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Determinants of Technological Capability of Firms in a Developing Country

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Abstract

This paper examined the factors associated with the accumulation of technological capability among metalworking firms in Nigeria. A questionnaire was administered to 200 firms, of which 133 (66.5%) responded. Data were gathered on internal and external factors which are believed to influence capability build-up in the firms. The empirical evidence suggests that prior work experience of the entrepreneur, in-house training of technical staff and networking with the industry association had significant and positive influence on the accumulation of firm-level technological capability. Collaboration between the firms and research institutes was found to be weak. We conclude that firm-specific assets such as entrepreneurs' training and experience as well as in-house training are highly important for the build-up of technological capability in developing country firms. The relative importance of interaction through the industry association casts some doubt on the relevance of university-industry interactions for these firms.

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1. Introduction

In addressing the slow industrial progress in African countries, various policies have been adopted. One of such policies is International Technology Transfer which is regarded as one of the factors responsible for the success of the newly industrialized countries (NICs) of East and South-East Asia [1]. Technology transfer is one of the

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motivations for the reliance of African governments on industrialized nations and the NICs for technological support to develop the domestic economy. Imported technologies enhance domestic competencies through diffusion of know-how, skills development as well as employment growth [2]. Studies on development activities among the NICs and some countries in Africa show that the pattern and the level of technological capabilities among these two economic blocs are significantly different [3,4]. Therefore, an important question is whether it is more appropriate for developing countries to continue depending on foreign direct investment (FDI) before acquiring considerable amount of national technological capabilities needed to understand and assimilate the advanced knowledge into their economy; or to acquire the latter before attracting FDI in a way similar to the NICs from Asia [5]. National technological capability has been described as the collection of firms' individual specific efforts and strategies needed to choose, install, operate, maintain, understand, adapt, improve and develop technologies [6]. According to Lall [3], these strategies consist of firms' skills and knowledge, equipment as well as various linkages available within the National Innovation System (NIS).

At the firm level, technological capabilities facilitate innovation which, in turn, drives productivity growth. Consequently, for a nation to improve its competitiveness or experience improved productivity and economic growth, it needs to pay attention to the accumulation of technological capability by firms. In developing countries, industry reports have continued to show that there are some innovations among the micro-, small- and medium-sized enterprises (MSMEs) which, collectively, signal the presence of some level of capabilities. For our purposes, firms were categorized as micro-, small- or medium-sized if they respectively employed 1-9, 10-49 and 50-199 people at the time of this study. MSMEs are important to the economy of most developing countries in terms of growth, productivity, technological competitiveness and employment generation. For instance, micro, small and medium firms in Nigeria account for about 90% of business activities and also contribute about 60-70% of employment in the private sector [7]. But the evidence is still thin on the factors influencing the accumulation of technological capabilities among these firms, particularly in Nigeria. Therefore, the objective of this paper is to examine the factors influencing the technological capability of MSMEs in Nigeria. For its relevance across most industrial activities, we have chosen to focus on the metalworking sector.

2. Literature review

Technological capability is one of the factors that enable a country and its enterprises perform some functions (especially innovation) critical to economic development and international competitiveness. Accumulating these capabilities, especially in developing countries, is considered to be a learning process which requires absorptive capacity. Murovec and Prodan [8] described absorptive capacity as the ability to learn and solve problems. It facilitates absorbing existing knowledge, assimilating it and in turn, generating new knowledge [4,9]. This underscores the importance of learning as a prerequisite to innovativeness [10,11]. Amara [12] describe learning capability as those assets that enable firms to transform and exploit their resources in order to develop product or process innovations. Drawing upon existing literature [e.g. 13-15], they identified five modes of learning: by searching, by training, by using, by doing and by interacting. All of these are known to significantly influence the accumulation of technological capability in any organization. Broadly, the factors that condition learning can be categorized as internal or external to the firm.

