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Technological learning in African industry: a study of engineering firms in Nigeria

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The engineering sector produces a wide array of products and provides significant technological learning avenues. This study examines the process of technological learning in small and medium-sized engineering firms in four Nigerian cities. It identifies the learning mechanisms adopted by firms and the determinants and motivation for investment. The firms studied were mostly set up by semi-literate traders showing that the learning process can take place without formal education or state intervention. Policy may consider assisting entrepreneurs to obtain more formal education to help them to acquire greater technological mastery. Improvements to the poor infrastructure would bring great benefits to small firms.

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CONSIDERABLE PROGRESS has been made towards an understanding of the factors underlying the process of technical change in industry. This was particularly true for developed countries (DCs) until about a decade ago, when attention shifted to the significant progress being made by the newly industrialising countries (NICs) especially India, Brazil and South Korea. The very broad assumptions about the technological category to which countries of the South belong began to change. The export successes of the Asian 'Tigers' and the realisation that industrial progress is undergirded by technological capabilities contributed significantly to a reconceptualisation of the role of technology in poorer countries (Dahlman *et al*, 1987; Westphal *et al*, 1993; Ernst *et al*, 1994).

This paper examines the process of technological learning in African industry. The learning dimension is important because it is the way in which 'follower' countries build up technological capability. For Amsden (1989), learning is a paradigmatic category. The older industrial nations had industrialised through inventions and innovations while countries that industrialised in the 20th century have done so on the basis of "learning to industrialize" Lall (1987). Technological accumulation and the technical change process came about through learning by:

- raising productivity and efficiency of production techniques;
- through adaptive innovations which may lead to a 'new' process or product; and
- through incremental technical change which adds to the endogenous knowledge base, Bell *et al* (1980).

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It is also important to know how learning proceeds, because that tells us what kind of benefits arise from the production process for learning and what resources firms will need to optimise investment in technology. The process of learning has a time dimension and so the learning time is an important variable for technology acquisition. Jacobsson (1993) and Bell *et al* (1984) point to the social cost of fostering infant industries, and the risk inherent in an unlimited learning period. Society bears some cost (subsidies, lost output and so on) when enterprises remain infant for an indefinite period, while the total benefit of protecting infant industries may well risk complete waste if measures are not taken to shorten and optimise the learning period.

This study examines how some private engineering firms in Nigeria are borrowing to learn, and learning to borrow technology (Lundvall, 1988). We surveyed 48 firms but only a few are selected for detailed micro-economic case studies.[1] We also kept the number of variables to a minimum in order to capture fully the important static elements and the dynamic learning process. The study focuses on the nature of technological learning, such as the sequence of learning (if recognisable), the types of accumulated capabilities, the motivation for investment and the rate-determining factors for technical change.

Learning: a conceptual review

Technological learning can be viewed in a broad or specific sense. This study will take a very specific view term as it concerns the ways in which firms go about accumulating technological knowledge. Bell *et al* (1984) identified two categories of learning used in the literature. The first refers to the methods by which a firm, individual or an economy accumulates a set of skills through education, training or experience. This category includes the hiring of skills and the well-known 'learning-by-doing'. The second category is technical change, which has been used interchangeably with learning in the literature. However, technical change does not result only from learning because other inputs are involved.

Lall (1982) suggested three sub-categories of learning which he called elementary, intermediate and advanced.

- Elementary learning includes 'learning by doing' and 'learning by adapting'.
- Intermediate learning consists of 'learning by design' and 'learning by improved design'.
- Advanced learning is 'learning by setting up a complete production system'.

The capital goods industry (CGI) has been the major source of learning and a generator of technical change that is capable of diffusing innovation across all sectors. Apart from the well-known dynamism of the sector in American history (Rosenberg, 1976) evidence from NICs such as India, South Korea and Brazil confirm this assertion (Teubal, 1984; Erber, 1986; Katz, 1986; Jacobsson, 1993). However, one learning variable that distinguishes the process industry from the GCI is the element of design. The mastery of the various degrees of design engineering makes the difference in the metalworking sector.[2]

Successful innovation learning is determined by three subprocesses: scaling, or adjusting imported processes to the technical market conditions; choosing the right materials; and creating an appropriate structural complexity

