ARTICLES

Knowledge Networks and Technological Capabilities in the African Manufacturing Cluster

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Clusters are characterised by two dynamic elements: the rates and types of technological learning, and the nature and intensity of networking. Firms in early industrialisation are largely imitative innovators drawing on a variety of formal and informal sources such as licensing and reverse engineering. There is, therefore, a significant correlation between firm-level technological capabilities and external knowledge networks. We define a knowledge network as a structure of interlinked actors that facilitate the process of learning in firms and institutions in the process of innovation. This paper identifies emerging knowledge networks in African clusters, illustrating with new empirical data from clusters in Nigeria.[1]

Introduction

NETWORKING CAPABILITY, THE ability of a firm to access and interact with knowledge bases within the national system of innovation, is determined to a large measure, by the firm's technological capability.[2] Among the set of technological capabilities possessed by a firm is linkage capability, the knowledge, skills and experience of a firm to access and learn from

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other agents in the national system, (Ernst et al. 1998). Within the broad spectrum of the innovation continuum there are firms of diverse competences, traditional routines and habits, and, for these reasons, different evolutionary trajectories. For instance, firms in a high-technology cluster, performing frontier research and development (R&D) may engage in intense and continual scientific and technological networks, exchanging information with firms, laboratories and other institutions with similar routines and organisational capabilities. At the other extreme may be found informal enterprises in the traditional sectors that carry out little or no innovation to the extent that they simply do production.

Three broad types of networks may be identified: social, trade/suppliers and knowledge networks. Social networks are created through family, kinship and ethnic ties (Perry 1999). Trade and supplier networks arise from buyer–supplier relations, and have long and sustained historical origins in Africa and Asia (Brautigam 1997, Perry 1999). We define knowledge networks as the structure and interactions of knowledge actors within the national system of innovation. A knowledge network comprises networks agents possessing different technological capabilities, in which core as well as linkage capabilities determine the depth of firms' innovativeness. The forms and intensity of knowledge networks are associated with the knowledge bases within as well as the competitiveness of a cluster. In relatively 'open systems' clusters tend to benefit from competitive learning, while closed knowledge systems 'may be associated with an inability to sustain competitiveness in the long run' (Bell and Albu 1999).

My aim in this paper is to examine emerging knowledge networks in African clusters using relatively recent empirical data from Nigeria. We focus relatively narrowly on those inter-firm linkages that promote innovation, defined broadly as the process by which firms master and implement the design and production of goods and services that are new to them, irrespective of whether they are new to their competitors—domestic or foreign (Ernst et al. 1998). The rest of the paper is structured as follows. In the next section we review the literature on the learning and linkages in clusters found in Africa, followed by a framework for analysing the nexus of internal capability and external knowledge networks. Section two identifies emerging knowledge networks and in-house firm activities, while section three reports in-depth case studies. The last section concludes the paper.

Enterprise Clusters in Africa

Clusters in Africa posses different structural and sectoral attributes, and their levels of capabilities vary widely. The first and most commonly reported are the informal enterprise clusters in the automotive, clothing and garments sectors. Examples include the informal enterprises in the Mathare Valley, Nairobi, auto mechanics in Lagos and Ibadan, Nigeria, blacksmithing in Awka, Nigeria, and grain milling in Burkina Faso (McCormick 1999, Dawson and Oyeyinka 1993, Van Dijk and Rabelloti 1997). The next set of clusters employ relatively higher technical skills and serve a market segment in the higher income bracket. They are a mix of small and medium firms, but largely small enterprises. Notable examples are carpentry in the Suame cluster in Kumasi, Ghana, and footwear makers in Aba and Onitsha, Nigeria (Dawson 1991; Oyelaran-Oyeyinka 1997a, 1997b). At a higher level still are clusters that manufacture more specialised products employing relatively more sophisticated technologies. They are distinguished by their greater subcontracting, more extensive local and global trade, and production linkages. The ones reported in the literature include the Nnewi cluster in eastern Nigeria, the clothing producers in the Witwatersrand in South Africa, and the Lagos clusters (Oyelaran-Oyeyinka 2001, Rogerson 2001).

Network cluster capability is as much a function of firm size as it is of its core capabilities. Small firms that posses the most basic technological capabilities are likely to exhibit limited domestic and probably very weak or no regional and global linkages. Learning in this kind of firm is through apprenticeship, and knowledge bases tend to be tacit and locked in within a craft-based sector (UNCTAD 1994, Valenchik 1995). Small, more dynamic to medium firms tend to engage in greater supplier and trade networking and posses higher levels of production capability. Learning is from both tacit and codified knowledge bases as they tend to be more open to external sources of knowledge. Larger firms are engaged in greater subcontracting and have acquired higher linkage capabilities.

