important because one may want to decompose the overall inequality into its constituent parts.

It is possible to show interfarm inequality in irrigation distribution in Nigeria at two levels: (1) the national level and (2) the basin level. Because irrigation-distribution policy is a major federal issue but conducted through the different RBDAs, it made sense to examine the inequality along RBDA lines, especially when RBDAs are not state specific. We had to modify the Theil index used to decompose the overall inequality because the interbasin-inequality component is not relevant in this context. We calculated just the interfarm size inequality in each of the two basins.

Results and discussions

Equity in irrigation distribution

Table 2 provides information on the data we used to determine the level of inequity in irrigation distribution in the two basins.

Two things especially distinguish the provision of irrigation technology in the two areas:

1. Irrigated-land allocation in the lower Anambra Basin project is done by authority alone, whereas in the Tungan Kawo project, the Water Users' Association participates in the allocation process.
2. LAIP is located in the high-rainfall area. The Tungan Kawo project, on the other hand, is in a drier area, where irrigation is crucial.

The analysis may, therefore, throw light on just how equitable land distribution is under the two different allocation systems.

Table 2 shows that the sampled total net irrigated area of 590 ha in the LAIP is operated by 500 farmers. The total area possessed by this group is 831 ha. The farms larger than 2 ha constituted only 14% of the population and controlled slightly

Table 2. Farm-size distribution of irrigated and nonirrigated areas in the lower Anambra and the Tungan Kawo projects.

Size class	Farmers (<i>n</i>)	Total area possessed (ha)	Net irrigated area (ha)	Rainfed area (ha)	Distribution of irrigated area (%)	Distribution of rainfed area (%)	Distribution of total area (%)
<i>The Lower Anambra Basin</i>							
≤0.5	270	180	135	45	22.90	18.67	21.66
>0.5–≤1.0	85	210	88	122	15.00	50.62	25.27
>1.0–≤2.0	75	173	127	46	21.51	19.09	20.82
>2.0	70	268	240	28	40.68	11.62	32.25
Total	500	831	590	241	100.00	100.00	100.00
<i>The Lower Kaduna Basin</i>							
≤0.5	7	14.93	14.93	—	6.29	—	6.29
>0.5–≤1.0	27	57.60	57.60	—	24.26	—	24.26
>1.0–≤2.0	20	42.67	42.67	—	17.97	—	17.97
>2.0	26	122.20	122.20	—	51.47	—	51.47
Total	80	219.40	219.40				

Source: Calculated from survey data and relevant River Basin Development Authority records.

more than 30% of total area. On the other hand, 54% of the sampled farmers operated on ≤ 0.5 ha and had about 31% of the land area, but they were allocated only 23% of the total sampled net irrigated area. Farmers in the largest farm-size group (i.e., >2 ha) constituted about 14% of the sample and had control of about 41% of the irrigated land.

If there are benefits from access to irrigation, it follows that of the total benefits created through irrigation, almost 41% accrued to the top 14% of the farmers and only 23% accrued to the bottom 54%. The other farmers fell between these two extremes (see Table 2).

For Tungan Kawo, we could not obtain estimates of cultivated rainfed area. There are indications that the farmers in the basin rely completely on irrigated agriculture because of the low annual rainfall. From the survey, it was obvious that rainfed farming is not very significant in the study area. We were able to obtain more reliable land-holding figures only for irrigated plots. Because this satisfies the main objective of the paper, it was considered adequate. It is obvious that the bottom 9% of the sample farms were on 6% of the irrigated area, whereas the top 33% controlled about 51% of the irrigated area. Farms ranging from >0.5 to 2 ha (about 59%) controlled about 42% of the irrigated area.

The apparently skewed distribution of irrigated land, which favours large and presumably richer farms, is common around the world because rich farmers use their influence to appropriate most of the technology. Sampath's (n.d.) study in India showed roughly the same pattern.

It would, however, appear that the distribution is more equitable in Tungan Kawo Basin than in Anambra Basin. So, bearing in mind the differences in irrigated-land distribution in the two areas, one can propose a hypothesis that farmer participation in irrigated-land allocation and distribution would foster equity in access to irrigation technology.

We tested this hypothesis by applying Theil inequity measures to the data in Table 2. The results appear in Table 3. The estimates in Table 3 strictly measure interfarm size inequity the two basins. The estimates are obviously lower bounds because they are based on grouped data. Sampath (n.d.) argued that grouped data can be used for this estimate if we assume that within each size class, every farmer receives the size-class average value, which in reality may not be so.

Table 3. Theil indices for irrigation inequity in the Lower Anambra and Tungan Kawo basins.

Location	Total area	Irrigated area	Perfect inequity ^a	Deviation from perfect inequity ^a (%)
Lower Anambra Basin	0.1020	0.1190	2.699	-95.59
Tungan Kawo Basin	0.0320	0.0320	1.119	-98.32

Sources: Survey data and relevant River Basin Development Authority records. Theil indices are from Theil (1967).

^a Perfect inequity is when only one household receives 100% of the irrigated land. The higher the negative value (deviation from perfect inequity), the more the distribution tends toward perfect equity.

As hypothesized, there appears to be a higher level of inequity in irrigation distribution in the lower Anambra Basin than in the lower Kaduna Basin, where the Tungan Kawo project is located. It would, thus, appear that farmer participation in

irrigation distribution could be useful in reducing inequity. The Tungan Kawo Water Users' Association, established in 1990, was headed by a traditional chief and had three representatives from NRBDA and two representatives from the Niger State agricultural-development project. There was a representative from each of the 13 farmers' unions in the area.

The functions of the association included the following:

- to serve as an advisory body to facilitate communication between NRBDA and the beneficiaries of the scheme;
- to compile a register of interested farmers and to review it periodically as the need arose; and
- to organize farmers for the maintenance of the field channels and other irrigation facilities.

The objectives of the association included

- allocating land to their members;
- organizing the farmers and educating them about the proper use of irrigation water to minimize waste;
- teaching the farmers and hired labourers how to avoid the destruction of the canals; and
- ensuring payment to the NRBDA (i.e., payment for land and water used by the participating farmers).

The association takes its land-allocation function seriously and organizes the farmers in blocks. In addition, it has been involved in clearing the canals of weeds and other obstructions, thereby ensuring the smooth flow of water. The association spends money to announce plot allocations and participates in conflict resolution.

Although LAIP has a Water Users' Association (with all the 4000 farmers as members) and the Lower Anambra Cooperative Society, their functions appear not to include land allocation. AIRBDA lists the functions of the Water Users' Association as

- on-farm water management and distribution of the water through the canals into the plots;
- maintenance of irrigation facilities; and
- formation of communication links between project management and farmers.

AIRBDA argues that the association was still new in 1993, with members yet to fully understand their functions and responsibilities. The authority assumes its irrigated-land distribution is equitable and only worries about fair distribution of water moved from the canals to the plots. Our results indicate, however, that this is not so. Oramah (1991) also revealed that poorer farmers are allocated plots mainly at the tail end of the main canals, making it difficult for them to obtain adequate irrigation water. There are probably two sources of inequity in the scheme — the irrigated-land distribution and the irrigated-farm location by income group.

The higher level of inequity in irrigation distribution in LAIP may explain why the LAIP authorities complained of farmers' organized expression of anger and vandalization of irrigation facilities. The problem has probably not reached a crisis point in the LAIP area because there is also rainfed farming. There was no vandalism at Tungan Kawo. Clearly, the greater farmer participation in the Tungan Kawo project contributed to greater equity.

Women's access to irrigation technology

Access to new production technology (pump irrigation, tractors, fertilizers, herbicides, improved seeds, etc.) is largely tied to participation in the irrigation projects. On the basis of Braun et al.'s (1989) argument, we state that if project production is closely supervised, the adoption of new technology in the two basins will be to a large extent synonymous with access to farm plots through whatever allocation procedure. Plots can be allocated to households on the assumption that each household will farm the plot as a unit, bear the costs of production, and equitably share the returns among household members. Research has established that in most households headed by a man, the returns accrue to the man, who may not necessarily give any of it to his wife. If the man does not spend his money on household welfare, this may have adverse effects on the most vulnerable group, women and children.

In this study, the investigation of this issue is restricted to the LAIP because religious restrictions prevented our doing a proper interview of women in Tungan Kawo, although the officials insist that they do not discriminate in irrigated-plot allocation.

Historically, in the lower Anambra Basin, women have owned their own plots and planted rice, maize, and vegetables. Yam is considered a man's crop. In conducting the study, we hypothesized that the irrigation authority would realize this and allow a direct allocation of rice farms to women, although their husbands might also be allocated such plots, in keeping with the independence of the women.

To test this hypothesis, AIRBDA was asked whether it allocated plots to women. In response, the authority stated that when the project was started in 1982, it allocated plots to women without any restriction until it started receiving reports of marital problems, including divorce. The officials stated that because of the illiteracy of the women, the sudden improvement in their welfare caused them to disrespect their husbands. As a consequence, it became the policy of LAIP not to allocate plots to married women but to their husbands, who could choose to give the women control over the plots. The officials also explained that "80% of the work done in the field is performed by women so if they are given plots, the farms will suffer from labour shortage." The officials, however, indicated that irrigated plots were allocated to widows and young female graduates who were without alternative employment.

Table 4 provides information on women's access to irrigation. From the table, it can be seen that in the dry season of 1993 only 4% of the sampled plots were under the control of women, and 92% were under men's control. Comparable figures during the rainy season were 10 and 88%. It is, thus, obvious that in the dry season, when agricultural activity depends so much on irrigation, women are further constrained.

Table 4. Distribution of irrigated plots by sex, LAIP (1993).

Crop	Men (% of sample)	Women (% of sample)	Invalid responses (% of sample)
Dry-season irrigated rice	92	4	4
Wet-season irrigated rice	88	10	2

Source: Sample survey.

Table 5 shows the division of labour in the study area. We discovered that for land under irrigation, land preparation, threshing, milling, and transportation services are provided by the authority at a fee, whereas seeding and transplanting, weeding, fertilizing, and harvesting are done by the farmer. From Table 5, it can be seen that

75% of the work in dry-season rice production is done by hired labourers, all of them women. Twenty-five percent of the work is provided by family labour, of which women provide 10% and men provide 10% (mainly nursery preparation, rodent control, and chemical application). Children scare away birds. For wet-season irrigated rice, the proportions are not much different. As evident in Table 4, rice farming is dominated by men. For maize and vegetables, regarded as largely women's crops in the study area, about 90% of the labour is family labour, of which 10% is provided by men. The men supervise all the work done on the rice farms and also grow yam and cocoyam and do some fishing in the many rivers and streams draining the basin.

Table 5. Hired and family labour input per hectare and by sex, LAIP (1993).

Crop	% hired labour		% family labour		
	Men	Women	Men	Women	Children
Dry-season irrigated rice	—	75	10	10	5
Wet-season irrigated rice	—	70	18	8	4
Wet-season nonirrigated rice	—	40	35	20	5
Maize or vegetables	—	10	10	65	15

Source: Analysis of data, 1993.

Table 6 shows the division of tasks by gender in the LAIP area. The table indicates that women provide most of the planting, weeding, and harvesting labour. Women's work takes longer to complete and is more arduous. For example, it takes roughly 16 days to weed a hectare of rice. It also takes about the same amount of time to plant and harvest the same hectare. Men, on the other hand, use knapsack sprayers to apply insecticides and use traps and scarecrows against rodents.

Table 6. Division of labour by sex (dry- and wet-season irrigated rice farming), LAIP (1993).

Activity	Sex performing >50% of task
Clearing, slumping, and land preparation	Tractors of the authority
Nursery	Men
Binding	Women
Planting	Women
Weeding	Women
Fertilizer application	Men
Harvesting	Women
Bird control	Children
Rodent control	Men
Insecticide application	Men

It would, thus, appear that the new rice technology provides additional employment for women in the dry season. It is not, however, clear how it affects the time women allocate to their crops during the wet season or whether it leads to reduced hectareage allocated to such plots or reduces the time women spend in doing other household chores. This issue is all the more crucial because there are no indications that labour migrates from other areas to take advantage of the employment opportunities offered by the new rice technology.