Process of innovation

The process of innovation in LDCs (less-developed countries) essentially consists of elementary and intermediate learning. In this paper, we conceptualised the process as an evolution towards greater structural and material complexity. This evolution, as suggested by Sahal (1981), is made up of three sub-processes: a disproportionate growth or change in the subsystems; change in the material of construction; and increase in the complexity of its structure. Teitel (1984), Lall (1987) have made the same point. We propose that mastery of these three sub-processes at the firm level constitutes the micro-determinants and the rate-determining steps for successful innovation learning in LDCs. These are:

- *Scale factor*: adjusting imported processes and machinery to the desired technical and market conditions of the environment. Scaling could be towards larger or smaller size. This is exemplified by the evolution to large scale in process industries and the dramatic miniaturisation in the electronics sector.
- *Materials factor*: change in scale factor almost invariably calls for change in materials of construction. Choosing the right materials to replace, for instance, more expensive imports presupposes a knowledge of the metallurgy and materials behaviour. What makes materials substitution difficult is the necessity for good (sometimes fairly elaborate) testing facilities, and, more importantly, the services of the individuals who have the skills and experience not only to test but to carry out the substitution.
- *Structural complexity factor*: when the scale and materials of an object change, structural change almost certainly is introduced. While for the firm

Table 1. A typology of technological learning and capabilities acquisition

Technological capability	Required technological learning
Production capability	Learning by doing: - process production, management, engineering repair and maintenance
Investment capability	Learning by: - bargaining and project identification - doing detailed design - setting-up and commissioning plants - modernising existing plants
Minor change capability	Learning the: - ability to adapt and improve continuously - incremental upgrading of product design and process technology
Strategic marketing capability	Learning by accumulating: - knowledge and skills for collecting market intelligence, for development of new markets and for establishing distribution channels and customer services
Linkage capability	Learning by accumulating: - knowledge, skill and organisational competence to transfer technology within a firm, between firms, and between a firm and the domestic science, technology and engineering infrastructure
Major change capability	Learning by accumulating: - knowledge and skills for creating major changes in the design and core features of products and production processes. It is the learning that culminates in the creation of new technologies

Source: Adapted from Ernst *et al* (1994)

> this might mean a simpler operating system, a unique and altered configuration would have been introduced which may demand very specific skills and materials. It may well be that only a component of the entire system was affected, but as a result, for "functional and geometric" consistency, internal harmony may demand "compulsive sequences" (Rosenberg, 1976).

These factors are particularly important in engineering industries, where the knowledge of design marks the leaders from the laggards. For LDCs, the emergence of mechatronics (the combination of electronics with mechanics) introduces added complexity. "Mechatronics enhances technological co-ordination between processing, assembling and testing" (Imai, 1987) to achieve greater precision, but it calls for added learning and presumably extra innovation expenditure (to train electronics instrument engineers and materials specialists). In addition, whether size evolves to large or small scale, complexity in structure may result.

Table 1 provides a more elaborate typology of technological learning and the capabilities that need to be mastered to attain competence in process and product manufacturing. Acquisition of these six-levels of capability suggested by Ernst *et al* (1994) is mediated by macro-economic determinants which the authors hypothesised as the "incentive system".[3]

Importance of the sector

Two broad factors recommended an investigation of the engineering sector in Nigeria. First, in accordance with the National Input–Output table of 1990, the sector was ranked first in a list of priority sectors to be supported using very tight quantitative criteria (NISER, 1990). Second the engineering industry is of a generic character which engenders learning. For instance, the sector produces heterogeneous products, which tend to increase the probability of technical adaptations.

In addition, the need for process modifications arising from process industries, often of necessity involves the engineering sector. Lastly, the diffusion of skills and knowledge in a user–producer relationship invariably originates from machine tools centres. These factors, among others, promote technological learning because the industry gives rise not only to products but to information, which becomes technical knowledge about products and processes.

Data collection and sample firms

The paper focuses very narrowly on the ways in which firms learn to acquire technology and how they sustain production and improve on imported machinery and processes. Forty-eight engineering firms located within Lagos, Benin City, Ibadan and Nnewi in Nigeria were studied. Three engineering sub-groups were included: basic metal and fabricated metal; electrical and electronics; and automotive components and miscellaneous assembly.