2.1. Internal factors

The quality of human resources has been identified as an important firm-specific asset that enhances capability accumulation. In particular, qualified scientists and engineers as well as highly educated entrepreneur who provides strong leadership are beneficial [16]. The stock of knowledge and skills brought into the organization by the entrepreneur and the workforce through their earlier formal education and training forms the enterprise capability base. Sectors that experience rapid technological progress are also expected to hire highly educated workers because they require less training in basic skills. For instance, Bartel and Lichtenberg [17] used industry-level data to show that high-growth manufacturing industries in the 1960-1980 period exhibited greater relative demand for educated workforce. In contrast, Keizer [18] argued that neither the education of the manager nor the percentage of employees with higher education is significant in explaining the innovative efforts observed among the small and medium scale

engineering firms in the Netherlands. In Nigeria, accumulation of technological capabilities through internal training and apprenticeship system seems to be prevalent among MSMEs due to the cost of external training. In addition to such training, investment in research and development (R&D), informal experimentation, minor adaptations to products and processes, and the use of information and communication technology (ICT) also contribute to their technological effort [19]. For instance, some major changes in manufacturing that have produced much of the observed product innovation across sectors in developing countries can be attributed to the major technological advances in ICTs [20]. This has led to the lowering of cost particularly in small and medium firms that could not previously compete on the basis of scale [19-21]. We therefore propose that internal factors are positively associated with technological capability.

2.2. External factors

Ilori [22] described the national innovation system (NIS) as the network of institutions in the public and private sectors, whose activities and interaction initiate, import, modify and diffuse new technologies. In this context, interacting with various actors (such as universities and research institutes, professional and trade associations, competitors as well as customers and suppliers, and development finance institutions), all of which are situated within the NIS, can help in providing necessary information about the market, technologies, technical assistance, and external staff training [12,19]. For instance, Massa [23] reported that entrepreneurs consider networking with other firms as a very important part of their innovation efforts while Kaminski [24] observed that collaboration with suppliers can contribute to the innovativeness of SMEs. Academics may also be motivated to engage in collaboration with industry since they also benefit. In a recent study, Abramo [25] hinted that university researchers that collaborate with operators in the industrial sector had a better overall personal research performance in both output and functional scientific strength more than their colleagues that do not engage in similar collaboration. In Nigeria, Oyebisi [26] observed that there are some interactions existing between Nigerian universities and the industrial sector. In sum, we propose that firms' interactions with other actors within the NIS are positively associated with capability accumulation.

3. Methodology

Figure 1 summarises the foregoing discussion and illustrates the propositions that we test with the variables of interest. In order to avoid the challenge of technological and economic diversity occurring in cross-sectoral studies [11], we focused on a single sector (the metalworking industry). The industry is a centerpiece of developing nations' industrialization efforts. The activities of this sector are widely relevant as they culminate in the production of machines, spare parts and components used in, among others, the automobile, construction and agricultural industries.

3.1. Data collection

A sample of 200 metal fabricating firms was randomly selected from the directories of the Manufacturers Association of Nigeria and State Ministries of Commerce and Industry in Lagos and Ogun States of Nigeria. These states have been selected for strategic reasons. The majority of the MSMEs operating in Nigeria are located in Lagos State. In fact, the state alone is purported to host over 2000 manufacturing firms and account for about 60% of the country's industrial investment [7]. Lagos State, which is already constrained for space, is bounded in the north and east by Ogun State and in the south by the Atlantic Ocean. This strategically positions Ogun State to accommodate firms that are seriously in need of large factory space for their manufacturing operations. Before the field work, a draft of the questionnaire adapted from similar studies [27,28] was reviewed by experienced academics and pre-tested on some purposively selected firms outside our study area. Each questionnaire was addressed to the target firm's owner or production manager. A total of 133 (66.5%) completed questionnaire were retrieved and found useful for our analyses.