Attempts to provide taxonomy of clusters, given the diversity of experiences, particularly in developing countries, are on going. Pedersen (1997) identified two types. The first is the diversified industrial cluster, characterised by vertical specialisation of individual enterprises and vertical diversity of the cluster as a whole. In this cluster there is a broad sectoral specialisation, but within the sector individual enterprises and the cluster

as a whole are not narrowly and horizontally specialised. Efficiency gains depend on collaboration within and outside the cluster. The second type is the subcontractor cluster, characterised by a narrow vertical and horizontal specialisation by both individual enterprises and the cluster as a whole. Its collective efficiency derives from reduced transaction costs due to reliance on larger firms as subcontractors. Amin (1994) identifies three generic kinds: craft-based, artisinal or traditional sector industrial clusters (for example, footwear, garment making and metalworking); high-tech clusters (for example, Silicon Valley); and clusters based on interaction of large and small firms. This is similar to Pedersen's subcontractor cluster. Mytelka and Farinelli (2000) provide a functional categorisation of clusters that are either public-induced or constructed clusters, such as industrial estates and EPZs, or spontaneous clusters that could be informal, organised or innovative (Table 1).[3] Low levels of inter-firm linkages characterise informal clusters, but organised clusters have advanced somewhat in this respect. There is relatively greater networking within and outside their national borders, as exemplified by the firms in Nnewi and the surgical instruments cluster in Sialkot, Pakistan. In what follows we provide a framework that classifies clusters using the combined attributes of technological capabilities and knowledge network capabilities.

TABLE 1
Firm-level Scientific and Technical Functions

	In-house functions		*Scientific & technical functions within firms*			
Cluster strategy	*Applied research*	*Experimental development*	*Design engineering*	*Production engineering and quality control*	*Technical services and training*	*Product forecasting and product development*
Dynamic (imitative)	2	3	4	5	3	3
Emergent (dependent)	1	2	3	5	2	3
Static (traditional)	1	1	1	5	1	1

Source: Adapted from Freeman and Soete (1997).
Notes: 1 = weak or non-existent; 5 = very strong.

Learning, Clusters and Knowledge Networks: A Framework

An industrial cluster is a dense sectoral and geographical concentration of enterprises comprising manufacturers, suppliers, users and traders. A cluster is not simply a geographic phenomenon. Inter-firm interaction and sectoral specialisation are the defining features of a sustainable cluster (Nadvi and Schmitz 1994).

Clusters are characterised by two dynamic elements: the rate and type of technological learning, and the nature and intensity of linkages or networking. Small and medium enterprises (SMEs) in early industrialisation are largely imitative innovators drawing on a variety of market mechanisms or formal sources such as joint ventures, licensing and informal sources like reverse engineering and learning by doing (Kim 1997). As is widely reported in the literature, while these categories of firms may not engage in frontier technologies, the dynamic and evolutionary technical change processes in which they are engaged constitute important sources of learning and do lead to substantial productivity growth (Bell and Pavitt) 1993, Mytelka 2000, Ernst et al. 1998).

An imitative innovation strategy in the African or any context demands considerable explicit efforts on the part of firms, and the process of modifying processes and products leads firms on an uncertain but a learning and competitive trajectory. In this paper we make the proposition that the most competent firms in Africa are technological imitators that import, modify and adapt technologies. Freeman and Soete (1997) identified and rated firm-level activities within a spectrum of the innovation process. In an adaptation of the innovation strategies framework proposed by Freeman and Soete, we suggest that small and medium firms in Africa carry out the six functions listed in Table 1. We identify three categories of enterprise clusters, which are dynamic, emergent and static. Table 1 and Figure 1 are combined to elaborate the firm's technological capability with network capability in three quadrants that are fluid tendencies and tend to change over time since we deal with dynamic agents. We suggest that dynamic clusters are successful dynamic imitators, whereas emergent clusters adopt a dependent strategy and tend to react to threats rather than voluntarily imitate and innovative. Static clusters prefer a traditional strategy of non-innovative adoption of production technology. None of the clusters in Africa could be classified as an advanced cluster, quadrant A. We provide further elaboration in Table 2.

