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# Industrial innovation in Sub-Saharan Africa: the manufacturing sector in Nigeria [1]

B. Oyelaran-Oyeyinka *, G.O.A. Laditan, A.O. Esubiyi

*Nigerian Institute of Social and Economic Research (NISER), Ibadan, Nigeria*

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**Abstract**

This paper presents the findings of a study on the innovative behaviour of over 50 firms in a Sub-Saharan African country, Nigeria. The study examines the engineering and agro-allied sectors and the nature of linkages they form with research and development institutions (RDIs). We found evidence of significant innovative activities, albeit of adaptive and incremental kinds. Linkages between firms and between firms and RDIs are mostly on an ad-hoc basis. Interaction remains fairly weak but developing. Firms innovate largely in response to materials constraints and scale bottlenecks. Poor physical and engineering infrastructure constitutes a particular constraint category shaping the rate of innovative activities.

## 1. Introduction

In response to the obvious need to promote scientific and technical progress, most of less developed countries (LDCs) set about formulating science and technology (S&T) policies in the 1950s. Supported by the UNESCO and other UN agencies, these countries focused on the establishment of research and development institutions (RDIs) relying on them as the primary source of technical knowledge, from which pool of knowledge the productive sector might draw at as when necessary. By all accounts, this has turned out to be a misguided conception of the real behaviour of technical and economic systems.

Recent developments in the theory of innovation have emphasized the systemic nature of innovation, the unavoidable interdependencies of technical, economic and social sub-systems, and the evolutionary dimension and content of extant technological systems. The uncritical emulation of received social policies which seems to have served well the needs of developed countries (DCs), has cost the LDCs much effort and resources; these countries missed two vital historical and policy imperatives. First, there are historical antecedents to the structures of innovation which by then served as exemplars for the LDCs. This antecedent history can be traced through the conceptual shifts and evolution of innovation theory that started with Schumpeter, aptly

* Corresponding author.

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described in Freeman (1982), Schmookler (1966), Mowery and Rosenberg (1979), Nelson and Winter (1982), Nelson and Dahlman (1993), Lundvall (1992), Von Hippel (1988) and Bell and Pavitt, 1993. The evolution of theory has culminated in an increasingly sophisticated way of looking at the innovation process. The present state of knowledge reveals what has always existed in fact, and exposes the conceptual flaw in the way the LDCs had conceptualized and formulated innovation policy. There are three main issues.

First, we refer to the 'birth' of the idea of the national system of innovation (NSI), which according to Freeman (1987) describes "the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies". In other words, a dynamic system of innovation would have stronger national systemic interactions much more than cross-national linkages. Secondly, technical dynamism is undergirded by pervasive interaction among all social elements: legal, financial, commercial, technical and political. This contradicts the conception of innovation as consisting, in the main, of two isolated sub-systems: the R&D islands 'doing' research the productive sector *for* which research is done. Again conceptually, innovation is separated from diffusion as well as from very important evolutionary processes of continuous modifications and adaptations in the life of industrial systems. Received theory and policy making in Africa has no place whatsoever for incremental innovation. Although this might well be a theoretic hangover from Schumpeter, the trivialization of the process of technical emulation has not done the LDCs and Africa in particular much good.

## 2. Problem definition in innovation research in LDCs

For long, innovation research in LDCs has defined the innovation problem as one of how to create linkages between the R&D islands and the productive enterprises. There are two broad reasons that are ascribed to the poor performance of RDIs in LDCs.

1. The 'lack of' factor: seen as the inadequacy of finance, human resources and poor infrastructure.
2. The linkage factor: that is, even where a particular RDI is productive, its output may still remain largely unutilized by the productive sector. The linkage factor has attracted very wide commentary and research attention. There are three elements here:
   - 2.1. Gaps in the dissemination of information about RDI outputs.
   - 2.2. Lack of what we call 'bridging' facilities, especially strong engineering firms, capital goods and engineering consulting outfits that are needed to translate ideas into capital-embodied technology.
   - 2.3. Relevance of RDI outputs.

While the 'lack of' factor is an important feature of the LDCs environment, and crucial to the realization of innovative ideas, it alone cannot explain the failure of this experiment. South Korea was in much the same economic state as most African countries some 3 decades ago. It was equally saddled with 'lack of' factors. Although India has achieved greater dynamism in industry, it has taken a similar view as African countries with strong accent on 'doing science' with much the same result: laboratories full of unutilized inventions and limited linkages (Alam and Langrish, 1984; Govindarajulu, 1990).

On the other hand, the linkage factor has more fundamental dimensions to it; it is both a cause and an effect of the 'systemic incoherence' of the innovation system in Africa (Bell, 1990). What we are saying in effect is that the view of the innovation process within an evolutionary and systemic perspective better represents reality. Therefore, the definition of research problem in this study does not agree entirely with the views of innovation failures related earlier. A meaningful definition of the problem we suggest places the interactive units, like RDIs, bridging institutions and user firms, within a system where interdependencies and constant feedbacks underpin continuous dynamism. This assumption undergirds the objectives and methodology of this study.

## 3. Objectives of the study

The overall objective of the research project was to analyse the factors influencing the successful adoption or non-adoption of industrial innovation by Nigerian firms and the nature of interaction among them. In doing this, the project considered the following

1. the institutions;
2. the technical/industrial innovations;
3. the network of bridging facilities (the engineering sector) that is necessary to translate R&D output into productive use;
4. the users of capital goods produced by the bridging firms, that is processing firms.