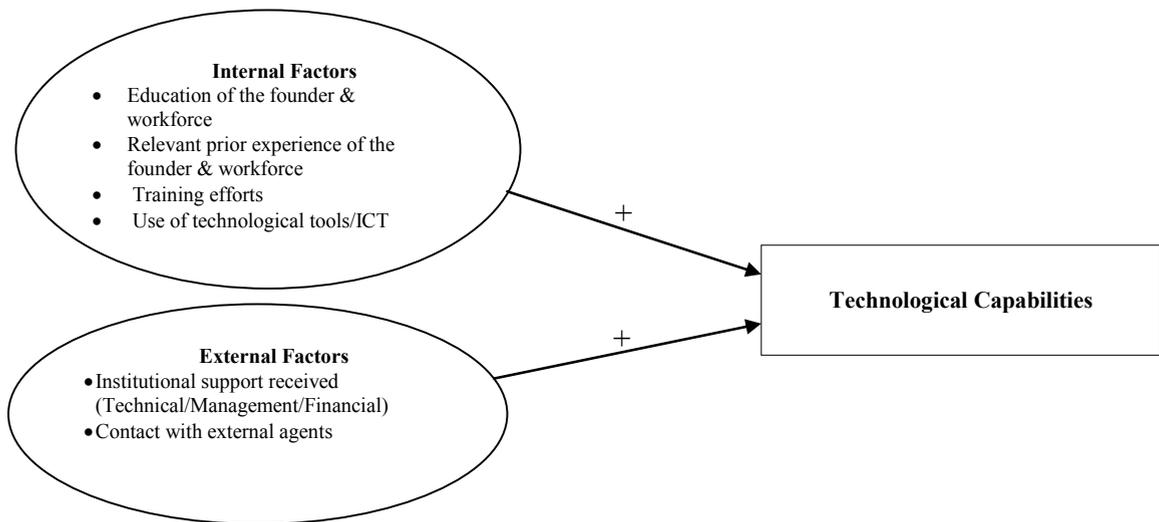


Fig. 1. Conceptual framework of factors influencing technological capability (adapted from Egbetokun, 2009)

3.2. Study variables and their measurement

The variables in Figure 1 were operationalized as follows. Education of the entrepreneur and workforce (in which we have limited ourselves to the production manager alone due to sparse data on other employees) was represented by the highest academic qualification obtained (primary, secondary or tertiary). Their prior working experience was captured in the number of years spent in metal fabricating firms or metallurgical research centres before establishing or joining the current business. Training efforts were measured by binary indicators of whether a firm organized a training programme for the technical staff in the past three years, and whether the training was carried out in-house or through a consulting firm. The use of technological tools and ICT was measured by rating the usage ('none', 'little' and 'a lot') of specific welding processes and computer-based facilities. Institutional support was indicated by whether a firm received assistance and the type of assistance (technical, management or financial) from actors such as universities and government research institutes. The frequency of contact with external actors (see Table 6 for a list) was also captured. In the next section, the foregoing factors are first described before relating them to technological capability in an ordinary least squares (OLS) regression framework. The dependent variable in the regression is a technological capability index (TCI) created from a total of 26 questionnaire items (*see appendix*) which capture various aspects of technological capabilities as classified by Lall [3] and widely adopted in micro-level studies [28]. They were rated on a scale of 2 (systematic), 1 (ad-hoc), and 0 (none) to capture different levels of competence. The scores on all items were summed for each firm, giving a maximum score of fifty two (52). The resulting scores were then normalised between 0 and 1 to give the overall TCI.

4. Results and discussions

4.1. Descriptive results

Table 1 presents the educational qualifications of the founders and their workforce. In general, the production managers are better educated than firm founders. Every one of them completed at least some post-primary education in contrast to about 70% of the entrepreneurs. In fact, the majority (58.3%) of the production managers had post-secondary qualifications whereas most of the entrepreneurs had only completed secondary education and about 10% post-secondary education. It may well be that the entrepreneurs try to make up for their own weak academic

background by hiring better qualified personnel. However, since we have considered only production managers in lieu of the entire workforce, this intuition cannot be stressed. Nonetheless, our findings show an improvement on what Ogbimi [1] reported that 55.5% of MSMEs operators in Nigeria had only primary school education. The improved human capital may be one of the drivers of the improved productivity and innovativeness reported in this sector.

Table 1. Educational Background.