FIGURE 1
Evolution of Knowledge Network in Clusters

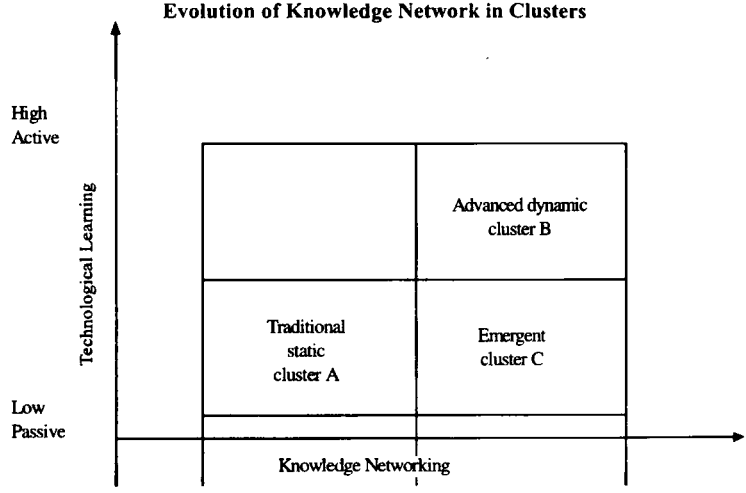

TABLE 2
Typology of Knowledge Networks in Clusters

Quadrant	*Cluster description*	*Network transaction*	*Product/market*
D	Advanced cluster; high rate of learning & knowledge creation	Knowledge networking (H); technological learning (H); R&D intensive	High product specialisation & complexity; globally competitive; global linkages (H)
C	Dynamic cluster	Knowledge networking (A); imitative innovation; propensity strong linkage capability	Competitive global/domestic; growing product specialisation; emerging global but strong domestic linkages
B	Emergent cluster	Knowledge network (L); imitative innovation & learning; average linkage capability largely domestic	Locally competitive; low global but average domestic linkages
A	Static/ Traditional	Knowledge networking (N); poor learning; supplier networking; mainly agglomerative benefits; very weak linkage; capability	Not competitive; may be declining

Notes: H = high; A = average; L = low; N = none.
Source: Compiled by author.

In addition to internal firm-level capabilities, firms need to develop network capabilities for a number of reasons. First, competitive pressures, which alter the nature of markets and the required technical conditions, induce firms to reach for knowledge bases outside of themselves in order to reinforce extant sources in-house. Second, growing firms need to re-invent themselves through the acquisition of new skills and new knowledge and technical information. Third, the need to honour obligational relationships, for instance, in a subcontracting or supplier relationship, compels firms to develop linkage capacity for feedback on products and services. In sum, a knowledge network with which this paper is concerned enhances a firms ability for production and process innovation. Reasons for the formation of knowledge networks will vary a great deal depending on the technological capability and strategic focus of firms, the extent and type of market segments and product, and the structural characteristics of network agents within the national system of innovation.

Emerging Knowledge Networks

The paper reports findings from a study on two clusters (Ikeja and Isolo) in Lagos, Nigeria, carried out in 2000. The two clusters fall within our definition of emergent clusters, albeit at the low end of this cluster type. The clusters evolved partly from policy promotion, but also naturally evolved over time. In other words, while these clusters would not compare with European types with strong networks, they, however, fulfil the spatial agglomeration, and partly subcontracting and collaboration criteria. Fifty out of seventy-five firms responded in the study that employed survey questionnaires combined with in-depth interviews. Lagos, with a population close to 7 million, is home to about 60 per cent of all manufacturing firms in Nigeria, and is well served by a large port, and relatively big and sophisticated market. The dominant products in the two clusters are fabricated metals (ISIC [International Standards Industrial Classification] 381), rubber and rubber products (ISIC 351–56).

We found the following forms of interactions among firms: linkage with input suppliers (raw materials); linkage with machinery and equipment makers; linkage with spares and component suppliers; and linkage with private maintenance firms (Table 3). Firms also engage in subcontracting networking.

TABLE 3
Networking with Input Suppliers (%)

Inputs	*Sources*	
	Domestic	*Foreign*
Raw material	62.9	37.1
Machines		
New	42.5	57.5
Second-hand	33.3	66.7

Sources: Oyelaran-Oyeyinka (2001).

Linkage with Input Suppliers

This is a critical network for most SMEs since much of firm's efforts are directed at exploiting the comparative advantage of local raw materials, a strategy long encouraged by various Nigerian governments. Firms were given incentives to substitute local materials for imports by the establishment of, among others, the National Economic Reconstruction Fund (NERFUND) in the mid-1980s. The eligibility criteria for access to the Fund was to set up process plants that utilise 100 per cent domestic inputs. This policy encouraged the establishment of firms, many of which are in sustained input user–supplier networks, with 62.9 per cent of respondents sourcing raw materials locally. While small firms tend to rely on raw materials suppliers for 'doorstep' delivery, medium-sized firms make their own transport arrangements. Both small and medium firms receive significant proportions of inputs in processed forms. Up to 37.1 per cent of the imports are components made from special metals, electric motors, other electrical and electronic components that are not easily manufactured in Nigeria due to a combination of scale economy disincentives and engineering complexity. These imported parts are then coupled with locally fabricated ones. Over 90 per cent of firms claim that they are satisfied with the quantity and quality of local inputs, a measure of the capability of suppliers to meet user standards. Most firms realise that the basis for competition has changed, and a new market orientation is needed. Evidently, inherited practices and attitudes are hard to change, but changes to the process and technical characteristics, originally tailored to domestic production and consumption patterns, will have to be made. This study did not systematically pursue the response of firms to competitive pressures, but the often changing policy of the government and the promotion of economic nationalism (through substitution of local raw