Conclusions

In this study, we examined the equity and gender implications of irrigation-technology development in Nigeria. Two projects were chosen, one in the high-rainfall area (the LAIP in the lower Anambra Basin) and the other in a relatively dry area (Tungan Kawo project in the lower Kaduna Basin). The two projects are also distinguished by their use of farmer participation in irrigated-plot allocation: the Tungan Kawo project has farmers' input in plot allocation.

Using Theil's (1967) indices, we determined inequity levels in irrigated-plot allocation for the two areas, based on data obtained for 1993. Results indicate that inequity in irrigation distribution was higher in LAIP than for the Tungan Kawo project. This indicates that farmers' participation in irrigated-plot allocation probably lowers inequity in distribution.

Further, women's access to and role in irrigation were investigated in the LAIP area. The results indicated that it was a recent official policy to restrict women's participation to single women, in response to men's complaint that the economic empowerment engendered by women's access to this technology threatened the men's control over their wives. The officials also argued that allocating plots to women deprived the projects of labour needed to accomplish key tasks in irrigated rice production. It was also observed that <10% of the plots were allocated to women. The study revealed that women provide most of the planting, weeding, and harvesting labour, either as hired labour or as family labour. Their efforts in person-days constituted the bulk of labour needed for irrigated rice production (about 70% of the labour required).

Implications for policy

These conclusions provide the basis for some recommendations. First, following the seeming success of the Tungan Kawo Water Users' Association in ensuring some equity in irrigated-plot distribution among the farmers, it may be wise for LAIP officials to strengthen their association and orient it to work along the same lines as the association at Tungan Kawo. Other irrigation schemes that are without such an association should think about introducing one. When farmers have a say in such an important function, it will probably be fairly done, thereby preventing unnecessary friction. These associations are known to have performed fairly well in Asia, improving the efficiency and effectiveness of the irrigation systems.

There is the need to realize that restricting married women's access to irrigation is discriminatory and counterproductive. We do not want to be simplistic and argue that the traditional roles of the men be ignored. But we believe that if these men realize that the empowerment of the women translates into the empowerment of the entire household, with direct benefits to the children, they are likely to rethink the issue. However, the proper way to address the issue is to use a water users' association to educate the men and allay their fears. The household as a unit should be emphasized. This way, a common ground can be found, which may make it possible to abandon this discriminatory policy and, perhaps, allow the benefits of the project to permeate the households.

There is no doubt that the authorities' argument based on labour constraints is invalid because the problem can be handled by economics: if women's access to plots reduces their availability as hired labour, this will, of course, raise wage rates and possibly make it attractive for more migrant labourers to come to the basin to take advantage of the new, attractive opportunity. This way, the benefits of the scheme may even become more widespread. Women's benefits from the projects will

be mainly improved employment opportunities and, perhaps, higher wages. The denial of plots to women deprives them of the opportunity of being managers and has, indeed, displaced them largely from owning rice farms, which was one of their preoccupations before the project came on stream. Women are now restricted mainly to owning maize and vegetable farms, using poor technology. Men have, for their part, taken control of the high-yielding rice technology in the area, which has, consequently, increased their incomes. Returns from this technology have been estimated by Oramah (1991) as being higher than returns from the other, poorer technologies women have access to. It is now clear that the selection of rice, a women's crop, for promotion in the area has not benefited women but has, through official policy, dispossessed them of their control of such crops and the income that accrues from it.

This research indicates that the introduction of irrigation technology in Nigeria was done without any gender analysis. It is worrisome, especially when such a technology was targeted to women's crops. The lessons are obvious. Agricultural technology needs to be introduced in a manner that will enhance productivity, and guarantee equity. It, therefore, makes sense to include not only economists and engineers but also sociologists, anthropologists, and gender analysts in the planning for the introduction of new technologies.

This study has made the first attempt, but we still need answers to the following questions:

1. What is the effect of the sale of the greatest part of irrigated rice production on food security in the household?
2. Are the proceeds from the sale controlled by the man or his wife, and are they used to purchase enough food and other welfare goods for home consumption?
3. What is the effect of this sale of most of the rice on household nutrition levels, health, and general welfare, especially for the most vulnerable groups, namely, women and children?

The answers to these questions will no doubt complement this study by throwing more light on the effects of irrigation programs on households.

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CHAPTER 24

Female Farmers' Access to Technological Inputs in Nsukka

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Introduction

Research reports have confirmed that women all over the world are taking over farm activities from men (ILO 1977; Saito and Spurling 1992). Uwakah et al. (1991) pointed out that it is common for women to manage farms in all parts of the world while men drift about cities in search of paid employment. Kisekka (1981) reported that in Nigeria, 60–80% of the agricultural workers are women.

Saito and Spurling (1992) observed that despite the significant role of female farmers in the Third World, their level of productivity is constrained because agricultural technology has been designed on the assumption that farm managers are men. According to Saito and Spurling, this assumption gives rise to several other constraints on the progress of Third World female farmers: failure of extension workers to reach them; limited access to credit inputs; lack of access to relevant technological information; and lack of incentive to increase productivity. These observations may not strictly apply to all Third World countries, which all have different agricultural policies. Mbanelo (1990) and Nweke (1994), however, reported that most policies aimed at making agrotechnological inputs accessible to female farmers in Nigeria were actually directed toward men.

These studies did not specifically focus on female farmers' access to agrotechnological inputs. Furthermore, it is uncertain whether the failure of farm-technology policies to consider the role of female farmers has prevented women from having any access to farm technology inputs at all and, even if they do have access, whether the inputs are relevant to their farming objectives.

The available evidence relating to farmers' access to agrotechnological inputs is contradictory and, thus, inconclusive: Njoku (1992) reported that a high proportion of farmers have access to technological inputs, whereas Ogbodu (1990) found that farmers rely on crude farm implements and local resources. Neither mentioned gender.

Most nations of the world face food shortages (FAO 1977), and several causes have been suggested. Bryson (1980) observed that failure to stimulate and assist the farmers is a major cause in Africa. In Nigeria, the problem has been attributed to an acute dearth of male labour and a shift of farm responsibilities to the women (Igben 1988; Okigbo 1989; Uwadie 1993). Other studies revealed that in Sudan (El-bakri and Kamier 1990), Malawi and Kenya (Nonyelu 1991), Jordan (Basson 1983), and Egypt (Morsy 1990) women make up more than half of the farming population.

Nigerian studies

Studies of three major ethnic groups in Nigeria further indicated that, generally, women make up the bulk of farm labour. Esumoh (1990) noted that the traditional occupation of Ibo women was farming and that Ibo women were starting to cultivate crops that are traditionally regarded as men's crops. Iliya (1989) reported that in

1988/1989 the proportion of Hausa women involved in farm work rose by more than 50% while the male contribution to farm work declined. Uwadie (1993) reported that Tiv women were highly involved in specific aspects of farm work but were handicapped by an inadequate supply of farm inputs. Afonja (1990) reported that Yoruba cocoa farmer's wives and female independent farmers not only outnumbered men in cocoa production but also worked for longer hours.

Despite the extensive involvement of Nigerian women in farm work, they seem not to have been considered in policies formulated to guide the dissemination of agricultural inputs. Agricultural inputs are all the biological, chemical, mechanical, financial, and managerial inputs needed for the efficient farm management (Ogbotu 1990). Administrations in Nigeria have not yet recognized the ability of agricultural inputs to increase our food production and develop our agricultural sector.

The traditional small-scale system of agriculture in Nigeria is characterized by primitive implements, low-level inputs, low-yielding crop varieties, high land and labour intensity, and natural disasters, including pests and diseases, all of which suggest that there has been no increase in agricultural inputs.

By the end of the civil crisis in 1970, agricultural production almost came to a halt in the war-affected areas and in some other parts of the country. The military government had to depend on food aid from international agencies and food imports from developed countries. As a result, the federal Ministry of Agriculture and Rural Development invited the International Institute for Tropical Agriculture, the Nigerian research and extension institutions, and scientists to develop a national food-crop production plan. The objective of the research institutes would be to produce and multiply improved crop varieties and make them available to farmers through input-supplying agencies, and extension workers were to educate the farmers about the improved varieties and how to use them. The objectives of the input-supplying agencies included the production and supply of agricultural inputs and the elimination of the bureaucratic delays farmers encountered in their efforts to acquire them.

According to Idachaba (1984), the federal Ministry of Agriculture and Rural Development introduced some other programs to make agricultural inputs accessible: a national seed-service agency; fertilizer-procurement and -distribution programs; a pest-control program; a subsidized tractor-hiring and agricultural-mechanization program; a supervised agricultural credit-guarantee scheme to make loans in the form of fertilizers, agrochemicals, and improved planting inputs; and the World Bank-assisted Agricultural Development Programme.

As laudable as these programs may seem, there has been no assessment of their general implementation or, in particular, of their affects on female farmers. Idachaba (1984) implied that these programs were ineffective when he said that the constraints on Nigeria agriculture included the following:

failure of the national agricultural research system to generate new technologies . . . as well as the failure of agricultural extension services to extend available inputs to farmers . . . failure of public policy, the most serious elements of which include . . . inconsistencies in public policy which result in frequent revisions, modifications and quite often embarrassing policy reversals which end up frustrating the farmer and confusing the general public.

He did not state whether subsidized inputs, such as fertilizer, were disseminated mainly to male farmers, who are often favoured in such policies but are less active in farm work, or to the female farmers, who are very active in farm work but are often overlooked by public policies.

Nweke (1994) observed that, though women represent a high proportion of Awka farmers, they have not received equitable opportunities, rewards, or decision-

making privileges. According to him, women encounter more difficulties than men in gaining access to land, credit, technical facilities, and commercial outlets. He summarized these constraints, saying they were technological and cultural. Onwubuya (1987) and Ogbonna (1989) observed low participation of women in agricultural extension programs and blamed this on government policies that discriminate against women. His study area was outside Nsukka, so his finding may be inapplicable to Nsukka farmers and may also be a mere expression of an opinion.

Ogbonna (1984) reported that rural female farmers in Imo State lacked storage facilities and adequate production inputs and that pests and disease were affecting the women's agricultural productivity. Njoku (1992) conducted a study to identify obstacles encountered in the adoption of yam Minisett technological inputs by small-scale farmers in Amuzi and reported that 100% of the farmers had access to fertilizers (N-P-K); 45%, to herbicides; 88%, to insecticides; 90%, to Minisett dust; and 52%, to fungicides. In another related study, Ogbodu (1990) investigated factors affecting the adoption of agricultural inputs in Udi local-government area of Anambra State and reported lack of credit, continued reliance on crude implements, and unavailability of agrotechnological inputs. The results of these studies were contradictory; only one of the studies involved female farmers; and none focused on farmers in Nsukka.

Studies on Nsukka farmers include those by Onah (1987), Ogugua (1989), Olarewaju (1991), and Ikhare (1992). The general trend in their findings was that these farmers were dissatisfied with the agricultural programs' effects on the accessibility of farm technologies. However, most of the studies were of both sexes, so some of the findings may be inapplicable to female farmers in Nsukka. Furthermore, most of these studies were completed when Nigeria's economy was in better shape. Onah, in her study of rural women's response to innovations in cowpea preservation, processing, and consumption in Isi-Uzo local-government area in Nsukka, reported that 79% of the female farmers were unaware of the major technological innovations and 99.2% were unaware of the dehulling technique of preservation but were willing to adopt it if they were taught the technique. Ogugua observed that 66.6% of the surveyed farmers in Nsukka said the crop extension services were unavailable. Olarewaju investigated the contact-farmers' reaction to the state's agricultural-input services and reported that, though the farmers were willing to use the services, they were dissatisfied with the performance of the unit in bringing the needed technology inputs to the farmers. Ikhare found that farmers in Nsukka use mainly goat manure as the main source of soil fertility, which seems to imply that the technological inputs, such as artificial fertilizers, were inaccessible to them.