The specific objectives of the project are:

1. to examine the capability of R&D institutions (RDIs) and the criteria for the selection of research projects responsible for successful innovations;
2. to examine the capability of bridging institutions to effectively translate the output of RDIs into productive industrial use;
3. to examine the capability of user firms to effectively employ the machines and equipment of bridging institutions to produce consumer goods, and to generate in-house innovations (be it adaptive or incremental);
4. to design alternative sets of policies to address the outcome of the project.

## 4. Innovation in less developed countries

In this paper, an attempt is made to present some preliminary findings on the type and nature of innovation activities taking place in industries in Sub-Saharan Africa (SSA), probably the most technologically backward area of the world today. Much of what we know about innovation theory has come from the developed countries (DCs), and seen in the world view of advanced economies. It is tempting to dismiss the idea of industrial innovation in underdeveloped countries where hardly any revolutionary innovation has emerged. But inspired by the literature on Latin American and South East Asian technology creation efforts, and indeed earlier on by the pioneering works of Enos (1962), Hollander (1965) on firms in industrialized areas, the concept of innovation has been widened from its earlier Schumpetarian form, to accommodate non-revolutionary but equally significant incremental technical change that takes place largely on the firm's shop floor, rather than within research and development (R&D) laboratories. These are the kinds of innovation that we found in this study. Within the technological capacity of the SSA environment, some of these innovations made the difference between firms closing down and moving forward to make very healthy profits. To this extent, they constitute technical advance.

An elaboration of the concept of technical change, especially as it relates to its generation and application in the Third World, can be found in the technical change literature. For instance, Bell (1984) has classified technical change into three broad categories:

1. technical change that involves the introduction of new techniques (products and processes) into the economy through new investments in plants and machinery – this type of technical change 'broadens the industrial base of the economy';
2. evolutionary (incremental) improvement to existing techniques achieved by effecting technical change to existing products;
3. the generation of new knowledge through research within the firms or within separate R&D institutions.

Types 1 and 2 can be found in most of the more advanced less developed countries (LDCs), the newly industrializing countries (NICs), while Type 3 is to be found mostly in the more industrialized countries.

However, while organized R&D and basic research programmes have led to the more revolutionary breakthroughs, minor incremental technical change has generated equally substantial productivity growth. This is true for developed countries (as shown by the works of Solow, 1957, Dennison, 1962, Hollander, 1965 and others) as well as for the developing countries, as reflected in the literature on Latin America and India (Maxwell, 1977, Katz, 1987, Bell, 1984 and Lall, 1980). The work of Enos (1962) on the US petroleum industry is a landmark study on the technical changes for four new major processes in the petroleum refining industry, viz. thermal cracking, polymerization, catalytic cracking and catalytic reforming. For each process, he distinguished between the 'alpha' (which covers the invention, development and innovation) and the 'beta' (subsequent improvement to the basic process innovation) phases.

Enos found that the average cost reductions generated during the beta phase was much higher than that for the alpha phase. The ratio was 3:1 (4.5% compared with 1.5%). He concluded that:

> The evidence from the petroleum-refining industry indicates that improving a process contributes even more to technological progress than does its initial development (p. 180).

For LDCs, for which the cost of staying at the technological frontier is enormous, these findings take on added significance and meaning. Firstly, it means that the origin of technical change should be sought from a much wider variety of sources: from within the firms, production lines and machine shops, instead of looking only at the R&D laboratory. Secondly, technical efforts at improving existing old vintage plants promise as much economic return as investment in new vintage plants. This may well dispose (at least for a time) the need for costly investment in new processes, and plants. This point has since found empirical justification in the copious literature from the experiences of the newly industrializing countries (NICs). We note the differences in the socio-economic and technological conditions of the NICs and the SSA. However, in what follows, we review some of the issues that shape the nature and rate of innovation in those countries bearing in mind that the economic conditions prevailing in those nations only a few decades ago were very similar to what applies in SSA now.

1. In the LDCs, most of the firms are owned by multinational corporations. These firms hardly perform R&D within the environment, therefore the sources of innovation are located far away from the market. In the few countries of the LDCs where there are some fairly big indigenous firms, they obtain a large share (if not all) of their production facilities from the industrialized countries. The majority of them depend completely for their technical support on the technical partners.
2. The scale of operation, the size and characteristics of the markets in LDCs are radically different from those of the countries where the innovations originated in the first place. For example, the nature of the firms, private, public, joint venture, local, foreign and so on, create an entirely different industrial structure; while the size of the markets, except for the large countries with large markets, makes it necessary to scale down technologies imported from abroad. Examples from Latin America (Katz, 1987) reveal that automobiles and machine tools firms produce 20–100 000 and 100–500 units year$^{-1}$, compared with similar firms in the industrialized countries with five to ten times larger facilities. The implication of different scale size is that, firms in LDCs would normally follow a different evolutionary path of innovation and technical change. They may need to evolve different sets of spare parts and component manufacturing facilities, to fully realize the benefits of smaller plant sizes.
3. We know that the successful accumulation of scientific knowledge must be preceded by the accumulation of technological capability and build-up of a strong industrial base. The knowledge environment of the SSAs is arid. Both for innovation efforts in R&D institutes and for the operation and innovation within enterprises, the industrial environment lacks the necessary 'bridging facilities' like capital goods and machine tools plants.
   The growth of science-related industries in the West was predicted on the 'prior internalization of knowledge into the industrial environment'. The attempts to accumulate modern industrial systems, and to conduct research, requiring substantial science-based materials is bound to encounter severe difficulties without a strong industrial competence base. Take the role of enzymes in biotechnology research. Enzymes have a short lifespan, and must be stored under sub-zero temperatures to remain active. The scale of profitable production for an enzyme plant requires very substantial investments. Most SSA countries, that do research requiring enzymes, presently rely on import of the commodity from abroad. For those who cannot find the foreign exchange, that effectively is the end of research. Where and when enzymes are accidentally stored above specified temperatures in transit, scarce foreign exchange is lost. The implication of all these is that beyond the laboratory window, the industrial environment must provide the needed supporting context.