materials) on the one hand, while embracing wide-scale liberalisation and on the other, were cited repeatedly by firms as contradictory.

Linkage with Machinery and Equipment Suppliers

About 43 per cent of firms obtained new machines needed in the domestic market, while 58 per cent imported machines from external sources. The 33.3 per cent that depend on second-hand machines source them locally, while 66.7 per cent import from foreign sources. Much of the transactions take place within the clusters, but it is difficult to put a precise figure on the volume of such transactions. While countries discriminate against used machines through trade restrictions, there are strong arguments in its favour, particularly in low-income countries where low wages and technological learning imperatives make them attractive. The optimal scale of older machines make them more appropriate to the small markets of developing countries, and greater flexibility in use and the likelihood of familiarity of workers make vintage technology suitable for SMEs in Africa. New machines are, however, superior to used ones in three important ways (Navaretti et al. 2001): (*a*) old machines are likely to suffer more frequent breakdowns and therefore increase idle time; (*b*) they are less productive; and (*c*) finally, labour-intensive machines require greater craft (hand skills) than more automated machines. However, due to high interest rates and the high cost of sourcing foreign exchange, firms are likely to prefer used machines wherever they can find them, in spite of the risk of greater downtime and idle capacity. As Navaretti et al. observed, firms are reluctant to move into high-tech technologies because of the cost of investment in training to acquire the requisite skills to operate new and presumably more complex plants. Firms tend to slide down the productivity path when appropriate skills are not available to use new and modern machines.

As shown in Table 4, the key information sources for firm production and innovation are machinery suppliers, exhibition and trade fairs, client firms, publications and repair workshops (foundries and heat treatment shops). Other sources include staff of other firms, social and professional associations and consultancy firms within and outside the clusters. Firms confirm that some of the contact have been long lasting, while some are one-off interactions. The proximity factor, which co-location in the clusters engenders, tends to promote faster response to service demands. The

most enduring linkages are with machinery makers to which they return for production troubleshooting, while machine makers also tend to cherish the user–producer relation with clients. The dominant forms of inter-firm linkages tend to be of the market with suppliers and manufacturers that are located within clusters.

TABLE 4
Sources of Information for Production and Innovations

	Responses			
Sources	*Often*	*Occassionally*	*Never*	*Total*
Social/professional/associations	11.0	56.0	33.0	100
Export agents	2.2	60.8	37.0	100
Machinery suppliers	27.6	62.1	10.3	100
Exhibitions/fairs	27.7	63.1	9.2	100
Repair workshops	14.0	60.5	25.5	100
Client firms	23.1	34.6	42.3	100

Sources: Oyelaran-Oyeyinka (2001).

Linkage with Repairs and Maintenance Organisations

Firms depend largely on in-house engineers and technicians for minor repairs of machinery and equipment, but major repairs are contracted to independent machine shops with machine facilities such as founding and heat treatment. There is a growing relationship with public institutions and universities, especially for design of difficult parts and for testing of material.[4] This is due to the increasing commercialisation of university services as a result of which a number of 'university consultancies' have become more aggressive in marketing their capabilities. Another phenomenon is the substantial numbers of university 'outreaches', by which universities in all parts of the country now have 'study centres' in Lagos, Nigeria's commercial hub.[5] This may well have promoted greater interaction due to proximity of knowledge sources to firms since one of the major complaints of entrepreneurs had been lack of 'access' to knowledge sources. Maintenance and repairs are often joined with parts replacement. Some medium-sized firms have captive foundries (for in-house use), but due to undercapacity firms tend to use it as a profit centre for undertaking repairs and maintenance jobs for those that do not have such facilities. Independent or 'jobbing' foundries in particular have become relatively more sophisticated. The Foundry Association of Nigeria (FAN) has become an influential organisation that bids for big government contracts on behalf of its members.[6] FAN has members among the machinery

makers of Ikeja and Isolo, and as such knowledge networking is observed at several levels.