Research objective

The general objective of this research was to determine the type and proportion of agrotechnological inputs accessible to female farmers in Nsukka.

Research questions

Specifically, we wanted to find answers to the following questions:

1. What types of agrotechnological inputs are available to farmers in Nsukka?
2. To what extent are the available agrotechnological inputs accessible to female farmers in Nsukka?
3. To what extent are the accessible agrotechnological inputs relevant to the farming objectives of the female farmers in Nsukka?
4. Where are the sources of the agrotechnological inputs that are accessible to

female farmers in Nsukka?

Research hypotheses

This research was guided by the following three null hypotheses:

1. There is no significant difference ($P < 0.05$) between the expected and the observed proportion of female farmers who have access to agrotechnological inputs from different sources.
2. The mean accessibility rating (MAR) for the agrotechnological inputs is significantly ($P < 0.05$) independent of the female farmers' geographical location.
3. The mean relevance rating (MRR) for the agrotechnological inputs does not significantly ($P < 0.05$) depend on the female farmers' geographical location.

Research methodology

Design

The study was designed as a descriptive survey to collect data on the type, source, extent, and relevance of agrotechnological inputs accessible to female farmers in urban and rural locations.

Scope of the study

The study focused on 40 agrotechnical inputs divided into 10 classes: (1) human; (2) clearing; (3) cultivating; (4) fertilizers, chemicals, and seeds; (5) irrigation; (6) weeding; (7) harvesting, extraction, and processing; (8) preserving; (9) animal husbandry; and (10) transportation. The area covered by the study was the Nsukka agricultural zone of Enugu State. The Nsukka agricultural zone is divided into six local-government areas: Nsukka, Isi-Uzo, Igbo-Eze North, Igbo-Eze South, Igbo-Etiti, and Uzo-Uwani.

Population, sample, and sampling technique

The study population consisted of an estimated 15 000 female farmers in the six local-government areas. The sample consisted of 1500 female farmers. To ensure representativeness of the population and, thus, the generalizability of the results, this sample was drawn by a proportionate, stratified random-sampling technique. The stratification was done on the basis of local-government areas and geographical location (i.e., urban or rural). For the purpose of this study, all the local-government headquarters were designated as urban locations, whereas towns in the extreme outskirts of the local-government headquarters were designated as rural locations.

There were an estimated 2500 active and full-time female farmers in each of the six local-government areas. In each of the six local-government areas, 10% of the 2500 were drawn from each rural location and 10% were drawn from each urban location to make up the estimated 1500 subjects in the sample.

Instrument

A technological-input accessibility checklist (TIAC), which lists the 40 different agrotechnological inputs, was developed by the researchers and validated by experts in the Department of Agricultural Extension, University of Nigeria, Nsukka. For each of the technological inputs on the checklist, there were three areas of response: (1) extent of accessibility (rated on a four-point scale); (2) sources (purchased directly

from the market, subsidized through government agents, free from government agents, or obtained from male farmers); and (3) relevance (rated on a four-point scale).

The background section of the TIAC asked the subjects to identify their local-government area and geographical location.

Procedure

Field assistants were recruited and trained for the research. We identified active female farmers in the six local governments, the types of farm activities they engaged in, and the available technological inputs. From the identified female farmers, we determined the required sample size for the actual study. From the identified farm activities of the farmers and the available agrotechnological inputs, the TIAC was developed. The TIAC was pilot tested on a representative sample, which was not part of the actual sample for the study. Subsequently, the field assistants, using TIAC, interviewed the subjects (most of the female farmers).

Data analysis

Out of 1500 female farmers initially selected, only 1147 (76%) agreed to respond to the TIAC. Each of the responses to the TIAC was then scored. The mean ratings for the extent of accessibility and the relevance of each of the technological inputs were calculated and interpreted as follows:

Interpretation of mean ratings

Mean rating	Accessibility	Relevance
0.10	Not available (NA)	Not relevant (NR)
0.10–1.49	Rarely accessible (RA)	Relevant (R)
1.50–2.49	Moderately accessible (MA)	Moderately relevant (MR)
2.50–3.00	Very accessible (VA)	Very relevant (VR)

The following were used to analyze the data:

- *For research questions 2–4* — The means and percentages were calculated.
- *For research questions 2 and 3* — The mean ratings were computed for the two sets of respondents (i.e., rural and urban).
- *For null hypothesis 1* — The χ^2 test was used.
- *For null hypotheses 2 and 3* — The *t* test was used.

Results

Research question 1

What types of agrotechnological inputs are available to farmers in Nsukka? Table 1 lists the 40 agrotechnological inputs available to farmers in Nsukka and categorizes these under 10 headings.

Research question 2

To what extent are the available agrotechnological inputs accessible to female farmers in Nsukka? In Table 1, the MAR and its corresponding interpretation are shown for each of the inputs. All of the 40 inputs were generally accessible to female farmers.

Table 1. Agrotechnological inputs and their accessibility and relevance to female farmers in Nsukka.

Class of input	Type of input	MAR	Interpretation	MRR	Interpretation
Human	Extension service	0.95	RA	0.65	RR
	Veterinary service	0.48	RA	0.74	RR
Clearing	Cutlass	1.72	MA	2.89	VR
	Rake	0.40	RA	0.89	RR
	Spade	0.24	RA	0.48	RR
	Fork	0.20	RA	0.34	RR
	Garden trowel	0.41	RA	0.77	RR
Cultivating	Axe	0.93	RA	0.97	RR
	Pick axe	0.53	RA	0.54	RR
	Long hoe	1.56	MA	2.65	VR
	Short hoe	1.59	MA	2.58	VR
	Tractor	0.10	RA	2.40	MR
	Mower	0.14	RA	2.47	MR
Fertilizer, chemicals, and seeds	Improved seeds	0.24	RA	2.53	VR
	Artificial fertilizer	1.34	RA	2.31	MR
	Insecticide	0.18	RA	1.21	RR
	Fungicide	0.11	RA	1.02	RR
	Herbicide	0.13	RA	1.20	RR
Irrigation	Irrigation facilities	0.23	RA	1.00	RR
Weeding	Weeding knife	2.50	VA	2.50	VR
	Weeding machine	0.19	RA	1.32	RR
Harvesting, extraction, and Processing	Rice harvester	0.10	RA	1.04	RR
	Palm-oil mill	0.19	RA	1.41	RR
	Palm-kernel mill	0.30	RA	2.20	MR
	Gari mill	0.29	RA	2.67	VR
	Rice extraction	0.18	RA	1.14	RR
	Rice mill	0.17	RA	1.70	MR
	Maize extraction	0.14	RA	0.81	RR
Preserving	Fridge or freezer	0.17	RA	1.13	RR
	Metal tank	0.17	RA	1.24	RR
	Preserving chemicals	0.13	RA	1.03	RR
Animal husbandry	Incubator	0.14	RA	0.78	RR
	Animal building	0.29	RA	0.86	RR
	Temperature regulator	0.17	RA	0.37	RR
	Feed	0.27	RA	0.36	RR
Transportation	Bicycle	0.32	RA	1.72	MR
	Motorcycle	0.27	RA	1.29	RR
	Motor vehicle	0.17	RA	0.75	RR
	Wheel barrow	0.95	RA	2.17	MR
	Train	0.13	RA	0.44	RR

Notes: MAR, mean accessibility rating; MRR, mean relevance rating; MA, moderately accessible; RA, rarely accessible; VR, very relevant; MR, moderately relevant; RR, rarely relevant

However, the extent of accessibility varied. Only the weeding knife, with an MAR of 2.50, was very accessible. The cutlass, long hoe, and short hoe, with their respective MARs of 1.72, 1.56, and 1.59, were moderately accessible. The remaining 36 inputs, with MARs in the range of 0.10–1.49, were rarely accessible.

Research question 3

To what extent are the accessible agrotechnological inputs relevant to the farming objectives of the female farmers in Nsukka? In Table 1, the MRR and its corresponding interpretation are shown for each agrotechnological input. Cutlasses, long hoes, short hoes, improved seeds, weeding knives, and *gari* mills, with MRRs in the range of 2.50–3.00, were very relevant. Tractors, artificial fertilizers, palm-kernel mills, rice mills, bicycles, and wheelbarrows, with MRRs in the range of 1.50–2.49, were moderately relevant. The remaining inputs, with MRRs in the range of 0.10–1.49, were rarely relevant.

Research question 4

Where are the sources of the agrotechnological inputs that are accessible to female farmers in Nsukka?

Table 2 shows that the greatest proportion of the female farmers obtained most of their inputs by directly purchasing them. Extension and veterinary services, tractors, mowers, and trains were not directly purchased by any of the female farmers. In all, 66.57% of the farmers obtained the other 35 inputs through direct purchase. Twenty of the inputs were not obtained by any women through subsidies from the government; only 14.15% of the women obtained some inputs through subsidies.

All women received extension services and 83.45% received veterinary services free through government agents, but only 8.43% obtained other inputs this way. Twenty-four inputs were obtained from male farmers by 10.85% of the female farmers.

Null hypothesis 1

Null hypothesis 1 was that there is no significant difference ($P < 0.05$) between the expected and the observed proportion of female farmers who have access to agrotechnological inputs from different sources.

The observed χ^2 of 91.13 was much higher than the critical χ^2 of 7.82 for 3 degrees of freedom (df) at $P < 0.05$. This means that null hypothesis 1 can be rejected. In other words, the difference observed in the proportion of the female farmers that have access to the technological inputs from the DPM, SGA, FGA, and OMF is actual and not attributable to chance.

Null hypothesis 2

Null hypothesis 2 was that the MAR for the agrotechnological inputs is significantly ($P < 0.05$) independent of the female farmers' geographical location.

The *t*-test computation of the MARs for the rural and urban female farmers revealed that the critical *t* value of 1.67 for 78 df at $P < 0.05$ was much higher than the observed *t* value of 0.58. Therefore, null hypothesis 2 cannot be rejected. This implied that the accessibility of the agrotechnological inputs to female farmers was independent of their geographical location.

Table 2. Sources of technological inputs for female farmers in Nsukka.

Type of input	Source			
	DPM	SGA	FGA	OMF
Extension service	—	—	100.00	—
Veterinary service	—	16.55	83.45	—
Cutlass	65.27	—	—	37.73
Rake	100.00	—	—	—
Spade	100.00	—	—	—
Fork	78.31	—	—	21.69
Garden trowel	59.28	—	27.77	12.95
Axe	63.39	—	17.41	19.20
Pickaxe	92.98	—	—	7.02
Long hoe	75.68	—	—	24.32
Short hoe	79.26	—	—	20.74
Tractor	—	100.00	—	—
Mower	—	100.00	—	—
Improved seeds	96.80	—	—	3.20
Artificial fertilizer	70.01	28.94	—	—
Insecticide	72.37	27.63	—	—
Fungicide	79.07	20.93	—	—
Herbicide	88.93	10.07	—	—
Irrigation facilities	94.63	5.37	—	—
Weeding knife	66.87	13.25	—	19.88
Weeding machine	89.40	10.60	—	—
Rice harvester	100.00	—	—	—
Palm-oil mill	27.54	21.74	36.23	14.49
Palm-kernel mill	51.64	15.02	32.40	0.94
Gari mill	71.70	19.50	1.30	7.50
Rice extractor	70.00	10.75	11.25	3.12
Rice mill	77.42	9.52	5.38	6.45
Maize extraction	80.95	9.52	4.76	4.76
Fridge or freezer	82.96	7.41	7.41	2.22
Metal tank	100.00	—	—	—
Preserving chemicals	65.05	12.62	9.71	12.62
Incubator	79.31	20.69	—	—
Animal building	90.29	—	—	9.71
Temperature regulator	92.68	—	—	7.32
Feed	97.16	—	—	2.84
Bicycle	44.05	—	—	55.95
Motorcycle	37.08	—	—	62.92
Motor vehicle	35.53	—	—	64.47
Wheel barrow	88.06	—	—	11.94
Train	—	100.00	—	—
Total	22 663.47	337.07	433.98	400.79
Percentage	66.57	14.15	8.43	10.85

Notes: DPM, direct purchase from market; SGA, subsidy from government agents; FGA, free from government agents; OMF, obtained from male farmers.