Table 1
General information on firms major activities and dates of establishment

| | Types of major activities | | | | Date of establishment | | | |
|---|---|---|---|---|---|---|---|---|
| | Manufacturing | Research | Equipment manufacturing | Others | 1960 | 1961-70 | 1971-80 | 1981-now |
| Frequency | 39 | 1 | 14 | 1 | 12 | 18 | 11 | 14 |
| % | 70.9 | 1.8 | 25.5 | 1.8 | 21.8 | 32.7 | 20.0 | 25.5 |

4. On the sources of innovation, incremental and adaptive technical change constitute the main sources (Enos, Katz, Maxwell) and for this reason, LDC policy making may want to look outside established R&D laboratories.

## 5. The sectors under study

The two sectors studied were the engineering and the agro-allied. The study sought to know how these sectors interact with the RDIs. The choice of the two sectors was deliberate. According to the result of an input–output analysis of the Nigerian economy carried out by the Nigerian Institute of Social and Economic Research (NISER), these sectors were ranked very high (Nigerian Institute of Social and Economic Research, 1990) based on certain tightly defined criteria. [2] In addition to the input–output results the engineering sector is expected to provide linkages to other sub-sectors, for instance backward links to basic metal (iron and steel) and forward linkages to downstream activities such as automotive, construction, transportation and so on. Five major sub-groups of engineering have been identified as viable in Nigeria. They are: metal fabrication, foundries and forge shops, machine tools, vehicle assembly and electrical and electronics.

The agro-allied sector comprise enterprises of various sizes and provide inputs to both the foods and beverages sub-sectors. While it depends on imports for a large part of its machinery and equipment, significant technical advances have been recorded especially adaptations to the use of indigenous resources. The identified sub-groups are: textile and wearing apparel; food, beverages and tobacco; tanneries and leather goods; sawmills, wood products, pulp and paper, pulp and paper products; tyres, tubes and rubber products. The sector consists of subgroups within the ISIC code numbers 3112–3559.

The public RDIs in Nigeria fall into eight functional groups, viz. industrial, fisheries and marine, food crops, civil engineering, tree crops, livestock, medical and general agricultural services. Of these, two (industrial and civil engineering) were studied in this project. These institutions are fully funded by the government and administered by different ministries.

## 6. Analysis of research findings

### 6.1. Research findings

The research covered 100 firms and RDIs in three broad areas of manufacturing (process firms), capital goods and RDIs. The response rate was 55% with 70.9% process firms, 25.5% in capital goods and only a handful (1.8%) of RDIs. Some 45.5% are private firms, 47.2% are publicly quoted, 5.5% have mixed ownership and 1.8% are foreign owned. Some 51% accounted for firms employing less than 50 people, 34.5% of firms have between 51 and 100 people and 14.5% employ more than 100 people. Tables 1 and 2 shows the activities, ownership structure and firm size. Nigerian firms are not readily disposed to replying to mailed questionnaires, and as such the method used in this study is survey interview. By this, research personnel not only submit questionnaires personally, but it is followed up until it is retrieved. During the visits, we conduct interviews and familiarize ourselves with the facilities while also verifying claims made by firms. This in addition to expert assessment of innovation helps to

[2] The following criteria were used to rank the sectors: employment, value added, 'leakages' (foreign exchange) and domestic linkages.

Table 2
Firms ownership structure and size

| | Ownership structure | | | | No. of employees by category | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Private | Publicly quoted | Foreign | Private and publicly quoted | Administration | | | Technical | | |
| | | | | | 0–50 | 51–100 | Over 100 | 0–50 | 51–100 | Over 100 |
| Frequency | 25 | 26 | 1 | 3 | 28 | 19 | 8 | 22 | 7 | 26 |
| % | 45.5 | 47.2 | 1.8 | 5.5 | 50.9 | 34.5 | 14.5 | 40.0 | 12.7 | 47.3 |

authenticate the nature of innovation. This approach may well give a low response rate but, we believe, a more reliable picture.

## 7. The nature of innovation

The characterization of innovation into product and process is self-explanatory. In this study, it was reported that 39.1% of the recorded innovations were process while the majority 61% were product innovations. This is not unexpected. However, the other classificatory categories deserve some elaboration. For methodological clarity, it is pertinent to explain what exactly the terms being used denote in this study. First, *adaptive innovation or adaptive technical change* is, for our purpose, those activities directed at modifying the technical basis of production process prior to full-scale use; or the changes to a product before it is introduced to the market. Adaptive innovation will draw largely on known techniques and the existing knowledge base. The technical change process within this activity level hardly calls for 'new' knowledge as such. In most cases, adaptive efforts are necessary only to change process parameters to suit the technical environment of imported systems. In effect, an adaptive innovation is aimed at meeting technical preconditions. *Incremental innovations*, on the other hand, are those evolutionary technical changes aimed at correcting technical imbalances; and modifying minor, albeit significant, core or peripheral system 'noises'. This activity has been identified in the literature as contributing significantly to the economic change process and to productivity growth (Enos, 1962). It is also the basis for what Bell and Hill (1978) described as "autonomous technical dynamism". *Evolutionary incremental* innovation provides the basis for more significant major innovations in the future. Whereas emphasis has been put on major technological innovation in industrialized areas, minor incremental innovation with its vastly different characteristics seems to be more predominant in LDCs. These are the definitive findings of this study.