The firms included in the survey were mainly small and medium-sized companies, although less emphasis is put here on size than on technological learning. All the firms were visited using the interview survey method. While a structured questionnaire was completed by the management and engineering personnel, detailed discussions were held with emphasis on the origin, manufacturing start-up, firm competence and firm learning activities. A synthesis of the typical learning paths and technology acquisition strategies of nine representative firms are given.

General information on firms

Of the firms, 90% belong to the small and medium-sized enterprise (SME) category. Firms are categorised by number of employees: small firms have 1–49; medium-sized firms employ 50–199 persons; large firms employ above 200 employees. Some 57.1% of the companies are fully owned by Nigerians while the rest have mixed ownership. While 5.3% of the companies' equipment is less than 5 years old, 15.8% is between 5 and 10 years, 63.2% is between 10 and 20 years, and 15.8% is older than 20 years.

Table 2. Profile of firms in sample

Firm	Firm size	Main products	Ownership
1	S	Aluminium, brass, copper, iron castings	Nigerian
2	S	Aluminium machine spare parts, car alloys, cobalt joints	Nigerian
3	S	Automotive batteries	Nigerian
4	S	Iron sheets, steel products	Mixed
5	S	Rubber products	Nigerian
6	L	Automotive screens and glasses	Nigerian
7	S	Automotive batteries	Nigerian
8	S	Domestic grinders, pounders, motorised and pedal tricycles, food processing equipment	Nigerian
9	L	Utensils, roofing sheets, aluminium, vehicle bodies	Mixed
10	M	Iron rods	Mixed
11	S	Telephone equipment	Nigerian
12	M	Wire nails, welded mesh wire, galvanised products	Mixed
13	S	Tanks, semi-trailer bodies, canopies (steel)	Nigerian
14	S	Winding wires	Nigerian
15	M	Tin packages, metal packages	Mixed
16	M	Trailers, tankers, steel (warehouse)	Mixed
17	S	Metallic bottles	Foreign
18	S	Nails and wire	Mixed
19	S	Aluminium products	Nigerian
20	S	Aluminium products, tiles, industrial materials	Mixed
21	M	Aluminium products	Mixed
22	M	Automotive batteries	Foreign
23	S	Equipment and machinery	Nigerian
24	S	Tanks, fuel tankers, vehicle spare parts, steel products	Mixed
25	S	Tanks, canopies, building materials	Mixed
26	M	Steel pipe, buckets, wire mesh	Foreign
27	S	Electroplating metal, chrome, nickel, zinc, copper and zinc	Mixed
28	S	Milling mills	Nigerian
29	S	Domestic equipment [pots, pans (steel)]	Mixed
30	S	Wire mesh	Mixed
31	M	Palm kernel mills, oil mills, pounders, bakery equipment	Nigerian
32	M	Motor-cycle parts and components	Nigerian
33	S	Copper wire, aluminium wire, earth wire	Mixed
34	M	Cables and hoses	Nigerian
35	M	Motor-cycle and motor engines, roller chains	Nigerian
36	S	Gears, motor bushings, sprockets for machines, mould fabrication	Nigerian
37	L	Motor and motor-cycle batteries, motor spare parts	Nigerian
38	L	Generator engines, motor and motor-cycle parts, film processing machines	Nigerian
39	S	Motor-cycle seats, window louvres	Nigerian
40	M	Motor and motor-cycle spare parts	Nigerian
41	L	Automotive filtersNigerian	
42	M	Motor and motor-cycle engine pistons	Nigerian
43	S	Metal cabinets, machines parts	Nigerian
44	M	Power ropes, fan belts, industrial v-belts	Nigerian
45	S	Feeder pillars, electrical equipment	Mixed
46	S	Exhaust systems	Nigerian
47	S	Oil plant equipment, moulds, topple mills, hammer mills	Nigerian
48	M	Motor spare parts	Nigerian

Note: S = small
M = medium
L = large

Table 3. Sales growth rate by firm size 1990–1994

Size	Percentage growth rate of sales				
	Mean 1990–1994	1991	1992	1993	1994
All firms	–3.2	–3.5	–20.3	4.6	16.0
Small	–2.1	–2.3	–25.4	14.2	11.4
Medium	–1.3	–7.7	–9.9	–8.4	24.7
Large	–12.6	1.5	-27.7	–3.0	16.6

Technical and economic performance

Sales and sales growth rate

Between 1990 and 1994, the firms recorded an average growth rate of –3.2%, although growth differed by size, with medium firms being the best performers, albeit with a negative growth rate of –1.3%. (see Table 3) Considered by product group, growth rates differ significantly. While the electronics/electrical group recorded a mean negative figure of –14.4%, the basic metal group did not fare much better with –11.2%. The automotive components group grew strongly to record a mean of 9.3%.