Null hypothesis 3

Null hypothesis 3 was that the MRR for the agrotechnological inputs does not significantly ($P < 0.05$) depend on the female farmers' geographical location.

The critical t value of 1.67 for 78 df at $P < 0.05$ was less than the observed t value of 5.21. As a result, null hypothesis 3 can be rejected. This meant that there was an actual difference in the extent to which the agrotechnological inputs were relevant to the rural and urban female farmers; specifically, the inputs were significantly more relevant to the rural female farmers than to their urban counterparts.

Discussion of results

Types of agrotechnological inputs available to farmers in Nsukka

Generally, there are 40 agrotechnological inputs available to both male and female farmers in Nsukka. The available inputs, which are, generally, crude or low-level technology, are those appropriate for farm practice in Nsukka. For instance, most of the inputs require the direct expenditure of human energy. This aspect of the findings is in conformity with earlier research findings on some farms neighbouring Nsukka: Onwubuya (1987) and Ogbodu (1990) reported that Awka women and Udi farmers use crude and primitive farm inputs.

Types and extent of agrotechnological inputs accessible to female farmers in Nsukka

This study showed that out of the 40 agrotechnological inputs available to farmers in Nsukka, only weeding knives were very accessible to the female farmers. Furthermore, even though the rural female farmers appeared to have more access to the technological inputs than their urban counterparts, determined by the t test on MAR, this difference is not significant and, thus, negligible.

The generally rare accessibility of agrotechnological inputs to female farmers in Nsukka can be explained in two ways. (1) The traditional farm practices in Nsukka are gender related. For instance, clearing and weeding of farms are traditionally womens' responsibilities. And because no high-technology inputs that would be suitable for the women's farms are available (Mbanelo 1990; Saito and Spurling 1992; Nweke 1994), the women use the accessible, low-technology inputs. This explains the fact that the cutlass for clearing was moderately accessible and the fact that the weeding knife for weeding was very accessible. The moderate accessibility of long and short hoes may be explained by the fact that women use these tools in clearing and weeding of farms, especially during the dry season, when the soil is often hard, which makes weeding with the knife difficult. (2) Nigeria's severe economic policies have made the importation of most higher technology inputs, such as tractors, mowers, extractors, processing machines, incubators, and farm chemicals, very difficult. These policies have resulted in the scarcity of the inputs, despite the generally high demand. The prices for the inputs when available, thus, become so high that the peasant and subsistent female farmers cannot afford them. This supports the earlier research of Onah (1987), Ogugua (1989), Olarewaju (1991), and Ikhare (1992), who found that agricultural policies had not improved Nsukka farmers' access to farm technologies. Furthermore, this lends credence to Idachaba's (1984) observation that the ineffectiveness of agricultural policies is associated with several factors, including a failure of the national agricultural-research system to generate new technologies and the inconsistencies in agricultural policies, which result in constant revisions. Both the earlier research and Idachaba's study contradict Njoku's (1992) finding that a high proportion of farmers had access to agrotechnological inputs, although Njoku focused

on both male and female farmers in far-away Amuzi, in Imo State.

The relevance of agrotechnological inputs to the objectives of female farmers in Nsukka

This study showed that only cutlasses, long and short hoes, improved seeds, weeding knives, and *gari*-processing mills were very relevant to the female farmers. The study also showed that the extent to which these inputs were relevant depended significantly on the women's geographical location. The rural female farmers found the agrotechnological inputs more relevant than their urban counterparts.

The observable trends in the data (see Table 1) are the following:

- Some of the agrotechnological inputs that were either very or moderately accessible to the female farmers were also very or moderately relevant to their farming objectives (e.g. the cutlass).
- Some of the inputs that were either very or moderately relevant to the female farmers' objectives were also rarely accessible to them (e.g., tractors).
- Some of the inputs that were rarely accessible to the female farmers were also rarely relevant to their farm objectives (e.g., rakes).

That some of the inputs were rarely relevant but were very or moderately accessible can be attributed to (1) the women's general ignorance about their use; (2) the women's lack of access to extension services (Nweke 1994) to educate them about the relevance of the inputs; (3) the unsuitability of the inputs for the topography of the land; or (4) some sociocultural practices, such as the land-tenure system in Nsukka.

The poverty of the female farmers and the inconsistent government policies on procurement and distribution of agrotechnological inputs (Idachaba 1984) likely explains the fact that some of the inputs that were very or moderately relevant to the female farmers were rarely accessible. The combined effects of poverty, inconsistent government policies, ignorance, and physical and sociocultural factors may explain the fact that some of the inputs were both rarely accessible and rarely relevant to the female farmers.

Because the rural female farmers operate full time and are, thus, consistently more involved in the use of these farm inputs, the inputs are more relevant to these women than to the urban female farmers, who are mainly part-time farmers.

Sources of the agrotechnological inputs accessible to female farmers in Nsukka

The fact that 66.57% of the female farmers indicated that they purchased inputs directly from the market may explain the general inaccessibility of the inputs to female farmers in Nsukka. Because most of their farm outputs are consumed by them, with little or none left to sell, the female farmer has little or no money to buy the very costly technological inputs from the market. This may explain why various levels of government in Nigeria procure inputs (e.g., tractors, mowers, and some of the processing mills) and give them to the farmers free of charge or subsidize them. Even so, most of the inputs distributed in these ways are rarely accessible to the female farmers in Nsukka. This can be attributed to agricultural policies that are inconsistent (Idachaba 1984) or to input-distribution policies that discriminate against women (Saito and Spurling 1992).

Most of the farm inputs were originally designed for men (Mbanelo 1990), and the traditional position of men in Nsukka, as the heads of families, gives them the ownership of all the family property, including farm inputs. The female farmers in most cases would use the farm inputs only with the permission of their husbands. Therefore, such farm inputs as cutlasses, hoes, bicycles, motorcycles, and motor vehicles (where available) are obtained by female farmers only from male farmers.

Recommendations

Based on this study, it is recommended that the government review policies on production, procurement, and distribution of agrotechnological inputs. The review should aim at ensuring the production and procurement of technological inputs that are relevant to the female farmers' objectives. The policy on distribution should ensure the elimination of many of the middle agents, as these tend to hike up prices beyond the level of the government-fixed prices. In addition, various levels of government in Nigeria should very heavily subsidize agrotechnological inputs, as most of the female farmers are so poor that they cannot afford the high-level technological inputs that would maximize their farm outputs.

Further research should be conducted by agricultural institutes to determine the type of technological inputs that would be appropriate for female farmers. The findings of these studies could be used to design and manufacture agrotechnological inputs that are more relevant to female farmers.

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CHAPTER 25

Technology Transfer from the Adaptive Crop Research and Extension Project in Sierra Leone

Peter M. Kaindaneh

Introduction

Much of the world's intensive food production is on small land holdings. Farmers with limited resources are the mainstay of the food supply for billions of people, and this situation is likely to continue for decades, perhaps centuries. The potential for increased food production, therefore, would be tremendous if yield were increased on each hectare. But millions of farmers cultivating these small farms are uneducated or illiterate. This is by no means an indication of low levels of intelligence; on the contrary, these are very intelligent people. They farm to maximize the utility of what they produce or to maximize profit, depending on the social system and infrastructure where they live.

How does a program intended to increase production through adoption of new technologies reach a half billion farmers like these? Or, coming closer to home, what did the Adaptive Crop Research and Extension (ACRE) project do about improving the food-crop production in Sierra Leone?

It has long been recognized by experts in this field that the only way to significantly increase the productivity of the small-scale farmers in developing countries is to improve the farmers' technological capabilities. In the present state of the world, there can be few developing countries where any increase in domestic food production is not socially beneficial, through its effects on supplies available for domestic consumption, real food prices, and the balance of overseas payments. Because of the favourable effect of technology on crop yield, even subsistence farmers stand to gain from adopting high-yielding crop varieties.

In Sierra Leone, the agricultural sector is largely underdeveloped and is dominated by small-scale farmers. Though this sector employs approximately 75% of the population, it contributes 33% to the gross domestic product and 24% to export earnings. This clearly points to the inefficiency of the sector. The government's awareness of this problem has led to a significant increase in public investment in the agricultural sector over the last two decades. The main thrust of this increased commitment has been the introduction and support of integrated agricultural-development projects (IADPs). These projects have had increased agricultural productivity as their main objective, as well as improved standards of living for rural small-scale farmers, through the use of improved technologies. The new technologies normally include high-yielding crop varieties, improved agricultural practices, and labour-saving devices. One such IADP, which was operated between 1981 and 1987, was ACRE.

This study was designed to provide data on transfer of technology to the small-scale farmers in Sierra Leone and to determine the technological capability acquired by the farmers, as a result. ACRE was selected because of its emphasis on

locally conducted, adaptive (on-farm) research, combined with an effective extension delivery system.

The ACRE project

The ACRE project was coordinated by the Ministry of Agriculture, National Resources and Forestry (MANRF), Njala University College (NUC), and the United States Agency for International Development (USAID). The primary donor was USAID; the recipient of the grant was the government of Sierra Leone (GOSL); and the technical assistance contractor was Southern University – Louisiana State University. The project was built on the following premises:

- that the problems of small-scale farmers in Sierra Leone are low farm productivity and low standards of living;
- that increased crop productivity will help to raise the standard of living of the farmers and their families and, hence, enhance national development;
- that adaptive crop research will yield improved technology, appropriate to the local conditions, situations, and needs of the farmers;
- that the improved technology developed by the project can be effectively delivered to the farmers by an extension system;
- that the farmers will accept and adopt the improved technology after the utility and profitability of the technology has been effectively demonstrated; and
- that the project can be maintained and institutionalized by GOSL as a component of agricultural extension services, to help promote national development.

The ACRE project was, therefore, charged with responsibility for developing and on-farm testing of appropriate agronomic practices for use by the small-scale farmers in Sierra Leone. In essence, the project was expected to transfer technology and ensure the acquisition of technological capability.

Contact farmers were used to promote the transfer of the improved technology. (Contact farmers were those who agreed to try out the new technology as demonstration projects on their farms.) These farmers became the first to adopt the technology after it was successfully demonstrated, and then they influenced other interested farmers to adopt the technology.

Theoretical considerations

Technology diffusion

Technology diffusion (i.e., the transfer of technology) is the responsibility of extension services. The full benefits of agricultural research are not likely to be realized until the research results are appropriately communicated, especially to farmers with limited holdings. Some research results have been so successful that their widespread adoption occurred without concerted extension efforts. More frequently, however, there is a large gap between the productivity that modern research makes possible and the actual productivity realized by the vast majority of small farmers. The integration and widespread adoption of research results can be supported by extension services, by researchers (with farm-level experiments), by communications people (with mass media), by private suppliers, or, ideally, some combination of these.

Technical progress on subsistence farms changes the short-run production equilibrium because one or several production functions are affected, depending on

the type of innovation. Possible innovations for subsistence farmers are the following:

- changes in production technique;
- changes in the range of crops produced (e.g., the introduction of a previously unknown cash or subsistence crop); and
- changes in the yield capacity of previously cultivated crops.

These innovations tend to benefit aggregate production, labour, and land capacity. The production function shifts and allows a higher output, with unchanged labour, and the family attains a higher level of utility.

In the main, a farmer decides on an innovation in subsistence or market production or both, according to the same principle by which the incremental utility resulting from an innovation must pay for the marginal disutility accompanying the change.

When a new technology is introduced to the farmer, he or she does not immediately adopt it; there is a time lag while diffusion of the technology occurs over time and space.

The diffusion of a technology is really the accumulated outcome of many separate decisions of individual farmers; hence, to understand the diffusion process, it is necessary to study these factors (e.g., social and economic) that influence farmers' decisions.