Another characterization of innovation employed in this study is that of *original* versus *imitation*. *Original innovations* on the world scale constitute epochal events and do not happen all the time; they belong to the radical/revolutionary category. However, some products or processes may well be original to a particular locality, although the technical/scientific basis of such events may be nothing new. Radical/revolutionary innovations would ordinarily rely on frontier science and technology. A distinction has therefore been made in this study between, for instance, an innovation 'original to Nigeria' or 'original to the world'. Imitation as a corollary is therefore not used in a pejorative sense. In fact, an *imitative innovation* may well contribute more significantly to the economy than an original at a particular time and within a given context. In this study, we found no innovation that could be described as 'original' in the sense of being 'radical'.

Certainly the innovations were useful and contribute significantly to the activities of the firms. From this point, we equate 'adaptive' roughly with 'imitative' innovation for analytical clarity.

This study reveals that adaptive innovation constitutes the bulk of the technical change process in Nigeria's industries. Close to 79% of the innovations are adaptive while 21.4% are incremental. [3] On close examination, we found that the so-called revolutionary innovations were based on neither frontier scientific findings nor on now scientific breakthroughs at least at the world level. There were, however, technical breakthroughs of great significance within the firms. The particular case of the Guinness and larger beer malting processes constituted innovative responses to supply constraints brought about by an economic regime of scarce foreign exchange. Before then, barley malt was imported by the brewing firms but faced with the threat of fall in revenue and possibly collapse of the sector, the brewers adapted Nigerian cereals such as sorghum and maize to replace barley in the malting process. [4] This was to an extent that the effort achieved technical and commercial success and moved the sector from the path of import-dependence to a local resource-intensive one. The innovation represented a significant event in the sector's history. This, however, does not make it a radical innovation for three reasons. First, the science of brewing is fairly well established having been practised for centuries. Secondly, while the process and equipment might have been adapted to suit the specific Nigerian environment, the scientific and technical basis of manufacturing the process plant remain unchanged. Third, and significantly, the product remains 'larger beer' and 'stout' which are by no means new to the world or to Nigeria – the qualification of *newness* is central to the definition of a product innovation.

## 8. Sources of innovations

The source of innovation is interpreted here to connote both the sources of ideas and information for innovation as well as the source of support and technology for carrying out innovation. In the former, it is found that 67.3% of information came from established business channels while 32.7% came from personal contacts among company personnel. As for technology and support facilities for innovation, four main sources were identified: 52.7% of technology came from in-house 'R&D' efforts, 36.4% from parent company: 21.8% from customers and 12.7% was obtained from research institutes.

As was pointed out earlier, most of the relatively large firms in spite of their long history maintain important technical and management agreements with parent companies overseas, and we found that this relationship became very important in carrying out innovation projects; and as such, what is referred to here as in-house 'R&D' should be clarified. As was explained in the previous section, very little original research takes place within the firms surveyed, rather, most efforts are directed at some kind of adaptive and modification activity.

The share of the RDIs is rather modest at 12.7% and this linkage is not between RDIs and the large firms which invariably have overseas technical partners, but between RDIs and the relatively small/medium firms and capital goods firms. There are a few collaborative efforts, however, between RDIs and the large firms but these are not long term and sustainable contracts. As expected, machinery suppliers' contribution is very negligible at 1%. It also confirms our findings that the contribution of research institutions outside productive firms is, at present, only *marginal* and constitutes a weak link in the innovation chain. The major activities of this group are useful and limited largely to small scale and informal sectors of the economy where they seem to be very active. Measured against the size of the Nigerian economy, however, the nascent capital goods sector is indeed relatively very weak.

## 9. Factors affecting decision to innovate

Freeman (1982) identified two kinds of innovation strategy, which are *offensive* and *defensive*. An *offensive innovation* strategy is aimed at achieving technical and market leadership by being ahead of competitors in the introduction of new products. In developed and developing countries alike, only very few firms can truly be classified as offensive innova-

[3] According to the brewing firms, a ban, in the absence of local substitutes, could well mean the end of their operations. The other option open to government was the imposition of high tariff which in a situation of scarce foreign exchange could result in high product cost. This could elicit customer resistance and drop in sales and subsequent loss of profit or worse.

[4] University–industry collaboration remains ad-hoc in nature but resulted in very important outputs from the firms.

tors. The kinds of research engaged in by an offensive innovator has been classified as *oriented fundamental research* or *background fundamental research*. This is not pure research as such but it is equally fundamental. This firm is evidently research intensive and may well have to depend to a large extent on in-house R&D capacity.

A *defensive innovation strategy* on the other hand may take the form described as *defensive, imitative, dependent or opportunist*. A defensive strategy does not translate to lack of research-intensiveness (an imitative strategy does not mean lack of R&D) but, as Freeman puts it, in "the nature and timing of innovations". The defensive strategist does not aspire to technical and economic leadership but he equally does not want to suffer laggardness by being saddled with obsolete technology; he does not want to take the risks and incur avoidable financial losses; he hopes to benefit from the mistakes of market leaders. Again, it may be that he lacks the capacity to undertake fundamental research necessary to assume and maintain technical leadership.