Capacity utilisation

The mean capacity utilisation rates for all firms (1990–1995) is 44.5%. The rates by firm sizes vary from 38.5% for small firms, 52.7% for medium and 45.5% for large firms. In effect, medium-sized firms performed better than large and small firms. Over time, there was a slight but consistent decline in the overall rates moving from 48.5% in 1990 to 42.7% in 1994. Table 4 shows the evolution of capacity utilisation by firm size.

Investment and technical change

Source of equipment

Firms were asked to indicate what proportion of their equipment was imported: 52.6% imported 81–100% of their machinery, while 26.3% sourced 61–80% of all equipment abroad. Only 19.1% fell into the 1–60%

Table 4. Capacity utilization by size of firm (%)

Year	Small	Medium	Large	Annual average
1990	42.5	55.0	48.5	48.6
1991	41.2	56.6	46.4	48.1
1992	42.8	53.4	45.6	47.2
1993	37.0	50.2	44.0	43.4
1994	35.0	49.7	44.8	42.7
1995	32.3	51.1	43.6	41.8
Firm average	38.5	52.7	45.5	

Table 5. Reasons for investment and technical change

Firm size	Old process improvement	Old product improvement	Different variety of existing products	Capacity expansion	Others
Small	52.3	20.4	–	22.5	20.0
Medium	59	16.3	16.7	18.7	50.0
Large	50	50	75	–	–

range. So the majority of firms, close to 80%, imported between 61% and 100% of their machinery.

Reasons for technical change

The reasons for making investment do not vary significantly among size classes. The majority of firms implemented technical change simply to improve old processes. Innovations for this purpose were carried out by 52.3% of the small firms, 59% of medium and 50% of large firms. While large firms seem to pursue equally changes to old products and old-product improvement, only 16.3% and 20.4% of medium and small firms respectively engaged in such innovation. Of the large firms, 75% invested in innovation to produce different varieties of existing products. Plant capacity expansion was invested in by 22.5% and 18% of small and medium enterprises respectively. This may indicate a significant potential for growth. Table 5 gives the details.

The study sought to establish not only the direction of technical change but the impetus for investing in the kinds of activities in which firms engage. Some 17.6% claimed to want to use indigenous raw materials, 58.8% wanted "to achieve greater plant efficiency" while 23.5% were "responding to market pressures". We wanted to know firms' perception of the product and process changes carried out: 83.3% considered the changes "minor" while 16.7% thought the changes were "major". Our own discussions with engineers in some of the enterprises revealed that, while significant technical changes were indeed being made especially in processes, the activities qualify largely as 'modifications' to existing plant and equipment.

Table 6. Determinants of investment, production and firm growth

Determinants constraints	Frequency (number)	Mild to average (%)	Frequency (number)	Severe to very severe (%)
Finance	22	52.4	20	47.6
Demand	18	57.9	13	42.1
Competition	17	84.0	9	16
Production-related	15	37.0	26	63
Factor inputs	14	31.7	20	68.3
Utilities	15	38.6	28	61.4
Tariff	11	56.1	30	43.9

The context of the responses is important: for instance, small firms rank electrical power as a constraint because of the high unit cost of power by private generation, whereas most of the medium-sized firms have installed generating sets

Determinants and constraints on firms

Table 6 summarises the responses of all firms on the constraints to starting, operating and expanding their businesses. The constraints are grouped into seven categories: credit; demand; competition; production problems; inputs; utilities; and tariff. The table gives the percentage of firms affected by each constraint category, and a ranking by respondents according to the severity of the constraints.