Subcontracting Relationships

Subcontracting refers to user–producer relations, a form of non-equity arrangement between firms in which goods and services are provided according to the specifications of the user. This mode of inter-firm linkage often demands communication and consultation, and in most cases leads to obligational relationships (Perry 1999). How much firms externalise their activities is subject to a number of factors, from the level of production know-how outside the firm, to the need for specialised intermediate inputs and cost reduction. The need for supply security, in timeliness and quality, and the decision on the choice of local as opposed to distant suppliers, particularly for low-volume supplies, play a part in firms' decisions in underdeveloped economies. A number of the SMEs in these two clusters subcontract aspects of productions relating to non-core operations such as packaging, labelling, printing and production of bulk materials. About 68 per cent of those who subcontract do so because of the greater efficiency of the subcontractors, a recognition of the role of specialists, while 10 per cent do so because of irregular demand. Cost savings by reducing inventory costs and the lower wages paid to subcontractors (16 per cent) are additional reasons for subcontracting (Table 5). Far more than before there seems to be a growing user–producer interaction developing among firms in these clusters. While 39 per cent of subcontractors approach SMEs on process-related problems, over 80 per cent do so in respect of product improvements. This might point to a new and important phenomenon of firms collaboration and learning from one another, far more than we found in a previous study (Oyelaran-Oyeyinka et al. 1996).

TABLE 5
Reasons for Subcontracting

Reasons	*Total (%)*
Irregular or low demand	9.7
Savings on inventory	6.5
Greater efficiency of subcontractor	67.9
Lower costs of subcontractors	16.1
Total	100

Source: Oyelaran-Oyeyinka (2001).

Linkage with Consulting Organisations and Other Networks

Management and technical training, as well as accounting functions, are routinely contracted to consultancy firms within and outside the clusters. Legal, management and technical consulting services such as specialised quality assurance services are provided in the main by private firms within and outside the local area.

In addition to the above linkages, we sought to establish the overall pattern of cooperation among firms. In all 24 per cent confirmed formal collaboration with consulting firms, a significant figure given the tendency of firms in Africa for secrecy. Nigerian entrepreneurs are notoriously individualistic, always seeking to protect trade secrets. In specific terms, 25, 26 and 37 per cent collaborate with others in product development, marketing and in purchasing inputs respectively. Core engineering activities predictably are carried out in-house, although this is a pattern not peculiar to Africa.

We sought firms' perception on the levels of collaboration, and this tended to be significant in sharing the burden of utilities, which 34 per cent rated as 'high' and 17 per cent as 'average'. There is also joint action in security and environmental enforcement, the former an important issue necessary for the protection of factory facilities and warehouses. Some of the factories are located far from residential areas and security can be very expensive in the absence or inadequate provision of state protection. Exchange of ideas on common problems, and visits to factory sites of collaborators and rivals alike are growing forms of firm collaboration. Proximity tends to engender inter-firm linkages. For instance, the repair function, which firms consider absolutely key to production, is carried out by 34 per cent of firms within the clusters, while only 10.5 are by outside agents. Product development, legal services, and management and technical consultancy are handled by 24, 63 and 59 per cent of firms within the cluster respectively. This is consistent with theory and, as Stiglitz (1987) observed, being in the right place with the right idea gives firms the advantage over followers. Being in a position to take advantage of any spillovers gives neighbouring firms an advantage over more distant firms.

Table 6 shows the relative weight assigned to the types of collaboration by firms. Sharing of utilities and joint security arrangements seem the most important non-core activities. Geographic proximity is demonstrably critical to knowledge networking. In all 33.7 per cent contract

maintenance to firms because of proximity, while only 10.6 per cent do so to firms outside the cluster. However, the source of skilled labour is largely outside the cluster, as 79 per cent of firms recruit from outside the cluster as labour 'poaching' is frowned upon (Table 7).

TABLE 6
Ratings by Firms of Horizontal Collaboration among Enterprises

	Frequency (%)			
Types of collaboration	*High*	*Average*	*Low*	*Linkage index*
Sharing of utilities (electricity)	33.9	16.9	49.2	2.19
Sharing of tools machines	7.7	19.2	73.1	1.42
Security and environmental enforcement	39.3	41.4	19.3	2.60
Joint savings and credit schemes	4.0	6.0	90.0	1.18
Training/apprenticeship	4.6	25.6	69.8	1.39
Joint sourcing of materials	4.0	78.4	17.6	1.90
Joint marketing	2.3	75.0	22.7	1.75
Joint purchases of expensive equipment	–	20.4	79.6	1.2

Source: Oyelaran-Oyeyinka (2001).
Notes: is weighted and normalised. 4 = high, 2 = average and 1 = low.