Defensive innovation strategy, while not absent from the developed country firms, will seem to describe appropriately the innovation landscape of firms in developing countries and quite specifically in Nigeria. Without exception, no single firm can be termed a world innovation leader among the firms in our sample. No single innovation would seem to have been undertaken purely for the sake of doing R&D. The majority of innovations were responses to *immediate threats* of deterioration in the established market and profit positions of firms. There were two main reasons why firms seemed not to do innovations voluntarily. First is the lack of technical and managerial capabilities to initiate such major endeavours. While most firms, especially the large firms, engaged in processing activities (brewing, confectionery and beverage making), have acquired considerable techno-managerial skills in production and marketing, they seem to possess less of the other capabilities such as design and basic R&D. Secondly, the relatively large firms rely so heavily on the technical expertise of their overseas affiliates that they have over the years neglected to develop local in-house innovation capacity. The smaller firms have simply not matured to the point where they can begin to acquire the sophisticated equipment, develop the manpower and indeed find the capital to finance even imitative innovations let alone original ones. For some small firms, the name of the game is survival and if and when indeed a time comes to choose between innovation and survival, this group will simply be made extinct. For instance, the Manufacturers Association of Nigeria (MAN) reported that 200 firms folded within a few months in 1993 "due to unfavourable incentive system" (*Business Times*, December 7, 1993).

From the survey response, we find that 52.7% of firms innovate in response to supply-side constraints – the 'lack of factor', viz. raw materials, space parts, equipment and manpower. Most firms in this category undertake innovation to change from imported to local raw material inputs. Some 29% claim to innovate in response to factor price as well as product market, a variable that has a relationship with, among others, the supply-side factor. Some 12.7% of the innovations is in response to achieving a greater share of the market. This factor affects mainly the relatively well-off brewery and beverages sector.

## 10. Capabilities and capacities within firms and institutions

For innovation to occur, a firm must possess in certain quantity some broad range of skills. These skill levels may not necessarily be radically different from the capabilities needed for production engineering, quality control and other such routine day-to-day operations. This is more so for firms that are far away from the frontier of knowledge.

For such firms, Bell and Hill (1978) observed that: "... the connectedness of science and technology, or the importance of research inputs may not simply be lower, but *may become of no importance*". We agree fully with this observation and this indeed is what we found in this project. Our findings show that firms which we surveyed are very far from the frontier of knowledge. They could elect to ignore the scientific basis of the production technologies.

In order to analyse the types of skills required properly, we recognize the distinction made by Bell and Hill on the difference between 'operating' and 'change' activities and correspondingly operating capabilities and *change-resources*. Change-resources are what are needed for effecting all kinds of innovations and under this categorization, and more specifically as it relates to technical knowledge, Bell and Hill (1978) locate six elements of change-resources:

1. for executing 'major' innovative activity;
2. for effecting the ripples of necessary adjustments that are introduced into the technical system once an innovation is introduced;
3. for executing 'minor' innovations;
4. for decision making about technical change – for search, identification, specification and evaluation to initiate innovative activity;
5. for effecting technical change involving the replication of known and tested techniques which may, however, be 'new' to the firm;
6. for operation-optimizing, such as pushing the technical efficiency of systems to design limits or even beyond.

The first one constitutes a separate category which exists largely in specialized R&D institutions, while for industrializing and industrialized nations, the remaining five are found within the operating structures of firms rather than within specialized laboratories. It is not necessary to go into the detailed exposition of how each of these elements functions within production systems. Suffice it to say that these change-resources must be present in certain measures for continuous dynamic technical change. Our findings and discussions with firm management reveal that these elements are only present to some degree and deployed to some limited and specific ends in firms with a workforce exceeding 50 employees and much more so within firms with over 100 employees. Affected in particular are processing firms in the brewing and beverages sector who have been the most affected by supply-side constraints of the mid-1980s. These firms have had to adjust relatively quickly to the new economic environment by wide-ranging adjustments to the firms' immediate operating environment. For firms with employees less than 50, these kinds of change-resources hardly exist. Earlier, we offered explanations for the absence of this important growth element. In the large firms, the strategy had been to simply redirect the skills of competent engineers/scientists from purely operational activities to change-activities. In a few cases, collaborations have been forged with national laboratories (outside firm) but more significantly, with overseas partners.

In developed country (DC) and even within advanced developing country (ADC) firms, the presence of a well functioning system of machinery and equipment is taken as given. In other words, analysis of innovation and technical change treats the availability of machinery as parametric. This is an erroneous assumption for the LDCs and certainly for the Nigerian firms which we examined. As we found in earlier sections, a lot of the firms continue to rely on their overseas technical partners for technical advice, spare parts and consumables decades after such firms have been established. Of necessity, capabilities to replicate previously imported machines (element No. 5) is an admixture of human skills and capital goods. This combination was found to be limited in the firms surveyed; this was also the case with the capital goods firms. To date, 85.5% of respondent firms continue to import machinery and equipment wholly from abroad. Some 14.5% of firms, most of which operate in technologically less-intensive areas fabricate their machine parts locally. Capabilities and capacities for maintenance, effecting minor innovations, keeping plants going through ingenious fabrications, adaptations of alternative parts, are preponderant among the less than 50-employee firms who need to survive at all costs in the absence of 'genuine' spare and component parts. Plant optimizing innovations are rare; in fact, none of the innovations surveyed was premised on this particular element.

Another key factor that is ordinarily treated as parametric in the analysis of technical change is the availability of utilities such as electricity, gas, telecommunications and water among other things that constitute the national infrastructure. In this survey, 69% of the firms described the supply of utilities as inadequate, 23.6% rated it as *just adequate*, while only 7.3% considered it to be *adequate*. The adequacy of utilities is important for two main reasons. First, it places an added financial and material burden on firms to provide them when and where they are not enough. From our survey, firms regard the cost of utilities as a major impediment to new investments since for either major plant vintages or even minor plant additions, extra financial provision would have to be made for utilities. Secondly, inadequate national infrastructure makes networking among firms extremely difficult. Transactional costs are high where communications are hindered either by poor telecommunications or frequent power outages. In some cases, linkage is not only made difficult, it is aborted.