Respondents were asked to rank on a scale of 1 to 5, their perception of the problems: 1 represented 'least severe' and 5 'most severe'. Since we are dealing with different product groups and different firm sizes, scoring a constraint as most severe (5) in one group may be the same as another group ranking the set of problems as average (3). Following Levy (1993), we have normalised the scores, and aggregated and averaged them over the full range of the respondent firms. In the normalised scores therefore, zero (0) means 'not binding' and 1 means 'most binding or most severe'. The scores are given in percentages.

Table 6 shows that finance and non-cost factors constitute obstacles to SME start-up, operation and expansion. Credit is rated more frequently in the 'very severe' category. For instance, the percentage of firms claiming 'severe to very severe' in different categories are:

- credit for raw materials70%
- credit to buy spare parts56.1%
- imported input prices66.7%
- local material prices53.3%

The different credit categories are averaged as one factor in the table.

In all of this, perception of constraints must be interpreted in full consideration of the operating context of the firms. For instance, small firms ranking electrical power as a constraint meant, in most cases, the inability to install their own plants because of the high unit cost of power by private generation. On the other hand, most of the medium-sized firms in our sample have installed heavy-duty generating sets as a matter of necessity. In this case, severity of constraint relates to high operating costs for spare parts, fuel and other related costs. Nonetheless the

Table 7. Summary profile of firms in detailed cast studies

No	Location	Size of employment	Principal products	Time in production (years)	Country source of technology
1	Nnewi	250 (1990)	auto parts, gaskets for motorcycles	7	Taiwan
2	Nnewi	40	switch gear	12	UK
3	Nnewi	–	roller chains, for all auto engines	2	Taiwan
4	Nnewi	160 (1995)	auto tubes, damper	8	Taiwan
5	Nnewi		crumb rubber	4	Taiwan
6	Nnewi	70 (1995)	automotive parts	8	Taiwan
7	Nnewi	120	auto fillers	8	Taiwan
8	Nnewi		auto parts; pistons for automobiles and motorcycles	10	Taiwan
9	Nnewi		auto parts: power ropes	9	Taiwan

normalised scores provide a basis to compare across firm and product classes.

We notice that all classes of firms rate competition as only less than average in severity. Very few of our sample firms export to Europe for instance. However, there is a considerable amount of informal trading and export of components and parts to neighbouring ECOWAS (Economic Community of West African States) countries. The markets in question (Chad, Benin Republic, Togo and Niger) are less demanding in product quality than the domestic Nigerian market. In other words, market context tends to condition a firm's perception. It is most likely that, were enterprises to compete in the export market with more mature foreign firms, their responses would reflect the more stringent requirements of product quality.

Detailed firm-level studies

This section provides detailed findings of the microeconomic studies and a synthesis of the main issues. We have focused on three key elements: the origin of investment in manufacturing technology; the technological learning strategy and mechanism; and the technological capabilities acquired. This very narrow focus permits us to obtain in-depth information about the dynamic learning processes and to permit some theorising about the ways in which firms acquire technological capabilities. In carrying out the detailed study, we chose to focus on a selected number of firms in a particular location, Nnewi, in Eastern Nigeria, for some important reasons. From the study, the macroeconomic survey revealed that firms in this location exhibit certain peculiarities which we felt merit in-depth investigation such as:

- age in production: most were started just before or during SAP (Structural Adjustment Programme);
- the ownership pattern: fully Nigerian, all owned by entrepreneurs of Nnewi origin;
- profile of owner: almost all the founders are illiterate or semi-illiterate traders who moved into manufacturing;
- country of origin of technology: practically all the firms obtained their technology from Taiwan;
- the learning path is uniform: from limited education to trade apprenticeship to trader to manufacturer; and
- all the firms were doing well, while most in Nigeria were folding up between the mid-1980s and early 1990s.

In what follows we examine the selected firms in the light of the static and dynamic factors of capabilities and learning respectively, with a summary of the findings of the detailed case studies of the nine firms.

Origin and investment strategy

Table 7 details the age of firm, source of technology and technical services, and the principal products. The firms studied fall within the SME category, but employ relatively sophisticated technology and produce products that require some measure of technical skill. While the size of investment is small relative to that in developed countries, in Africa they could qualify as capital-intensive at the SME level. The level of investment requires mastery of significant elements of investment capability. As the case studies reveal, the firms in our sample are all in the basic metals and automotive components sectors, where investment requires knowledge of machine tools product design at the early stages, and process and complex products design at later stages.