Technology adoption

Technology may be defined as the specialized knowledge, skills, methods, and techniques required for the production and distribution of goods and services. Technology can also be hardware. Agricultural technology can be embodied in people, tools, crop varieties, agricultural practices, and processing equipment.

A farmer is considered as having adopted a technology if he or she uses it to any extent. In this study, *adoption level* is defined as the number of technologies used. Several stages of the adoption process have been identified:

1. *The awareness stage* — The farmer learns about the technology and seeks more information.
2. *The interest stage* — The farmer becomes interested in the technology.
3. *The evaluation stage* — The farmer assesses the technology and decides to try it.
4. *The trial stage* — The farmer tries the technology on a small scale to determine its utility.
5. *The adoption stage* — The farmer uses the technology (either sequentially or in full).

In the early stages of the adoption process, the influence of external agents, such as the extension worker, is very great. The extension workers initially concentrate on the contact farmers, who will later influence the early adopters. This process may then enter a stage when the farmers tend to follow their neighbours' lead, and then there may be a bandwagon effect. The whole process, therefore, critically depends on the extension workers and the extension strategies.

Technological capability

Transfer of technology is essential for the development of technological capability. *Technological capability* may be defined as the ability to harness reason and scientific knowledge to solve particular problems. This usually involves the ability to

- identify the problem;
- identify the most relevant technology;
- acquire that technology on the best possible terms;
- assimilate that technology; and
- modify and adapt that technology to suit the local situation (i.e., develop an indigenous technology).

Those who have acquired technological capability can engage in technical change or innovation. In the case of small-scale farmers, this would include minor and major modifications of the technology to suit their environment.

Technical change

In the latter stages of the adoption process, as the farmers become more familiar with the new technology, they will alter inputs and other components of their farming system to exploit the advantages of the technology. The farmers learn the various outcomes associated with various decisions linked to the technology, and such knowledge helps them adopt the technology more fully. Such changes, referred to as multiple simultaneous innovations, can be complex and variable over time and space, so researchers have little prospect of predicting them on the basis of their own trials. After the farmers have internalized the technology, they can modify it for their own special needs; that is, they can effect technical change. This shows that the farmer has acquired technological capability.

The ACRE project

Aims

Improved agricultural practices and crop varieties

One component of the ACRE project was to introduce “software” technology: improved agricultural practices and improved varieties of upland rice, inland valley swamp rice, mangrove rice, biland rice, maize upland, sweet potato, cassava, groundnut, and cowpea.

Nutrition programs

The aim of the nutrition component was to improve the nutritional status of the small children, pregnant women, and lactating mothers on the farms in the target areas. Food-preservation and -processing techniques would be improved to complement the increased food production expected as a result of the other component of the project. Recipes would be developed and disseminated. Demonstrations would be used to teach appropriate technologies for food presentation and storage. Labour-saving devices for rural women would be found, and the women would be taught how to use them. There would be two nutrition instructors per zone; each instructor would visit four villages to give lessons in child care, sanitation, and gardening and demonstrate ACRE recipes.

Human resources

Most of the Sierra Leonean technologists employed by ACRE had a first degree or a masters degree. The director and the deputy director (who was also the research coordinator) were professors from the Agronomy Department, Njala University College, and the extension coordinator was from MANRF.

In addition to the Sierra Leonean staff, there were several experts from universities in the United States, who came at different times. These included a soil chemist, extension agronomists, agricultural economists, and plant breeders. Each US expert provided scientific and technical guidance and trained a local counterpart. Many of the senior Sierra Leonean staff benefited from this training and were able to complete a masters degree in extension-related fields in the United States. Some NUC staff did the same; these people were expected to return and be part-time ACRE staff (full-time NUC staff). After their return, the part-time staff carried out the research and extension activities for the project, including field trials and training of extension field workers, who in turn trained farmers and assisted them with their everyday technical problems.

Most of the extension and nutrition instructors had either a teacher's certificate from teacher's college or a two-year certificate in agriculture from NUC. Some worked as teachers or extension workers for MANRF. The extension and nutrition instructors received further training at ACRE seminars or in-service courses, and some took short-term courses at the International Institute of Tropical Agriculture (IITA) in Nigeria. The training of the extension and nutrition instructors was not as extensive as that of the senior personnel.

Technology

The technology embodied in improved agronomic practices came mostly from NUC, the Rokupr Rice Research Station (in Sierra Leone), IITA, and the International Rice Research Institute of the Maize Research Institute in Mexico. ACRE conducted crop-variety trials, comparing improved crop varieties with local ones under various management practices, and selected the most suitable combinations of practices for the small-scale farmers in Sierra Leone.

Extension practices

The ACRE project used a whole range of extension techniques to transfer the new improved technologies to the small-scale farmers. The extension staff offered

- field days and agricultural shows, where kits were distributed;
- on-farm results and methods demonstrations, with full farmer participation;
- farmer training during regular group meetings;
- regular farm visits;
- publicity brochures and pamphlets;
- farmer-certification ceremonies; and
- farmer compensation.

In ACRE's extension strategy, farmer involvement was paramount. The ACRE staff believed that combining research and extension in the same program and giving the farmer a central role to play would quickly lead to the desired technology transfer.

Staff survey

The data in this section were derived from a survey of ACRE technical staff, including researchers, senior extension officers, extension instructors, and nutrition instructors.

According to the ACRE staff, the on-farm results and methods demonstrations were the most effective extension practices. Next were the field days and agricultural shows and distribution of kits. When asked to indicate the least effective extension technique, 55% cited farmer training during group meetings. Farmer's group meetings

were usually poorly attended, and the extension and nutrition staff did not always have new ideas to share. The staff were asked to state whether they were given what they needed to perform their duties effectively, and 89% stated that their needs were always provided for. The items that were usually not available were fuel, transportation, farm supplies and inputs, and finance, in that order.

Summary

The ACRE project had some highly trained personnel, but the research and extension staff indicated that they usually were without what they needed to effectively perform their duties. In later years, the emphasis switched from equal support for research and extension to more attention and support being given to research.

Farmer survey

In this section, the results of the contact-farmer survey will be discussed. The cluster-sampling approach resulted in a total sample of 330 farmers, from among various zones, as shown in Table 1. The table shows that in all the zones, rather small proportions of the contact farmers were female. Most male contact farmers were heads of households, so land was not a crucial factor for these farmers. Most of the female farmers were first wives, so they, too, had no problem obtaining land for farming.

Table 1. Contact-farmer survey results.

Zone	Female	Male	Total
Kanema	7	64	71
Kabala	6	53	59
Rokupr	2	72	74
Makeni	9	52	61
Njala	10	55	65

Source: The survey of the contact farmers.

According to the farmer's survey, the on-farm results and methods demonstrations were the most effective extension technique. The reason was that in these demonstrations, the farmer was involved at all stages. Improved and local varieties were cultivated side by side and improved and local management practices were carried out side by side, so the farmer was able to compare and contrast the varieties and methods.

Improved crop varieties

An important objective of the ACRE program was to introduce improved crop varieties to the small-scale farmers. In Table 2 shows the number of contact farmers given various varieties in each zone. In the Kenema and Kabala zones, the emphasis seems to have been on sweet potato varieties (especially Ropot 11), whereas in the Rokupr, Makeni, and Njala zones, the emphasis was on rice varieties. Cowpea and groundnut do not seem to have been emphasized in any zone except in Njala.

The survey of the farmers showed that there were good adoption rates for sweet potato and maize across the country and a fairly significant rate for cassava and rice, but groundnuts and cowpeas did not do as well.

Table 2. Number of times improved varieties were given to farmers by zone.

Zone	Rice	Cassava	Sweet potato	Maize	Cowpea/groundnut
Kenema	30	28	42	15	1
Kabala	31	12	32	22	1
Rokupr	60	25	30	23	2
Makeni	45	19	16	29	6
Njala	47	19	16	29	17

Source: The survey of the contact farmers.

Sweet potato did well because the improved varieties had the characteristics that Sierra Leonean farmers were looking for. For instance, the varieties adopted were all early maturing and high yielding, with good cooking qualities. This cannot be said for the improved cassava varieties, which, though they far out-yielded the local varieties, lacked the desired cooking quality. Maize adoption was low because the farmers had problems acquiring fertilizer, which is required for maize to do well.

Farmers who did adopt a crop variety were saving seeds and propagating it from year to year. Seed retention and propagation are indicative of adoption of the technology embodied in the improved variety. However, farmers have been cultivating the improved variety side by side with the local variety. Under such conditions, some cross-fertilization was bound to occur. Thus, the farmer, in most cases, was no longer using the improved varieties but hybrids of the local and improved varieties.

Improved management practices

The improved management practices transferred by ACRE to the small-scale farmer included timely planting, proper spacing, proper plant densities, timely weeding, the use of fertilizers and other chemicals (such as herbicides and insecticides), good crop husbandry (such as ridging and row planting), and timely harvesting. However, it was clear that most of these farmers were using a modified form of the practices originally promoted by ACRE.

The farmers were using a reduced rate of fertilizer application because of the unavailability of this input when it was needed. The senior extension officer and the extension instructors indicated that the ACRE extension program did not make any arrangements to ensure that when the project ended, the farmer could continue to obtain such inputs. Also, the farmers did not really have a clear understanding of the various types of fertilizers, their uses, or how to blend them for a particular crop. Most farmers who go to buy fertilizer just asked for "crop medicine." Here, the main problem was the high rate of illiteracy among the farmers, coupled with the rather short time the extension agents could spend with each farmer (because there are two seasons per crop). The farmer did not have time to really learn the fertilizer and chemical technology.

In the case of sweet potato and cassava, most farmers had reverted to making large mounds (heaps) — the recommended ridges apparently require a lot more labour. For maize, though, some farmers still practice row planting, but they do not maintain the recommended spacing within and between rows. This may have been due to the fact that precise measurements are not part of the small-scale farmer's culture. To a small-scale farmer, 50 cm and 40 cm may not seem any different.

The farmers were asked to state the advantages and disadvantages of the ACRE practices. The most frequently mentioned advantage was that the practices led to high

yields; ease of management came second. The most frequently mentioned disadvantage was that the techniques were labour intensive.

Improved hardware technology

When the farmers were asked whether they had acquired any new type of tool (different from their hoe, machetes, and axes), they indicated that they had not. A few farmers cultivating rice were introduced to the use of shovels at some point, but this cannot be regarded as an innovation.

Farmer innovations

Most farmers said they had not made any improvements to the ACRE techniques. Some very progressive farmers, however, did make clever modifications to farming techniques. A farmer in the Kabala zone harvests his sweet-potato crop twice. Instead of cutting off the vines and turning over the mounds, he carefully digs up each potato, cuts it off the vine, replaces the soil, and leaves the vine and the very small tubers undisturbed. This farmer is able to save the cost of labour required for seed-bed preparation and planting new vines, and he enjoys the benefits of two crops. But it is hard to relate this experience to the acquisition of technology.

Discussion

The ACRE project concerned itself mainly with transferring improved crop varieties and agricultural practices to small-scale farmers in five operational zones, but ACRE also developed and disseminated various recipes for pregnant women, children, and nursing mothers.

In actual implementation, it seems that the concern of the nutrition component was centred on baking and the development of exotic recipes. Women were taught to make cassava bread, potato pie, and maize pap, etc. Cakes and breads were not in the local diets, and maize paps were time consuming, with only manual processing available.

In the farmers efforts to achieve food self-sufficiency, there is evidence of their ability to harness knowledge, which implies some acquisition of technological capability, but the improved practices promoted by ACRE were not fully appreciated. The average farmer did not have enough time with a project instructor to fully grasp the reasons why ACRE recommended these techniques, so the farmer changed them in ways that made them less labour and input intensive.