TABLE 7
Proximity as a Determinant of Inter-firm Cooperation

	In-plant		*Firms within clusters*		*Firms outside clusters*	
Type of services	*Frequency*	*%*	*Frequency*	*%*	*Frequency*	*%*
Repair of machinery	30	55.8	17	33.7	5	10.5
Source of labour	39	78.9	2	4.2	8	16.8
Product development	37	73.7	12	24.2	–	–
Accounting function	37	73.7	8	9.5	8	16.8
Legal services	4	8.4	32	63.2	19	38.4
Staff training	29	58.9	6	12.6	14	28.4
Management technical consultancy services	9	18.9	29	58.9	11	22.1

Source: Oyelaran-Oyeyinka (2001).

In order to explore further the links between networks and in-house technological capabilities, we conducted a number of case studies among the firms, the subject of the next section.

Case Studies

Process Innovation, Product Specialisation and the Nature of the Market

Further insights emerged from in-depth interviews with five firms selected on the basis of their reputations as leaders in the sector. However, the percentages in this section refer to the whole sample of fifty firms Three of the firms started out as agro-processing machinery makers, while the other two had planned to specialise in structural engineering products. As in the broader survey, all five of these firms had adequate complements of graduate engineers and technicians. Close to 60 per cent of firms used second-hand machinery, but had acquired considerable mastery of their equipment.

They were all in the main, imitative innovators. Twenty per cent claimed to have adapted original processes internally, with 12 per cent cooperating with external repair organisations in doing this. Firms seemed more competent in product innovation and 57 per cent had carried out product innovation, although the degree and depth of innovativeness may be debatable, and the products were evidently new to the firm. Based on these responses and in-depth interviews, we sought to place the firms in clusters within the cluster quadrants. We match four of the hypothesised activities of firms with firm responses using the assigned figures. We tested using simple weighed means for quadrants B and C, the dynamic and emergent categories, where we expected the clusters to fit.

Table 8 shows the result of our simple averages calculations. For instance, 20 per cent of firms undertake some applied research (mainly developmental work), most firms engage in product/process design (60 per cent) and 100 per cent do production, while 57 per cent engage in product development. If we assume a dynamic cluster category, the score is 68 per cent while it is 72.5 per cent if weighted scores are calculated based on an emergent cluster. In other words, these clusters are certainly not static and are far above an average emergent cluster, tending more to a dynamic cluster. These simple calculations are understood to be highly context specific, and reflect dynamic tendencies. Since these are averages, some firms within might be highly developed, while others may tend to be average. What the exercise reveals are indicative of how we might in the future systematically provide empirical justification for cluster capabilities and their knowledge networking propensities.

TABLE 8
Rating Firm-level Technical Functions*

	Applied research	*Process and product design*	*Production and quality*	*Product development*	*Weighted mean*
Per cent performing	20	60	100	57	
Emergent cluster assumed	0.2	1.8	5.0	1.7	8.7 (72.5%)
Dynamic cluster assumed	0.4	2.4	5.0	1.71	9.51 (68%)

Note: *The percentages refer to the whole sample.

We sought to know from the firms whether internal technological constraints induced observed firm knowledge networking and whether product diversification, which was prevalent, was market induced. In what follows, we discuss the responses of firms under three headings. Table 9 shows firm characteristics and market orientation.

Market Size

According to the firms, demand for specific products have slowed and due to the non-perishable nature of engineering materials it is unrealistic to expect sales of the same products on a continual basis in a regime of low economic growth rate. This kind of answer reflects the domestic market orientation of these firms, most of which have earned decent profit in the past by exploring the large but rather limited, low-quality segments of the Nigerian market. Low growth rate in demand forced them into production of other products easily handled by their extant facilities to reduce idle time and to engage otherwise idle engineers and generate revenue. Most firms attribute slow growth to reduced consumer incomes as a result of devaluation, and in some cases firms in fact claim to have reduced material quality to save costs in order to meet the kind of price levels affordable by customers. Market size is also limited by poor marketing strategy since most firms rely on pamphlets and trade fairs to advertise their products. Market demand, more than any reason, was the main factor inducing external knowledge networks.