In all but one of the cases, the road to manufacturing was through trading apprenticeship to importer and finally to manufacturer. All the entrepreneurs raise capital from trading, and thereafter strike a manufacturing partnership with suppliers. None of the founders had previous production experience, except one who had worked with a multi-national corporation and then gone on to establish a business along the same lines.

In the process of trading, the entrepreneurs accumulated considerable experience in their line of business; some in fact sponsored themselves to study the factory operations for a while in Taiwan before making a commitment. Once persuaded, most went ahead to import machinery and equipment. In addition, the services of pertinent engineering personnel were contracted for setting up the plant. While a few did

Sample firms succeeded in acquiring investment, production and minor innovation capabilities in good measure: major innovation capabilities are yet to manifest, since firms are still basically copying and modifying foreign designs

feasibility studies, others simply assumed the existence of a market. Procurement of machinery is sometimes done piecemeal, as capital becomes available, until a whole plant assembly is ready. The pattern of investment is strikingly uniform for all the firms.

Technological learning mechanism

For all the firms, the dominant objective after acquiring the machinery and equipment is to master the production capability thoroughly. Two aspects were particularly prominent: product technology and process technology. Product technological capability is the skill and knowledge to improve product design or to come up with a new design. Process technological capability is the skill and knowledge to do design plant and layout of the assembly line, and undertake quality control and maintenance and industrial engineering.

Most of the firms focused on mastering product capability. Perhaps this is because a hallmark of a firm's competence is the ability to offer the market a product which is as good as, or better than, available alternatives. All the firms have acquired product capability to copy foreign designs, while others are beginning to demonstrate competence for designing new products.

Product modification and the ability to adapt the process to local raw materials is fairly widespread. However, among the elements of process technology, the most widely acquired are quality control, maintenance and industrial engineering. The pattern of firm growth is to vertically integrate in order to keep knowledge and skills in-house. In a few cases there are inevitable horizontal relationships between firms and independent workshops and foundries, but also commonly between suppliers (of raw materials) and firms, and between firms and traders.

The most important mechanism for technological learning is in the beginning, with external training of start-up/pioneering staff undertaken either in Taiwan or on-the-job. In each instance, instruction was given by the foreign technical partner. The majority of start-up staff are semi-literate coming from a trading background and without formal engineering schooling. This training mode is thus very basic and central to a firm's technological capabilities acquisition strategy.

None of the firms received state support for training. On-the-job training during production takes the form of 'close marking'[4] the foreign technical partners. Overall, firms in our sample succeeded in acquiring investment, production and minor innovation capabilities in good measure. Major innovation involving advanced design skills and process capabilities are yet to manifest, since firms are still basically copying and modifying foreign designs.

Conclusions

Manufacturing origin and investment strategy

The majority of the firms studied imported between 61% and 100% of their machinery from abroad. All but a handful of the Nnewi firms imported machinery and equipment from Taiwan. Technical services, both for initial investment and subsequently for production, were foreign. Initial investment was made largely because of the need to exploit perceived market opportunities. For Nnewi entrepreneurs, the origin of manufacturing investment is, without exception, found in trading. All started as traders and once enough capital had been accumulated, they explored technical partnership with a Taiwanese partner. All but one firm had previous manufacturing experience.

The nine Nnewi firms present a particularly interesting phenomenon. Most of them were started just before or during the SAP years. They are all fully owned by Nigerians. The owners constitute a distinct category of previous traders with a common ethnic background (all are of Igbo extraction). The firms are spread over a geographic space that has been transformed into a prosperous economic enclave similar to an industrial district. This study did not set out to examine or explore issues of clustering or networking in a systematic manner, but it would seem that there is some measure of communalism that is cultural and ethnically determined. Whether this potential of proximity has been usefully explored to enhance local efficiency through the use of available knowledge, skills and information remains to be seen. We do know, however, that Nnewi has explored the external linkages profitably through trading and later investment in manufacturing with Taiwan.

Investment capability, which includes searching, sourcing, negotiating, scheduling of investment as well as erection of buildings and civil engineering construction seems to have been well mastered by the firms. Since the technology involved in the civil engineering and structural aspects of construction is relatively uncomplicated and has had a long history in Nigeria, it did not pose much of a problem for Nigerian engineers. It would seem that the entrepreneurs made extra efforts to acquaint themselves with details of the systems either locally or by attachment to suppliers' factories abroad before finalising transfer agreements.