There was a conspicuous lack of new tools and labour-saving devices on the farms and households of the ACRE farmers when the project folded up. From the start, it seemed that ACRE made little effort to promote "hardware" technology (i.e., technology embodied in tools, appropriate labour-saving devices, and machines). Initially, the project investigated such devices as a jab planter, a rotary planter, and a dibbler. In 1982, hand cultivation, work-oxen ploughing, planting, and weeding were compared with tractor ploughing and spacing. Cost data were collected, but the analysis was incomplete. The following recommendations were made:

Different planting methods for upland rice should be [tested]. Dibbling was effective in increasing yields but was dropped because of its tediousness and because alternative uses of farmer labour had higher return. But jab and rotary planters and other planting equipment which may be developed should be tested and may prove most effective and adaptable on farms.

These recommendations, made by the project's consulting agricultural economist, seem to have been ignored. It seems that the development of farm tools, processing

machines, and labour-saving devices was quickly abandoned. In fact, one senior extension officer, who had an honours degree in mechanical engineering and an MSc in agricultural engineering, was essentially doing extension work and zonal administration, instead of developing hardware technologies. He informed the researchers that he and other staff members carried out several studies on labour-saving devices (including a rotary-disc planter for grains), but their recommendations were always ignored by management.

Conclusion

A successful transfer should lead to a new and more productive small-scale farmer, with improved crop varieties, grown under improved agricultural practices. The result should be considerably higher yields.

The ACRE project actually did make an impact on the farmers who adopted the improved varieties of sweet potato. But a lot more could have been accomplished had the project staff spent more time with the farmers and made arrangements to follow up. Because of the number of crops ACRE had to promote, one could hardly count the success rate of sweet potato, though remarkable, as a major accomplishment in technology transfer.

Policy recommendations

The government of Sierra Leone should ensure that IADPs, as well as the agricultural research institutes, are given all the assistance they need for effective operations. More than ever, the government needs these institutions to help achieve the ultimate goal of national food self-sufficiency. The IADPs, in collaboration with the government, should create farmers' cooperatives to ensure that farmers continue to get the relevant inputs, such as fertilizers, planting materials, and information, after the projects have ended. The government should ensure proper monitoring of the IADP so that it adheres to its objectives.

CHAPTER 26

Dirty Industries: A Challenge to Sustainability in Africa

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Introduction

Developed countries have been acclaimed for achieving a high level of socioeconomic growth and development, largely as a result of industrialization. This is precisely because industrialization has certain positive effects: it creates employment, wealth, and sources of foreign exchange; it develops infrastructure and endogenous technology; and it builds human capacity. In the same vein, it has certain negative effects (negative externalities): it pollutes; it causes ill health and disabilities; it degrades the environment; and it induces natural disasters.

The so-called dirty industries have become an object of concern, largely because they are perceived as critical in the infrastructure and industrial base for possible takeoff of development (Rostow 1960). However, the promotion of dirty industries by African nations and bilateral and multilateral agencies is questioned on a number of grounds. Dirty industries pose serious challenges to sustainability in Africa because the physical environment has very limited carrying capacity, as well as the debilitating effects of dirty industries on the biosphere and people. Equity and other moral issues are being raised by some; others argue that we should take the development path followed in the West and, lately, in Japan and South Korea, before we tackle the problem of industrial pollution.

The research problem

Literature on the subject can best be described as diverse and contradictory, although we observe some neutrality among some researchers. It is being argued that the higher environmental-protection standards and costs of pollution abatement are pushing dirty industries and their entrepreneurs from the developed countries into the developing ones. To further buttress this argument, some environmentalists argue that free trade (part of the current liberalization policies) undermines environmental legislation, agreements, and protection in the developing countries.

Closely related to this is the notion that developing nations have high assimilative capacity (that is, the natural capacity to absorb wastes and render them harmless). This school holds that developing countries should be content to have low or zero environmental protection standards because (1) the assimilative capacity of their environment is high (they are at relatively low levels of industrialization); (2) they are poor (they need any type of industry); and (3) they have a low demand for environmental services (see Pearson 1987).

A controversial memo on Africa, written by the World Bank's chief economist, echoed these viewpoints (Summers 1992). The memo discussed low wages and the high economic costs of increased illness and death resulting from pollution,

but it argued that Africa was still mostly unpolluted and, hence, ought to be able to serve as a hazardous-waste dump for the developed countries and as an appropriate location for dirty industries.

Some African policy-makers and prodevelopment activists claim that the increasing concern about global environmental issues in developed countries is a ploy to distort international trade and retard the pace of developing countries' economic growth. Another argument (developed even by some Africans) is that being a poor continent, Africa needs all the help it can get, and pollution and environmental degradation are the price of development. Many African governments' ambivalence about environmental protection is, perhaps, an expression of this view (see Olokesusi 1987a, b, 1988; Mwangi 1993).

Finally, there is the apparently orthodox economic argument that uniform international environmental regulations will shift dirty industries from countries where marginal pollution damages are high to those where such damages are low. If dirty industries relocate to Africa and other low-wage countries, they are merely doing so on the basis of traditional trade theory – comparative advantage (see Balassa 1979; Duerksen and Leonard 1980; Low 1992).

Dirty industries are characterized largely by (1) high intensity of energy use per unit of output; (2) high intensity of toxic release per unit of output; (3) high cost of pollution abatement per unit of operating cost; (4) high level of environmental pollution; and (5) high socioeconomic costs (e.g., ill health) relative to the benefits (e.g., employment).

Undoubtedly, dirty industries both create and contribute to global environmental problems like the greenhouse effect, ozone depletion, and acid rain. At the national level, land degradation, lake eutrophication, human illness, biotic destruction, and forced relocation are common problems. Forced relocation, in particular, is common in the mining industry — a major dirty industry in Africa. Table 1 shows that mining activities can create barriers in the path of sustainable development.

Table 1. Environmental effects of minerals extraction.

Activity	Potential effects
Excavation and ore removal	Destruction of plant and animal habitat, human settlement, and other surface features (surface mining) Land subsidence (underground mining) Increased erosion; silting of lakes and streams Waste generation (overburden) Acid drainage (if ore or overburden contains sulfur compounds) and metal contamination of lakes, rivers, streams, and groundwater
Ore concentration	Waste generation (tailings) Organic chemical contamination (tailings often contain residues of chemicals used in concentrators) Acid drainage (if ore contains sulfur compounds) and metal contamination of lakes, rivers, streams, and groundwater
Smelting and refining	Air pollution (sulfur dioxide, arsenic, lead, cadmium, and other toxic substances) Waste generation (slag)

Source: *After Young (1992).*

The environmental damage resulting from the excavation of any mineral is a function of the ecological character of the mining site, the quantity of material moved, the depth of the deposit, the chemical composition of the ore and of the surrounding rocks and soils, and the nature of the processes used to extract the minerals from the ore. Moreover, the scale and type of damage vary dramatically with the type of mineral being mined (Young 1992).

The energy consumed by industries and the volume and types of pollutants emitted are determined by the production technology and pollution-control technology in place. The choice of production technology is determined by the local availability of raw materials; energy sources; patterns of trade in semifinished products; raw-materials input (e.g., recycled aluminum waste instead of bauxite in aluminum production); host-country environmental legislation, enforcement, and related policies; entrepreneurial awareness; etc. Dirty industries are dirty partly as a result of the unclean technologies used in extraction, processing, and production. Such unclean technologies are inimical to sustainable development, as indicated by Figure 1.

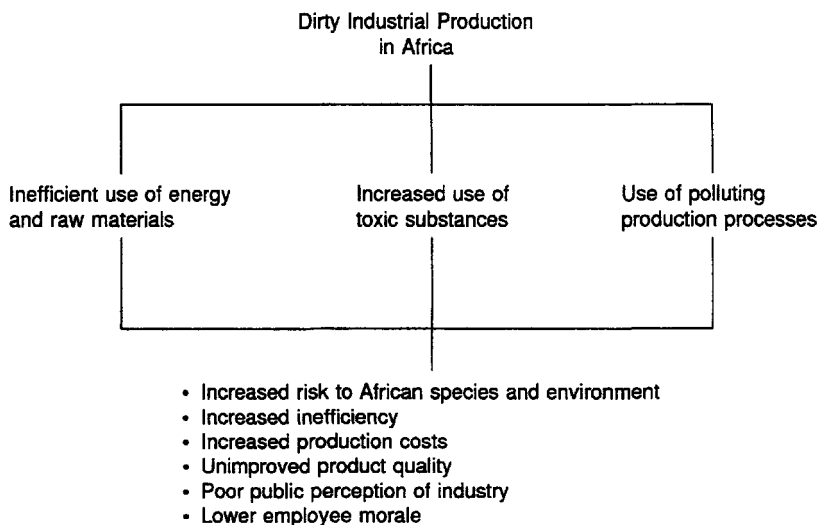


Figure 1. Dirty industries in Africa and the costs to sustainable development.

To ascertain the truth of these viewpoints, various researchers carried out studies in Latin America, Asia, and the United States (see Walter 1975; Pearson 1976; Portier 1979; Leonard 1984; Agarwal et al. 1985; Lucas et al. 1992). Often, the contention is that dirty industries have deliberately relocated from Western countries, but others claim otherwise, stating that the cost of pollution control is 1–3% of industrial costs; hence, other factors should be held accountable for any relocation observed.

Objectives of the study

The general objective of the study was to ascertain the reality and extent of international migration of dirty industries to Africa and its implications for sustainable development in the continent. The specific objectives were the following:

- definition of the concepts of dirty industries and sustainable development;
- examination of the linkages between sustainable industry and industrial development;
- examination of the rationale and evidence for dirty industries' migration to Africa;
- identification of issues and trade-offs (if any) associated with the dirty industries' migration;
- identification of the policy and sustainable development implications of dirty industries' migration and the trade-offs associated with it; and
- identification of a pertinent research agenda for more rigorous empirical studies.

Methodology

The data for this study were collected from secondary sources, that is, a review of current literature on the theme. The scope of analysis was dictated by the nature of the available data in general and of Africa, in particular.

General discussion

A number of empirical studies have been carried out on the relocation of dirty industries to developing countries. The studies differ in methodologies and data: some use regression analysis of investment data by location and industry; others use inferential analysis of environmental-control costs; a few rely on surveys of firms, surveys of business literature, case studies of firms and countries, or anecdotal evidence.

Pearson (1976) used the costs of environmental control in 18 US industrial sectors to estimate the possible increase in exports that developing countries might expect to result from differences in environmental-control costs. He reported that the range of likely increases in developing countries' exports was 129–257 million United States dollars (USD) annually from 1973 to 1977. For 1978–1982, the annual increase was from 116 million USD to then-existing levels of developing countries' exports of manufactured products. These increases appear modest because of an 8% annual increase in the growth of manufacturers' exports occurring in the developing countries in 1973–1982.

In a study of the effect of environmental regulations and the location of US industries, Duerkseen and Leonard (1984) found that

- US foreign investment in pollution-intensive industries grew no more rapidly than in all other manufacturing;
- host countries that received the most overseas investment in pollution-prone chemicals, paper, metals, and petroleum refining were other industrial countries, not developing ones; and
- the share of US foreign direct investment in pollution-intensive industries that went to developing countries did not increase significantly, compared

with that going to other industrial countries (see also Bartik 1988; Leonard 1988).

By the same token, Walter (1975) asserted that there was a trend to locate new capacities of the Japanese aluminum industry abroad because of environmental considerations, together with considerations of availability of raw materials and cheaper electric power in the host developing countries. In 1977, for example, Kawasaki Steel opened a sintering plant in Mindanao (the Philippines) to refine imported iron ore for its blast furnaces in Chiba, Japan. However, the Japanese Stop the Pollution Export Committee wanted the sintering plant closed. The plant has not closed, but the Mindanao people are still bitter about the acute socioeconomic and environmental impacts of the plant, according to Rocamora (1983). Portier (1979) observed that in the United States there was a trend to relocate industries producing asbestos, mercury, pesticides, and other environmentally hazardous substances to Mexico and Brazil.