TABLE 9
Selected Firms: Nature of Innovation and Market Orientation

Firm (size, year established)	*Product mix and technology (selected)*	*Reasons for market orientation*
F1 (medium sized, 1990)	Imitative and dynamic adaptations: briquetting machine; ice-block making machine; domestic cold room for fish; toilet roll making machine.	Exports to Ghana, Benin and Cameroon. 'Don't put your eggs in one basket'. Low market demand for single product.
F2 (medium sized, 1991)	Imitative, and dynamic adaptations: palm nutcracker; auto candle-making machine; hammer mills; cosmetic product plant; cold stores; bakery oven.	Diversification because of idle capacity, low demand for the product. Established a training centre in collaboration with a Nigerian university. Exports to West African Countries.
F3 (medium sized, 1995)	Imitative, dynamic adaptations: cassava and instant yam tablet plant; palm kernel oil extraction plant; automatic water processing plant; soap making plant.	Specialises in agro-industrial equipment fabrication. Has networks all over Nigeria. Exports to the sub-region.
F4 (medium sized, 1992)	Imitative, dynamic adaptations: underground fuel and water tanks; automatic sachet water and filling machines.	Diverse products. Firm specialises in civil and structural products and has a team of skilled engineers. We have 'the ability to follow the dynamics of the trade which gives us advantage over our competitors.
F5 (medium sized, 1973)	Imitative, dynamic adaptations: steel structures; underground fuel tank; motor body building, electric poles.	Firm has two facilities connected with oil marketers, state governments and hotels.

Source: Oyelaran-Oyeyinka (2001).

Nature of Production and Product Type

Engineering production industries could be just as vertically integrated as process industries (such as refining), but the former is much more amenable to discreet operations or batch operations. This is the origin of small jobbing shops such as forges, foundry and heat treatment, and it is largely for this reason that engineering industries are populated by large numbers of small firms. The propensity for multi-products production is high because of the complementarity of skills, a manifestation of technological convergence.[7] Firms, therefore, capitalise on available facilities to produce different kinds of products because 'the facility is available'. Machine makers in our sample fabricate bakery ovens as readily as palm kernel nutcrackers since they are all agro-processing products. These so-called concurrent scale economies benefit firms in keeping plants running, but slow enterprise movement towards product specialisation. It also leads to the issue of underemployment of skills, which we examine next.

Skills Implication of High Vertical Integration

Machinery and component manufacturers in our sample exhibit behaviour consistent with the pattern in developing countries. The tendency to widen the product mix implies that the proportions of parts for machining and fabrication is multiplied. Since firms are unable to keep, and in fact unwilling to employ, and train technicians for every separate process, individuals are made to master several unit operations. On the contrary, in a regime of high rates of outputs for single products, there is division of labour that in turn facilitates technical learning, and makes full use of the knowledge, skills and experience of engineers and technicians. Amsden (1985) suggests that faster growth rates lead to productivity gains for three reasons. First, greater economies of scale and specialisation; second, more investment embodying new technologies; and, third, technological learning about production processes. The overall effect is the accumulation of tacit technological capability because technology advances when the growth rate of demand accelerates. Importantly, as firms grow in sophistication, better use is made of engineers' theoretical knowledge and the two components of machinery manufacture—machining and assembling—begin to receive greater but differentiated attention. Firms then produce higher-quality products as product specialisation grows, capacity utilisation also grows and unit cost drops. The particular

phenomenon we find in these firms and our discussions with engineers show that their skills are under-utilised.

A recent survey of firms in food processing (Adeoti 2001) confirms the relatively high local 'skills intensity' of the sector relative to textiles, for instance.[8] While the figure for food processing, owned largely by Nigerians, is 0.714, that for textiles, dominated by Asians, is 0.135. In the Lagos clusters a high proportion of owners have university education. It is likely that given the skills intensity of these firms, engineers and technicians will have been able to meet the competitive pressures arising from demand for high-quality products. In other words, specialisation has not been promoted because 'the division of labour is not only limited by size and growth rates of the market but also by *type*' (Amsden 1977). The path to higher-quality competitive products demanded in the export markets is not helped by the pattern of demand and production found in low-income economies. In effect, poor subcontracting of core activities and the resulting lack of specialisation due to the size, growth rates and type of markets may result in underemployment of skilled labour or a stifling of progress towards local creation of higher engineering skills. The types and nature of linkage arrangements between firms and subcontractors include advance payment, and organisation of production and transportation of parts or products. When subcontractors breach agreement (for example, delivery of poor-quality goods), the contracting firm often requests that the job be redone and at times offer supervisory assistance.

Conclusions

The study examined the nature and intensity of networks and firm linkages, such as subcontracting, as knowledge bases for long-term sustainable development of clusters in Nigeria. Greater subcontracting tends to deepen local inter-firm linkages, where we assume subcontracting to be an important type of contractual linkage. We also found greater propensity for collaboration among firms in the metropolitan clusters induced in part by the need to lower transaction costs, although these are limited to non-core firm activities. Firms still undertake most of their production activities in-house. We conclude that the Lagos clusters fall within the emergent and dynamic cluster categories. There classifications and relative tendencies are context specific. In the main, there are a number of specific and important findings from the study with implications for industrial policy.