For instance, frequent power outages compelled 92.7% of surveyed firms to acquire standby electricity generating sets. Some 5.5% of the firms cannot afford to acquire their own, while 1.8% of the firms share power with nearby firms with excess capacity. The high proportion of private firms with generating sets reveals the poor state of infrastructure and the little confidence industries repose in the public utilities to meet their supply requirements.

The effect of poor infrastructure on routine production activities, and for that reason on change activities, could be very significant. To the extent that technical change is incremental and evolutionary, the availability of infrastructure has become a 'strategic' concern in achieving future comparative advantages. Planning becomes difficult and coordination among economic agents within the national economy, talk less of cooperation with international agents, doubly so. Spontaneous inter-organizational linkages made possible by all purpose infrastructure is a prerequisite for 'networking' – that complex of backward and forward linkages which is taken for granted in dynamic industrial environments. We find that these 'anomalies' seem to redirect adversely the focus of firms. Instead of taking a long-term perspective of 'internal' infrastructure as a component part of a firm's strategic growth process (e.g. skills development, re-training to match new technologies etc.), firms are being compelled to deal with what should essentially be issues of public policy. Firms are also compelled to provide, at great costs, for this public policy failure (through provision of alternatives) and where such options are beyond firms' capacity, they simply give up. Many firms have had to abort innovative undertakings due to such considerations.

For instance, 44% of respondents have had to abandon innovations due to financial problems. Some 42% 'due to other factor inputs' not readily available, 12.7% due to lack of machinery and another 23.6% due to differing unspecified reasons.

In sum, the issues of capacity and capability within firms in a Sub-Saharan African country such as Nigeria need to be broadened to include most of the above-stated reasons. These factors influence significantly the path and process of inventive activities. It is misleading to consider them as fixed factors of technical change.

## 11. Linkages

Linkage can be defined broadly or in a narrow technical sense. In the former, Weiss (1987) defined it as "an inducement to activity on the part of one enterprise created by the action of another". In a narrow technical sense, linkage refers to the network of relationships of productive units, within a framework of intra-industry and inter-industry 'externalities'. 'Externalities', defined as effects created by individual producers or consumers felt elsewhere in the economy, have a very close connotation to linkages. We are more concerned with the more technical dimension of linkages reflected in the Hirschman (1958) conception which identifies two broad categories – the backward and forward linkages. *Backward linkages* refer to the interdependence of an industry on its supply source while *forward linkages* refer to the relationship between industry and its users.

Linkage, as a conception of inter-industry and intra-industry transaction may well take many forms and within the perspective of innovation process, mediated by both 'pecuniary' and 'non-pecuniary' externalities, specifically, technological externalities. Linkage in an a-priori definition of this project considers the potential inter-relation of RDIs (capital goods sector) and process industries within the structure of the Nigerian economy. The transactional forms will therefore be conditioned by the structure of the economy; the internal structure and organizations of firms, the institutions within the industry and consequently, the structural and systemic constraints and limitations at the national, sectoral and firm levels. This has to be since contrary to neoclassical preoccupations, our findings reveal that it is not so much the generation and the quantity of innovations that matters, but the ability of the system of innovation to ensure timely utilization of inventions – in other words, the coupling of the technical and the economic regimes.

Using these proxy measures identified earlier, we found that in the few linkages there were, the greatest interdependencies take place between the small firms (less than 50 and above employees) and public RDIs. The reason is found in their lack of financial capacity to undertake in-house RD&E. Therefore, of the 31% of firms claiming close linkages with RDIs, the greatest number are found in this class of firms. Some 20% of firms which have linkages with tertiary institutions are found among the bigger firms (above 50 employees). The nature of linkage is, however, not of a continuing and sustainable kind. The firms turn to universities for specific projects and in fact to certain individuals known for certain skills in certain areas relevant to the need of the firm. For instance, the crisis of raw materials that compelled local brewers to look inwards in the mid-1980s induced firms to seek collaboration with Nigerian universities in developing alternative processes and in equipment design. There are a few such examples but we did not find any significant long-term collaboration. Some 61.8% of firms claim established business contacts with other firms but this on closer scrutiny may not amount to significant linkage in light of the proxy measures. In monetary terms, the 7.3% of firms that maintain business contacts with overseas technical partners may well constitute the most dominant category. This category embodies the large firms (100 and above employees); the linkage includes in some cases considerable foreign exchange for the purchase of machinery and for payments of technical support fees. From the perspective of fostering indigenous engineering linkages, much of the learning opportunity may be lost where firms, established over 2 to 3 decades ago, have very little technical contact with local firms. The importation of foreign machinery where properly managed could lead to dramatic gains in local technical knowledge but where imported knowledge and machinery is seen as an end in itself, technological learning is foregone and consequently linkage possibilities are lost.

In this study, we found that the structure of the Nigerian economy discourages local interactions and the finding of weak linkages did not much surprise. That Nigerian industry has not moved much beyond primary import substitution may well be due to the failure of policy to foster a dynamic machinery sector. Over and over, we found genuine enthusiasm on the part of firm managers moving beyond rudimentary technical concerns but the shackles of the 'national infrastructure' seem equally formidable to foreclose technical progress.

## 12. Effects of firm structure, organization and the economy

### 12.1. Structure of ownership

Enterprise, firm or RDI behaviour will seem to be influenced by whether they are public- or private-owned – the motivations, work habit and strategic directions follow different patterns.

### 12.2. Structure of the economy

Specifically in relation to innovation, the pertinent factors are the relative proportion of what the economy consists of, that is, multinationals (MNC), small and medium enterprises (SMEs) or family business. We found that RDIs direct their focus mainly to SMEs and tend to emphasize the use of indigenous resources; MNC, unless compelled by law or when they foresee a threat to their present profit or capital base, tend not to consider the use of local resources. These have their R&D and knowledge competence bases in the home economies. Even firms with dominant Nigerian shareholding but with overseas technical partners tend to promote such external links rather than foster indigenous interactions.