Leonard (1984) found evidence of some migration of hazardous industries (for example, asbestos, textiles, and building supplies) to Mexico from the United States. The author rationalized the migration and expansion on the basis of low wage rates, proximity to the US market, and Mexican government incentives for domestic processing of materials. UNEP (1981), on the other hand, has given examples illustrating that relocation is essentially due to environmental factors.

Castleman (1979, 1985), in an effort to determine the effect of the US Occupational Safety and Health Administration on industrial relocation to the developing countries, came to rather ambiguous conclusions. In the earlier study, Castleman found evidence of imminent relocation of industries with environmentally hazardous work places (e.g., with asbestos, arsenic, and mercury). In the later study, Castleman reported double standards in worker- and community-health protection provided by transnational corporations (TNCs) in developed and developing countries but claimed that this did not encourage relocation by US companies. However, workplace abuses are more prevalent in Asia, Africa, and Latin America than in the United States. Following the disaster at Bhopal, India, a number of lawsuits were filed against Union Carbide in US courts in 1984 and 1985. Union Carbide, which owns 51% of the Bhopal plant, was accused of knowingly and wilfully disregarding public safety in the design and operation of the plant. According to Agarwal et al. (1985), Union Carbide's facility in the United States has more safeguards than the Indian plant.

The problem of hazardous-waste management cannot be divorced from the dilemma about dirty industries that faces developing countries. For instance, the Mexican government, together with US authorities, developed the Maquiladora Programme in 1965 as a component of Mexico's border-industrialization program, which had the goals of generating employment and acting as a catalyst to industry. The Maquiladora Programme decree stipulated that any hazardous waste generated in processing activities must be shipped back to the country from which the raw materials came, although some recyclable wastes could remain. However, large quantities of untreated hazardous wastes were dumped in many locations inhabited by poor and vulnerable groups in Mexico. There is now a lucrative international trade in hazardous wastes, to the detriment of developing countries (Merk 1990; Shimmin 1990; Asante-Duah et al. 1992).

A closely related issue is the rapid rate at which hazardous-waste recycling plants are now being established in developing countries, particularly lead recycling plants in Brazil, Taiwan, Mexico, India, China, South Korea, and South Africa. Debt-for-equity swaps enable US companies to buy very cheaply into Chilean operations

and open up new, large-scale mines (*Metal Bulletin*, 1990). The use of incentives is also continuing to ensure developed countries' access (see Young 1992).

Knodgen (1979) examined the influence of environmental regulations and pollution-control costs on industrial location and foreign investment from the former West Germany. The author indicated that there is no explicit evidence that firms in the former West Germany relocated production to "pollution havens" in the developing countries. She argued that the cost advantage is narrowing because firms must now build to meet high standards expected in developing countries in the future. One of the major findings is that 90% of the firms surveyed claimed to use similar environmental-protection techniques in and outside the former West Germany to be internationally competitive.

Lucas et al. (1992) examined how the structure of manufacturing varies across countries and time as a function of the toxic emissions of the component industries. The underlying assumption of the study was that industrial-pollution intensity is the effect of product (or industry) mix. The authors found, however, that industrial-pollution intensity is also influenced by the processes used for each of the goods and the treatment of the waste that results from these processes. To this end, the author addressed three main lines of analysis:

1. *Development and sectoral composition* — to compare patterns of pollution intensity in manufacturing with the level of economic development as measured by per capita income (the assumption is that pollution exhibits an inverse U-shaped relationship with capital income; that is, pollution is believed to, at first, rise faster than output at low levels of income and then rise more slowly than output above a critical income threshold);
2. *Organization of Economic Co-operation and Development (OECD) environmental regulation and displacement* — to examine broad differences in trends across differing periods to determine whether production relocation of dirtier industries has been more rapid during occasions of enhanced OECD environmental regulation; and
3. *Economic policies of developing countries and pollution intensity* — to ascertain whether periods of trade liberalization have led to more rapid growth in the pollution-intensive industries in the developing countries.

Lucas et al. (1992) concluded that across countries, there does exist an inverse U-shaped relationship between gross domestic product (GDP) per capita and the total estimated toxic releases from manufacturing relative to GDP. That is, toxic releases per unit of production tend to fall in higher income countries, although throughout the 1960s intensity remained constant, being independent of income. This decline was claimed to be a consequence of the declining share of GDP accounted for by industrial output, rather than a consequence of any shift toward a less toxic mix of manufacturing industries. Growth in toxic intensity has been more rapid in the developing countries. The study gave evidence of relocation of dirty industries from the OECD member countries to developing nations. The authors concluded that fast-growing, closed economies were very rapidly adopting toxic-intensive industries in the 1970s and 1980s. On the other hand, fast-growing, open economies had an essentially toxic-neutral structural change in the 1970s and a strong shift toward a less-toxic structure in the 1980s. It is worth noting that, quantitatively, these effects were more important during the 1980s than the 1970s. Again, the strength of the openness effect in the 1980s was more than twice that in the 1970s.

In another recent study, Low and Yeats (1992) used actual trade flows and a modification of Balassa's (1965, 1979) revealed comparative advantage (RCA) model

to determine whether there was a locational pull of dirty industries toward developing countries and, if so, to assess its magnitude. The study measured a country's RCA in a specific industry by the share of that industry in the country's total exports relative to the industry's share in total world exports of manufactures. The authors examined how the composition of countries with RCA in dirty industries changed over the period 1965–1988. The findings are interesting:

1. In 1988, the environmentally dirty products accounted for about 16% of world trade.
2. In the same year, industrial countries accounted for approximately 285 billion USD, or 75% of all shipments of these products, with almost 40% of world exports coming from the European Economic Community (EEC). The African countries exported about 12.8 billion USD of these goods, representing about 3% of world trade. Petroleum and nonferrous metals accounted for about 12.16 billion USD, or 95% of the African exports.
3. The environmentally dirty products' share of industrial countries' exports is falling, but the share observed for eastern Europe, Latin America, and west Asia is increasing.
4. Of the 25 largest exporters of environmentally dirty products in 1988, the only African country is South Africa (Table 2). For this country, the metals product group account for 80.50% of the dirty goods. This is an indication of the prevalence of large-scale metalliferous mining and processing in South Africa.
5. Low and Yeats (1992) noted a disproportionately large increase in the average number of developing countries with RCAs of >1 in dirty industries and that this expansion occurred in almost all of the polluting sectors. The increase in the number of developing countries with RCAs of >1 was about three times that of the developed countries.
6. Natural resource endowments seem to have a significant influence on RCAs, particularly in the nonferrous-metals sector: 33% of the dirty industries appeared to have a locational pull toward natural resources. In contrast, labour intensity was not found to be an important factor: only 15% of the sample goods (e.g., metal products) were manufactured by labour-intensive processes, and none counted as 10% more labour intensive than the US average for all manufacturing activity.

The generally low cost of compliance with environmental regulations (1–3% of total costs or turnover) has not caused large-scale migration of dirty industries to developing countries. Nonenvironmental factors, such as competitive strengths and weaknesses in labour, capital, technology, and natural-resource endowments, and other factors contribute to location decisions.

Discussion of the African situation

In view of the significance of the mining industry in Africa, it is best to start our discussion of the African situation from there. Moreover, the share of mining in the GDP at constant-factor cost is high — 60 317 and 57 865 USD in 1980 and 1990 — but manufacturing accounted for 25 497 and 34 410 USD in the same years, respectively (ECA 1991).

Many developed nations have been making strenuous efforts to ensure continued access to cheap mineral supplies through international trade and aid policies. To this end, most of the European governments and the Japanese government subsidize foreign mineral projects through loans with preferential interest

Table 2. The twenty-five largest exporters of environmentally dirty goods in 1988.

Exporting country	Share in total exports of environmentally dirty goods (%)					1988 exports of environmentally dirty goods		
	Ferrous metals	Nonferrous metals	Refined petroleum	Metal mfg.	Paper mfg.	Share in country exports (%)	World trade share (%)	Value ($\times 10^6$ USD)
Germany, Fed. Rep.	25.8	13.8	3.1	20.4	10.2	15.8	11.9	45.6
United States	7.3	14.8	11.1	15.1	9.4	10.5	7.4	28.5
Canada	7.3	23.2	6.1	6.4	27.7	23.8	6.6	25.2
France	32.7	13.3	6.7	12.7	9.5	14.6	5.7	22.0
Belgium-Luxembourg	36.7	16.1	10.1	9.8	6.6	23.5	5.4	20.8
Netherlands	13.8	14.9	31.2	9.6	8.9	20.2	5.3	20.3
Japan	50.5	8.8	1.2	20.5	5.4	8.1	4.9	18.9
United Kingdom	23.4	17.1	14.4	13.8	7.7	14.1	4.5	17.3
Italy	25.0	8.3	10.5	25.1	7.2	13.8	4.2	16.0
Sweden	20.3	6.1	5.7	10.4	34.1	33.0	4.0	15.3
Finland	10.5	6.9	4.2	2.6	56.1	52.3	2.6	10.0
Soviet Union	8.0	26.2	52.7	0.5	1.9	29.0	2.2	8.3
Brazil	44.7	16.4	11.4	3.2	7.5	24.3	2.1	7.9
Austria	27.6	12.5	0.8	16.8	22.4	24.6	1.8	6.9
Spain	28.7	9.5	18.5	14.5	5.6	18.4	1.8	6.8
Korea, Rep. of	48.0	5.8	6.5	24.4	3.9	11.8	1.7	6.6
Taiwan, China	12.9	7.4	2.3	49.3	2.7	10.0	1.6	6.2
Norway	1.7	42.8	7.8	4.4	15.2	27.3	1.6	6.0
Australia	7.4	48.3	5.6	4.4	1.4	19.8	1.5	5.7
Switzerland	12.9	21.0	1.0	27.7	8.9	11.2	1.5	5.6
China, Peoples Rep.	17.9	17.3	14.4	21.8	2.6	9.6	1.4	5.2
Rep. of South Africa	31.6	48.9	1.2	1.4	3.7	41.0	1.3	5.0
Singapore	3.2	3.7	73.7	6.4	1.8	19.2	1.3	4.8
Venezuela	5.5	17.1	72.6	0.9	0.5	49.7	1.1	4.3
Saudi Arabia	0.4	0.6	95.1	0.7	0.0	14.9	1.1	4.1

Source: Low et al. (1992).

rates, loan guarantees, and direct foreign investment.

The Bureau de recherches géologiques et minières, a French government agency, helps French companies with funding for exploration and development of overseas projects. Germany offers investment guarantees, minimum rate-of-return guarantees, and favourable loans for its companies' offshore mineral investments. These governments, along with the government of Japan, often align with the US government in supporting efforts by the World Bank, the International Monetary Fund, and International Development Agency to fund mineral development projects in developing nations, sometimes even with the explicit goal of having access to future mineral resources. Developing countries that have benefited from this strategy in Africa include Zambia, South Africa, Nigeria, Zaire, and Central African Republic.

Despite the nationalization policies of the 1970s, most African mines are owned and operated in collaborations with foreign companies. The management is nearly always in the hands of the foreign company.

The TNCs dominate the international marketing of Africa's minerals because of the need to integrate the production process with marketing operations. This raises the issues of equity, economic domination, loss of national decision-making power, and, especially, the extent of the refining done in the country and, thus, the value added. These issues, along with those of greater exploration and production in the face of declining demand for and prices of most African minerals in the world market, the environmental problems, local job losses, and weakened industrial linkages, hamper sustainable development in Africa.

Table 3 shows the employment characteristics of industries in tropical Africa. Essentially, the table shows that African dirty industries are labour intensive. The manufacturing value added per worker was highest for the glass industry in 1980, followed by nonferrous metals. In 1990, pottery and china topped the list, followed by rubber products. Although there was not much variation over the decade, there were diverse and irregular shifts among individual industries, with a significant increase in employment.

Critical issues and trade-offs

Issues

Africa's transition to sustainable development is imperative. Sustainable development can only be achieved by the decisions and actions of each member nation, on the basis of its own interests, needs, and priorities, including its responsibilities to the regional and wider international communities.