Capabilities acquired

The conceptual framework emphasised the importance of technological learning, which is the way in which firms acquire and build up technical knowledge and competence. Learning represents the dynamic component of the process of the acquisition of capabilities. In this section we discuss the various learning techniques employed by the firms and the nature of the technological capabilities acquired.

A number of broad channels for learning were identified:

- the apprenticeship system of training;
- on-site training at supplier's factory;
- on-the-job training in Nigeria;
- expert contracting;
- support mechanism provided by public institutions;
- learning through transactions with local and external agents;
- learning-by-doing production and maintenance.

At the early stages, most firms rely on the technical expertise of machinery suppliers and set great store by on-site training at the supplier's factory abroad. The period of training ranges between three and nine months and essentially emphasises learning production and maintenance methods. Product technology is often mastered quickly, while process technology (covering the skill and knowledge of plant design, modifying plant layout, quality control, maintenance and industrial engineering) take longer. The process of acquiring knowledge and skills continues with on-the-job training: those who had foreign exposure become trainers to others, while still learning the process technology themselves.

Expert contracting is a common learning channel especially with firms at Nnewi. The contract could last for a short or long time depending on the complexity of the tasks. Long-term relationships sometimes emerge, whereby transactional exchange between Nnewi and the supplier's factory in Taiwan become a loose network for an indefinite time. Services are then paid for as rendered — a sort of 'cash and carry' consulting service. Because most of the start-up staff at Nnewi are semi-literate without formal technical or engineering training, this initial technical instruction becomes extremely important. For this reason, entrepreneurs tend to favour employing their immediate kith and kin, for fear of losing staff who may not be committed to the long-term goals of the firm. 'Close marking' of foreign experts becomes an important technique since the foreigner has a finite time to spend at the factory.

Firms also seem to have gained from visits to the supplier's factory and from exchange with local suppliers, but these tend to be secondary channels. A few have benefited from technical advice and information from external support services but again this tends to be on a limited scale. The kinds of horizontal linkages and sub-contracting relationships that made the Taiwan model a source of inspiration for entrepreneurs at Nnewi has not fully emerged. Firms rely considerably on internal human and machinery assets and so tend to be vertically integrated. Some have acquired special machinery services, such as foundries, to take advantage of economy of scope and to acquire capabilities for minor modifications and maintenance.

Some semblance of R&D is taking place but not in the formal sense. This is particularly so in the area of adaptation of local raw materials where a lot of 'experiments' are being undertaken. For instance, one of the Nnewi firms producing rubber-based products has undertaken major diversification of its product mix through internal as well as external efforts. The firm has achieved 95% by weight in local content and won the Nigerian Industrial Standards Award in the process. Although the company sends samples to Taiwan for quality assurance tests, much of the compositing of inputs is done locally.

In sum, a weak local capital goods capability continues to slow down the full acquisition of major innovation capability. Firms have acquired investment and minor change capabilities in product and process technologies. However, transition to full-scale construction of equipment will have to rely on the support of an external environment and a friendly incentive system that encourages the development of prototypes into full-scale equipment.

Determinants of investment and technical change

The conceptual framework advanced earlier in this study emphasised the role of the incentive system using the framework proposed by Ernst *et al* (1994). Central to this is the dynamics of interaction. For instance, policy is important, but what determines success or failure is policy dynamics. Market forces flow from different sources: factor markets (labour and capital, size and structure of demand, and industry structure). Institutions mediate the functioning of markets and the formation of skills, capital and information. Yet these are relatively weak and underdeveloped in Africa and thus many of the constraints identified by respondents in this study have to do with the supply-side factors: credit, market deficiencies and access to factor inputs.

The study confirmed some of what the literature had cited as being the determinants of firm start-up, growth and dynamic responses, such as learning and acquiring new capabilities. Some of them are:

- The majority of SMEs tend to be limited in their investment behaviour by capital, employee size and skills requirement.
- Initial and start-up capital is quite often provided by personal savings rather than by formal institutions, although there are some exceptions.
- Formal institutional loans to SMEs continue to be scarce; the propensity to grant loans tends to rise with growth in firm size, because of doubts about

repayments and the perceived high costs of 'small' loans.
- Local external support (to the firm) is a secondary source of support for investment and technical change due in the main to weak institutions.