### 12.3. The macroeconomic environment

State policies and leadership concerning major macroeconomic variables have a very strong influence on the rate and patterns of the innovation process. Such policies and impressions gathered from this study include:

- policies for technological accumulation derived from the conceptual fixation of policy makers and their advisers;
- industrial policies and system of incentives have strongly conditioned firm behaviour in the areas of training, long-term planning and the like;
- the state of industrial infrastructure such as communications, electricity and so on;

Table 3
Innovations examined in the study

| Innovations | Type and nature of innovation |
| --- | --- |
| 1. Malting of Nigerian sorghum | Process; adaptive, original to firm |
| 2. Beer production from sorghum | Process/product; adaptive, original to firm |
| 3. Starch extraction from sweet potatoes | Process; adaptive; original to firm |
| 4. Production of porcelain insulator/refined kaolin | Process/product; adaptive, original to firm |
| 5. Design, development and production of; | |
| ● cassava processing | plantprocess; incremental |
| ● mini food grinder | product adaptive innovation |
| ● tricycle | product) adaptive innovation |
| ● 3 and 4-wheel-based cars | product) relative to Nigeria [a] |
| 6. Melting furnace | Product; adaptive relative to world, |
| 7. Inoculants | product; adaptive, relative to world standard |
| 8. Cocoa conversion to butter fragrance | product/process; incremental, innovation |
| 9. Guiness malt | product; original to firm, adaptive relative to Nigerian standard |
| 10. Fibre ropes, sheet packings and asbestos gasketing tape | products; adaptive, imitative relative to world standard |
| 11. Use of local molasses | Process; incremental innovation |

[a] An "original" product is one that firms perceived to be new on the market and different compared with that found elsewhere. For instance while a tricycle is not in itself new to the world, firms that put together the local design and fabrication for the first time in Nigeria, consider it "original" to Nigeria. Where firms combine for instance certain varieties of maize and sorghum that is native to Nigeria to produce beer, such firms consider the innovation "original to world".

- institutions are largely shaped by the attitude of the state. For instance, very little store is set on the explicit promotion of interaction among the sub-sectors. If state policy lends support, these sub-sectors may have been better influenced in such a direction.

These statements on the effect of macroeconomic environment should be regarded as impressionistic because they derive from the responses gathered from the microeconomic actors. We did not explore these factors in a systematic manner and our conclusions should be treated as tentative.

### *12.4. Factors internal to the sub-sectors*

We found the following internal factors crucial to successful innovation process – how and in what specific ways they do this is hard to separate.

Table 4
Sources of information leading to innovation

| | Personal contacts | Established business channels | Others |
| --- | --- | --- | --- |
| Frequency | 18 | 37 | – |
| % | 32.7 | 67.3 | – |

- Management type and organizations environment.
- The type, nature, quality of manpower.
- The capital base of firms/institutions.
- The quality of facilities and types.
- The quality of leadership.
- The support of board/management to the technical group.

The next section presents details of these findings.

## 13. Details of research findings

### *13.1. The nature of innovative activities*

See Tables 1 and 2.

In this section, we sought information on the nature and sources of innovation. The nature and character of innovative activities can be described in many ways as presented in Section 4.

The list of innovations examined in this survey is shown in Table 3. The judgement as to whether a product or process was adaptive, incremental, original (in relative terms) or imitative was made by the firms themselves. We of course have evaluated the basis of firms' judgements given our own under-

Table 5
Sources of technology for innovation

| | Parent company | Customers | RDIs suppliers | Machinery R&D efforts | In-house | Others |
|---|---|---|---|---|---|---|
| Frequency | 20 | 12 | 7 | 1 | 29 | 1 |
| % | 36.4 | 21.8 | 12.7 | 1.8 | 52.7 | 1.8 |

Table 6
Factors influencing innovativeness

| | Change to local raw materials | Achievement of greater share of the market | Development of more efficient processes | Response to supply nonstraints request | Market demand/ client |
|---|---|---|---|---|---|
| Frequency | 29 | 7 | 6 | 29 | 16 |
| % | 52.7 | 12.7 | 10.9 | 52.7 | 29.0 |

standing of the industrial environment. [5] In sum, with minor qualifications, the responses seem to conform to our definition of these concepts.

From the survey, the nature of innovations was found to be as follows: [6]

1. Process innovations 28.6%
2. Product innovations 50%
3. Combined product and process 21.4%

1. Adaptive innovation 78.6%
2. Incremental innovation 21.4%

### 13.2. Sources of innovations

Two main sources of information identified as leading to innovation were:

- established business channels – 67.3%;
- personal contacts – 32.7%.

While most of the medium and large firms in Nigeria are technically fully or partly Nigerian-owned, most have long-standing technical and managerial partnership agreements with a number of foreign firms. The source of innovation may therefore be a pointer to the nature of long-term firm collaborative plans. From the survey, the following were given as the sources of technology for the firms' innovations:

- Parent company – 36.4%
- Customers – 21.8%
- Research institutes – 12.7%
- Machinery suppliers – 1.0%
- In-house R&D efforts – 52.7%
- Others – 1.8%

As evident by the percentage responses adding up to more than 100%, firms in certain cases gave more than one source as the origin of innovations. This is as to be expected. Table 4 shows sources of information, while Table 5 shows sources of technology.