First, the clusters have relatively high levels of educated entrepreneurs and skilled workers. Due to the type of market that allows firms to produce and sell relatively unsophisticated products, it will seem that higher skill levels may not be exploited in the short term. Firms rarely engage in R&D, but product and process improvements are continually undertaken by factory staff, relying on experience rather than new forms of knowledge. However, what low educational attainment would mean for the long term development and competitiveness of clusters remains unclear.

Second, the role of subcontracting core activities that foster specialisation is still constrained by lack of demand. The size of the market, the growth rates and type of market, that is, between the low-income domestic and high-quality competitive export market, call forth greater levels of technological skills, and in the process lead to greater learning and technological capability acquisition. Technical, market and financial support to clusters remain weak or unavailable. Third, geographic proximity is important to sustained knowledge networks. Being present within a cluster in a metropolitan environment of Lagos tend to promote greater networking than in a rural cluster such as Nnewi, where inter-firm linkage is weak (Oyelaran-Oyeyinka 2001). Knowledge spillover is more pronounced between agents in a cluster than between those external to it, although we found that social norms delimit some benefits of agglomeration. For instance, the presence of skilled labour in a cluster does not guarantee costless 'poaching' of skills by rivals, an activity considered traditionally unethical. Also, although we did not collect systematic data on this, knowledge networks are significantly related to firm-level technological capability. As Mytelka (2000) observes, actor competence is intrinsically linked with the traditional habits and practices of firms, which inevitably defines the domestic and global reach and intensity of firms' linkages.

There are general and specific policy implications from this study, but the suggestions here are made in very general terms and are by no means uniformly applicable to all clusters in Africa. First, the clusters are largely medium sized, with potential for considerable capabilities acquisition. They carry out manufacturing with relatively sophisticated technologies. They are as such not the stereotypical micro enterprises for which Africa is known. Second, some firms sell into the export market, albeit in the region, and have the potential to expand production, but are severely limited by poor public goods delivery—water, power supply and telephone—facilities that are parametric for goods made by foreign firms, with which they compete in the domestic market. Third, firms in

the cluster are owned by individual who are resourceful and educated, with a full compliment of skilled workers. Firm dynamism tends to be limited by market type and size. The role of policy, therefore, appears evident, but in reality complicated. To start with, the provision of basic infrastructure should be made a priority in industrial clusters. In addition, real services provision, such as training, quality assurance and control, should receive state assistance in collaboration with trade and professional associations. A full range of technical, financial and marketing support services should be studied and adapted for clusters with the objective of making them competitive, both locally and globally. The role of education, not limited to formal training, should be examined for both urban and metropolitan clusters. Finally, firms grow when markets expand and, more importantly, when income levels are able to sustain high-quality consumer goods. Policies to promote greater purchasing power of consumers should be seen in the light of enterprise promotion, leading to the evolution of higher levels of subcontracting and specialisation.

NOTES

1. The study draws partly on a UNU/INTECH discussion paper titled 'Networks and Linkages in African Manufacturing Clusters: A Nigerian Case Study' (Oyelaran-Oyeyinka 2001). I am grateful to Anthony Bartzokas and Lynn Mytelka on earlier version as well as an anonymous reviewer for useful suggestions on the journal version.
2. A system of innovation is made up of a network of agents in interaction with the institutions and policies that condition their innovative behaviour (Freeman 1987; Lundvall 1992).
3. Most clusters in developing countries fall into the informal and organised type categories. Informal clusters generally contain micro and small firms whose technologies are far from the frontier, and have relatively low technological capabilities. Organised clusters have considerable technological competence, engage in training and invest in the apprenticeship system. Firms undertake technical upgrading, undertake design adaptations in response to the market, and can be highly organised and cooperate among themselves.
4. One of the most diversified firms in Isolo had entered into a partnership with the Ladoke Akintola University of Technology to establish a technical training centre called the Techno Polytechnic Centre. The precise functions of the centre were not investigated as it is still at an incipient stage.
5. Study centres undertake both bachelor's and master's degrees, particularly in business administration, which is quite popular among busy executives who cannot afford to take leave. Most of the lectures take place on weekends and in the evenings to allow working candidates attend classes. An important fallout may well be the access provided by the centre offices to firms. This of course is speculative and no study has been undertaken to test this conjecture.

6. FAN undertakes engineering contracts for big national agencies like the National Electric Power Authority (NEPA).
7. For an elaboration, see Rosenberg (1976).
8. Skill intensity is the ratio of the number of engineering and scientific personnel to the total number of persons employed by the firm. These figures of local skill intensity relate to Nigerian engineers and technicians.

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