In varying degrees of intensity, firms identified the following as significant determinants of technology development efforts:

Demand-side factors:

- competition: local and foreign;
- factor inputs: access, availability and cost;
- demand: level and pattern;
- markets: evolution of domestic and foreign markets with implications for widespread segmentation;
- changes in factor prices: determines direction of technical change.

Supply-side factors:

- the nature of technology;
- technological information: access, type and quality;
- National level technological capabilities: communication, roads, other utilities;
- finance: credit for investment and working capital;
- education: training (formal and informal);
- stimuli/motivation: profit motive, family contacts and so on.

Suggestions for policy

This paper has examined the learning behaviour of a number of small and medium-sized engineering firms from Nnewi. Nnewi town, a semi-urban town in Southeast Nigeria, is an emergent industrial cluster. Industrialisation at Nnewi has been achieved largely with imported technology from East Asia. A variety of learning modes were employed by the entrepreneurs for acquiring technological capabilities. While the model of industrial development exemplified by the present study is yet to be fully understood and requires more detailed empirical examination, there were some very useful insights. Given our present state of knowledge on the subject, we suggest the following as relevant to policy:

- The group of SMEs in our study consisting almost entirely of semi-literate traders demonstrates that it is possible for industrialisation to take place with minimum state intervention.
- Learning to industrialise at the early stages in the process of technological capability acquisition may take place without much formal education, as demonstrated by the wide variety of mechanisms employed by Nnewi entrepreneurs to assimilate imported technology. Evidence from this study suggests that the process of industrialisation can be 'jump-started' by concentrating state resources on vocational and skills development at the early stages.
- However, at this stage learning has focused largely on acquiring production and minor innovation capabilities. It is likely that advance into more difficult levels may require greater technological mastery and probably greater levels of knowledge. Policy may consider assisting entrepreneurs to acquire more formal education (entirely possible on a part-time basis) to ease the pains of learning.
- The negative effects of poor infrastructure on SME production activities is proportionally more pronounced because of their relatively low investment capital and scale of operation. This is an area in which strong state support is required, to provide well-functioning power, water, communication and transport systems within this and all identified clusters. When state support is targeted at groups of firms 'collective efficiency' and 'economy of agglomeration' is enhanced, in addition to helping firms to produce goods at lower cost.
- While full-scale domestic inter-firm linkages have not fully been developed among the Nnewi firms, there is evidence that some reasonable interaction through inter-firm exchanges is already emerging. There are also, as a result of the common value system — borne out by the strong ethnic affinity of the communities — practices such as informal financing and the apprenticeship system which have been highly instrumental in the growth of Nnewi. There is a need for policy to understand better how the system works and to promote it. This could be done in full consultation with community and business leaders in the area, with the hope of promoting more robust and enduring institutions. The practices in other areas of the country should be studied.
- Finally, this group of entrepreneurs has employed imported technology, largely from Taiwan. It is important to understand why Taiwanese technology and not technology from other countries has been the most appropriate. Policy may also consider assisting the firms to move into new areas by the use of tariff and other measures if firms are to build on the present success.

Notes

1. Of these, nine were selected for in-depth interviews.
2. Design capability entails deeper knowledge of materials by which equipment manufacturers are able to specify machinery parameters. Design has two broad components: detailed and basic. Detailed design specifies product parameters without changing its class or general category. Basic design capability is that required by a firm to specify new products completely; its acquisition may lead a firm to new product or process innovation.
3. The 'incentive system' has three main elements: policy dynamics; market forces; and historical practices of firms. Policy

dynamics describes the way in which policies interact to give rise to different results depending on the context and the timing of their operation. Market forces refer to issues such as the size and nature of the market and the pattern of competition. Historical practices refers to firm evolution and tradition. The concept embodies strong elements of selectivity in policy-making.

4. 'Close marking' is a metaphor employed by one of the firms to describe its learning strategy. This term comes from the game of soccer by which a tough defensive player tries to 'mark out' a dangerous opponent, particularly a striker. This metaphor describes the one-on-one pairing of local and foreign technical personnel during initial training and production.

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