### 13.3. Factors affecting decisions to innovate

The most prominent factors affecting the decisions to innovate are supply-side factors. Some 52.7% relate to changes from imported to local raw material inputs which is identified as 'response to supply constraints'. The next important factor is market demand/client requests with 29.0% while 12.7% of the reason to innovate was to achieve greater share of the market. Only about 11.0% embarked on innovations in order to develop a more efficient process (Table 6).

### 13.4. Duration of innovations

From Table 7, 60.0% of innovations took less than 6 months, while 41.8% took between 6 and 12

[5] We based our evaluation of innovations on what the literature says about the particular technology and expert opinion on the relative innovativeness of firms' efforts.

[6] Again the judgement as to whether an innovation was adaptive, incremental or revolutionary was in relation to the firm's own past efforts and capabilities.

Table 7
Duration of innovations

| | < 6 months | 6–12 months | Over 12 months |
|---|---|---|---|
| Frequency | 33 | 21 | 1 |
| % | 60.0 | 41.8 | 1.8 |

Table 8
Sources of machinery and equipment required for innovation

| | Local | Foreign |
|---|---|---|
| Frequency | 8 | 47 |
| % | 14.5 | 85.5 |

Table 9
Sources of finance for innovations

| | Parent company | Firms'own funds | Loan from banks | Others (Govt. allocations, EEC, etc. |
|---|---|---|---|---|
| Frequency | 9 | 41 | 18 | 7 |
| % | 16.4 | 74.5 | 32.8 | 12.7 |

Table 10
Factors militating against successful innovations

| | Lack of finance | Lack of equipment | Lack of raw materials | Others (specify (no response) |
|---|---|---|---|---|
| Frequency | 24 | 7 | 23 | 13 |
| % | 43.6 | 12.7 | 41.8 | 23.6 |

Table 11
Role of utilities in the innovative process

| (a) Adequacy of utilities supply | | | |
|---|---|---|---|
| | Very adequate | Just adequate | Inadequate |
| Frequency | 4 | 13 | 38 |
| % | 7.3 | 23.6 | 69.1 |
| (b) Ownership of electricity generating set | | | |
| | Yes | No | Sourcing additional power from nearby companies |
| Frequency | 51 | 3 | 1 |
| % | 92.7 | 5.5 | 1.8 |
| (c) Usage of firms own generating sets | | | |
| | 10% of the time | Less than 50% | Greater than 50% |
| Frequency | 11 | 22 | 18 |
| % | 21.6 | 43.1 | 35.3 |

Table 12
Linkages for innovations

| | Public RDIs | Universities/ polytechnics | Manufacturing firms | Others (technical partners, EEC, parent companies, individual/clients, etc. |
|---|---|---|---|---|
| Frequency | 17 | 11 | 34 | 4 |
| % | 30.9 | 20.0 | 61.8 | 7.3 |

Table 13
Usefulness of RDIs in the innovative processes

| | Very useful | May be useful | Not useful |
|---|---|---|---|
| Frequency | 29 | 24 | 2 |
| % | 52.7 | 43.6 | 3.7 |

months and 1.8% of the firms could not give specific durations of their innovations. [7]Issues relating to capacities such as machinery, finance, and utilities were discussed fully in previous sections. The details are provided in Tables 8–11.

### *13.5. Linkages*

The issue of linkages (Table 12) among industrial firms, the capital goods sector and RDIs is central to this study. The intensity and nature of linkage were represented by proxy measures such as the:

- utilization of R&D results by industry;
- industry funded research by R&D institutions in areas relevant to industry;
- Joint R&D programmes between firms and between RDIs and firms;
- exchange of technical and research personnel;
- utilization of RDI facilities by industry;
- use of specialized materials or technology of industry by RDIs and vice versa.

The precise monetary significance of inter-firm transactions was difficult to establish, but most firms consider them very crucial Table 13. For instance the early stages of developing an alternative malting process using local varieties of grains benefited from the collaboration of Nigerian Breweries and Guiness with the Institute of Agriculture (Ahmadu Bello University), Zaria. These two firms also worked with FIIRO at the developmental and pilot stages. The mini food grinder was a collaborative project between the Obafemi Awolowo University, Ile-Ife and a private company, Addis Engineering Ltd. This 'pounded yam' machine has become the company's leading product with hundreds of sales made yearly. The only characteristic of these 'linkages' is that they tend to be ad-hoc and project-type rather than sustained institutional cooperation.

## 14. Conclusions

This study came up with a number of observations on the motivations, sources, nature and types of innovation that are undertaken within Nigeria's manufacturing firms. It confirms some of what received theory has to say but threw up further insights particularly about the constraints to innovation and the need to look beyond the known factors that induce innovation in a particular direction in underdeveloped areas. Some of our findings may well apply to other countries but no such definitive claim is made here.

For policy, theory and research purposes, three main issues derive from this study. Firstly, we find that public research institutions (RDIs) interact more intensely with small firms employing less than 50 persons. This category of firms seems to lack, or sees no need to undertake, in-house R&D and therefore relies on RDIs for solutions to bottlenecks rather than developing new products and processes. Most medium scale firms (more than 50 employees) tend to develop foreign linkages (joint ventures or technical partnerships). This is then supplemented with in-house R&D. Secondly, it would seem that greater industrial networking in the form of inter-firm RDI–firm and university–firm linkages would be desirable for innovation efforts. For now, the level of domestic interaction is weak while foreign linkages with medium and large firms is not only strong but has been long-lasting. Greater domestic linkages between process and capital goods firms would likely attenuate the 'lack of factors' (spares, components and so on). Lastly, the innovation efforts have suffered from poor national infrastructure. Firms spend significant proportions of investment capital on basic utilities.

[7] Duration of innovations is the time between when a firm conceived the idea and began to make explicit investment and when it commercialized the process or product. At this point, the product is accepted in the market and the process works.

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