A major challenge is to develop an acceptable and successful strategy for sustainable development. The transfer and development of technology are crucial aspects. The use of environmentally sound technologies, whether exogenously or endogenously developed, can contribute significantly to productivity and the sustainability of resources through renewable-energy generation, pollution control, and waste reduction.

The relationship between inputs and outputs and the holistic impact of economic activity on the environment is not static but dynamic. Consequently, the question is whether the positive forces of substitution, technological innovation, and structural change can compensate for any deleterious effects of the overall growth in scale.

The process of industrialization should always take into account the true monetary value of the environment and its protection. Formulating an environmental

Table 3. Tropical Africa: manufacturing employment (1970, 1980, 1990).

	Employment			MVA/worker ^a	
	1970	1980	1990	1980	1990
Food	176	285	355	91.3	90.8
Beverages	38	74	94	89.7	93.9
Tobacco	24	39	33	83.4	110.5
Textiles	153	264	285	88.5	76.5
Apparel	42	67	126	84.7	84.6
Leather	6	13	18	127	117.7
Footwear	15	25	31	98.1	106.3
Wood and cork	70	110	67	124	162.9
Furniture	22	45	35	114.3	103.4
Paper	10	25	35	91	69.3
Printing	28	51	51	101.3	85.3
Industrial chemicals	13	26	30	83	91.5
Other chemicals	23	56	71	118.8	100.2
Petroleum refining	5	9	14	68.2	56.1
Petroleum and coal products	0.2	0.7	1.1	34.7	26.5
Rubber	18	26	20	97.4	172.6
Plastics	6	42	29	81.1	95.3
Pottery, china	1	2	2	135.3	219.7
Glass	4	6	8	150.3	98.6
Nonmetallic minerals	31	52	55	87.1	115.4
Iron and steel	11	22	36	142.5	101.2
Nonferrous metals	3	7	6	57.5	96.4
Metal products	52	97	93	101.7	110.8
Nonelectrical machinery	8	19	16	100.2	138.1
Electrical machinery	13	33	31	96.4	118.5
Transport equipment	29	65	59	263.4	155.4
Professional and scientific goods	0.3	1.4	2.4	77.9	130.4
Other	9	15	20	89.6	76.2
Total	812	1476	1625	99.7	99.7

Source: UNIDO (1991).

^a manufacturing value added/worker index; 1970 = 100.

policy on the basis of the costs to society of environmental damage rests on the assumption that environmental conditions will worsen without pollution control. It is crucial to determine the monetary costs of damage and protection. What factors influence the value individuals in different countries place on environmental protection?

As shown by the memo written by the World Bank chief (Summers 1992), the perception of the assimilative capacity of the developing countries' environment raises some pertinent questions. How can developing countries be convinced beyond reasonable doubt that the World Bank, its affiliates, and similar agencies have not been secretly encouraging the transfer of unclean technologies from developed countries through loans? If so, it would mean that these banks have been earning interest on loans and credits given for the transfer of environmentally unfriendly industrial technology. Available evidence suggests there is rapid environmental degradation in Africa, coupled with poverty and the unmet basic needs of the people.

How will this development pattern create jobs and what type of jobs? Will these generally be blue- or white-collar jobs? Is there evidence to show that dirty industries generate more employment per unit cost of investment than "clean" industries?

African governments are generally ambivalent about environmental-protection issues, and this is closely related to the ease with which unclean technologies are imported into African countries. What factors are responsible for this ambivalence? Why are environmental policy instruments weak or poorly enforced? Are there enough local capabilities to establish environmental-protection standards based on locally determined norms, values, and acceptable pollution levels?

Most African countries are undergoing structural adjustment and trade liberalization in various forms. To what extent will the drive for export diversification put pressure on governments to neglect environmental protection issues and industrialize at all costs? Export-oriented industrialization in the absence of endogenous technology has made Africa dependent on foreign markets, capital, and technology. Would this process not merely be a closed loop? Would it not lead the region to incur more debts, deeper environmental degradation, greater poverty, and a more pervasive erosion of its sovereignty, democratic institutions, and policies? Will African industrial entrepreneurs, governments, donor agencies, and foreign technical partners respond by importing clean technologies and adapting existing technologies? The answers to these questions will help to decide whether the structural adjustment programs and trade liberalization have been helpful to sustainable development in the continent.

The occupational-health and industrial-safety standards in TNC firms in host countries are generally lower than in TNC plants in their home countries, which is of particular importance in a poor region, where emergency and health-care facilities are poor and water and sanitation facilities can be at best described as rudimentary. Why do we encounter this divergence, and what can be done to ensuring better house-keeping and safety?

The empirical work on the issue of dirty-industry relocation to Africa needs to be strengthened. Stricter environmental-protection instruments, including high-cost disposal, are creating a push effect in developed countries. On the other side, the desire of cash-poor African nations to import waste acts as the pull factor. This trade is an unwholesome one and raises the issues of double standards, equity (present and intergenerational), and weak (or nonexistent) monitoring and enforcement of international environmental laws.

The national environmental-protection agencies are either unable or unwilling to enforce established instruments. The appropriateness of these instruments and the capabilities and staffing of the national environmental institutions are critical to sustainable development. Strategies that promote more environmentally sound technologies and discourage environmentally damaging ones must involve the appropriate combination of market instruments and public intervention at each stage in technology acquisition and adaptation and the industrialization process.

The environmentally sound technologies (ESTs) are not discrete entities but a system that encompasses procedures, processes, products, and services, as well as equipment. This implies that to be sustainable, transfer of technologies to Africa must address human resource development and local capacity-building aspects of the technology options. The process of technology transfer and development should be equitable for nations, gender, and social status, bearing in mind the linkages and interdependency of all in the context of sustainable development.

How can African countries achieve a long-term partnership with suppliers and

users of technology? This would be crucial for training, institutional linkages, and technology adaptation.

The rate at which new technologies spread is largely determined by the pace of new investment. For example, retrofitting of existing facilities, the replacement of poorly performing equipment and machinery, and the addition of new equipment to the stock require initial investments in ESTs, which are often greater than those in existing polluting technologies. How can poor African countries secure the resources to acquire environmentally sound technologies or develop their own endogenous capacities? How can poor African countries best use technology and environmental-impact assessments (EIAs) in industrialization?

The transition to sustainable development requires effective access to technological information, including technology assessments. Especially crucial is information on environmentally sound technologies and on environmental risks from technologies on the international market. Africa needs to build up a critical mass of research and development (R&D) based on adequate and appropriate information.

R&D facilitates an anticipatory approach. Research activities and strategies to promote ESTs require a multidisciplinary approach and close collaboration across countries, firms, governments, research institutions, and nongovernmental organizations. How can Africa improve its policies and strategies for both R&D and technology assessments? How can external funding, R&D, ESTs, EIAs, technology transfer, technology choice, technology assessments, and environmental-protection instruments complement, supplement, and support host-country initiatives, actions, and priorities? To what extent can indigenous knowledge of the environment, industrial development, and pollution control be tapped by R&D and appropriately used?

Trade-offs

The relocation of dirty industries to Africa may contribute to an increase in some African countries' GNP, but the negative effects of the pollution and degradation on other sectors of the economy and on human productivity need to be examined carefully. There could be a labour and income advantage for some heavily polluting industries, but these advantages would be tenable only in the short term. In the long term, the effects of this comparative advantage rests largely on the opportunity costs of investing the resources in other sectors of the economy. Would greater employment have been created by alternative investments? The type of benefits accruing to society determines the trade-off between environment and income. Examples of such benefits are health and quality of life, aesthetically pleasing landscapes, monetized benefits, and the conversion of monetized benefits to other income-generating activities. Under proper management, the income optimization and time horizon of benefits should be compatible with many environmental, conservation, and improvement projects, plans, and programs.

The income-elastic nature of the willingness to pay to avoid environmental damage and ensure protection and the correlation of rising income with environmental quality explain why the poor and rich perceive some environmental problems and their solutions differently. This again has to do with the type of technology involved. Although rural Africans might be willing to tackle erosion problems, they may not be too interested in industrial pollution unless it directly affected their livelihoods.

Some pollution-control and resource-conserving technologies will be profitable to society and firms and others won't. Lack of profitability could be a result of distortions in the market prices of inputs. Corrective policies would reverse such trends, particularly in Africa, which largely depends on natural resources. Resource-conserving technologies should have greater priority.

Furthermore, Africa has a lower level of capital, hence higher opportunity costs. High priority may not be given to projects with a long-term horizon of benefit because priority is already given to satisfying basic needs. As a trade-off, there is likely to be greater interest in projects and technologies with monetized benefits.

The African environment is a resource, as well as being a constraint on development; as a constraint, the level of poverty deepens. Hence, *ceteris paribus*, an attack on poverty should lead to environmental improvements and resource conservation. Creating employment is a priority in the quest to alleviate poverty. Creating employment with environment-enhancing projects and allied technologies should be a desirable trade-off. This concerns particularly labour-intensive technologies, although they may be less attractive investments than capital-intensive alternatives.

Because human capital has to be improved to achieve sustainability, alleviation of poverty should be perceived as a social investment in the short-term consumption needs of the poor. It is equally a means of improving their own contribution to the accumulation of capital in the future. With respect to income generation in the future, a trade-off is implicit. This is because the degree of poverty alleviation has to be significant enough to generate productivity, consumption, income, and welfare; otherwise, the opportunity costs will be negative.

Finally, trade-offs among types of risk are often involved in dealing with waste. Deciding whether to incinerate waste or to bury it can make a difference in the degree and type of risk to which communities are exposed. Further work on the "best practicable" waste management system would be desirable.

Conclusions

Dirty industries are increasing in Africa and declining in some developed countries. Agencies from developed countries aggressively promote mining, a very dirty industry. We have been able to establish that dirty industries do generate a reasonable level of employment. However, we have not been able to establish that their expansion in Africa is due to nonexistent or weak environmental-protection standards and high pollution-abatement costs.

If dirty industries are needed for Africa's development, then further empirical research should be done on the issues they raise. What follows is an overview of such research entry points.

Recommendations

1. Researchers should elaborate the concept of sustainability in the African context: define it and test it with operational hypotheses.
2. Researchers should study environmental considerations and issues in the context of industrial technology choice and transfer and options for overcoming identified shortcomings in the technologies and for sustaining their desirable characteristics. Such a study should include comparisons of technical agreements (across countries, time, and industrial groups) to determine if there has been a focus shift in legislation and economic instruments toward environmental considerations.
3. There is a need for multicountry studies of industrial structure. Such studies should compare dirty industries with clean industries and examine how they operate, use raw materials, and pollute; their environmental management policies, plans, and programs; their ownership structure; and their types of

- technology. What are the factors in their differences? The comparison studies should be broad enough to include costs of pollution abatement; incentives; pollution-control measures; and the patterns of water and energy consumption.
4. There is an obvious need to study the nature of the employment generated by industries, including the gender and productivity of labour, within and between industrial sectors.
 5. Researchers should critically examine and compare existing environmental-protection instruments and institutions, with the aim of finding ways to strengthen them. Some of the issues would be the extent to which new risk-control initiatives undercut existing ones, whether this undercutting hinders existing control efforts or enhances bureaucratic resistance to new ones.
 6. There is the need to critically examine the issue of environment versus development to arrive at a more objective valuation of environmental resources and services. Such information is crucial in estimations of natural-resource carrying capacity, real GNP, project cost-benefit analyses, and EIAs.
 7. Researchers might also study alternative scenarios. Should Africa be left undeveloped industrially so that its environment is protected? If it is industrialized, then at what pace should industrialization proceed? Should African nations move on the assumption of an inverted U-shaped curve for pollution and income or an inflection relationship?
 8. There is a need to determine whether substitute technologies or products, particularly environmentally benign, endogenous ones, are available or likely to be developed to use in place of products or technologies that presently produce significant pollution. A comparison of the substitutes and the existing ones should include identification of hazards and assessment of risks.

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