Education	Primary	Junior Secondary	Modern	Senior Secondary	Technical	OND/NCE	HND/B.Sc.
Founder	23(25.2)	4(4.4)	2(2.2)	53(58.2)	9(9.9)	-	-
Production manager	-	-	8(11.1)	22(30.6)	19(26.4)	7(9.7)	16(22.2)

Note: Figures in parentheses are row percentages.

Relevant previous working experience is a critical element for building competence in any organization and in production as well. Table 2 shows that over 80% of the entrepreneurs and their managers had previously worked in a fabricating firm before establishing or joining the current firm. The proportion with no prior experience is rather small. As indicated in the aggregate responses, most of the work experience was acquired in other SMEs. In addition to this, a large share of the respondents reported learning the fabrication skill through the apprenticeship system. In most cases, an apprentice is allowed to work for a period of two to five years with his former master before starting his own fabricating business, and this further helps in deepening his competence. However, during the survey we observed that the spillover effect of prior working experience is stronger among the entrepreneurs and managers that had formally worked with larger fabricating firms. These sets of individuals are more organized in their production activities, and better off in the use of advance technological tools.

Table 2. Work Experience.

Prior working experience	No experience	Medium metal firms	Large metal firms
Founder	12(12.9)	71(76.3)	10(10.8)
Production Manager	6(8.3)	41(56.9)	25(34.7)

Note: Figures in parentheses are row percentages.

Regarding internal training efforts, it was found that about 75% of the firms had implemented several staff training programmes at the time of this study. All of the training was implemented in-house, making them more likely to be informal on-the-job training or formal internal training organized periodically. This is to be expected as MSMEs in developing countries would be reluctant in sending their staff for formal external training due to the high cost associated with such training mode [19].

The sources and types of various technological tools adopted by sampled firms are presented in Table 3 and Table 4 respectively. The sources of welding machines as indicated by the operators are locally fabricated (13.5%), imported (34.6%) and both local and imported (51.9%) machines. Many of the operators observed that though the locally fabricated machines are cheaper and easy to maintain, they preferred the imported ones because of their portability and efficiency. Table 4 further shows that the most adopted welding processes in the metal fabricating industry in the study area are shielded metal arc (100%) and oxy-acetylene processes (66.2%). This may be due to their cost effectiveness and perceived ease-of-use. We also found instances of some other welding processes such as plasma arc, flux cored arc and laser beam (0.8%) among the medium-sized firms.

Table 3. Firm's Technological Tools: welding machine .

Source	Frequency (%)
Locally fabricated	18(13.5)
Imported	46(34.6)
Local and imported	69(51.9)

Note: Figures in parentheses are percentages (n=133)

Table 4. Firms' Technological Tools: welding process.

Processes	A lot	A little	No
Shielded Metal Arc (SMAW)	133(100)	-	-
Oxyacetylene/Oxy-hydrogen (Oxy-fuel)	88(66.2)	9(6.8)	36(27.1)
Plasma Arc (PAW)	28(21.1)	-	105(78.9)
Flux Cored Arc (FCAW)	5(3.8)	26(19.5)	102(76.7)
Gas Metal Arc (GMAW)	-	-	133(100.0)
Gas Tungsten Arc (GTAW)	-	-	133(100.0)
Stud (SW)	-	-	133(100.0)
Submerged Arc (SAW)	-	-	133(100.0)
Laser Beam	-	1(0.8)	132(99.2)

Note: Figures in parentheses are row percentages ($n=133$)

The firms also deployed various types of information communication technology (ICT) in-house in enhancing their operations as shown in Table 5. The most widely adopted form of ICT device in the fabricating industry is the global system for mobile communication (GSM) with camera facility, which are widely used for copying (*stealing*) of product design from competitors' workshop. We observed a low in-house deployment of advanced ICT tools such as computer-aided design (CAD), computer-aided manufacturing (CAM), computer-aided engineering (CAE), computer-numeric control (CNC) and so on. The adoption rate of these technologies, which is a key technological capability [6] for this subsector that ought to bring about neat and well-designed quality metal products of international standard, is abysmally low. Some firms however outsourced the internet-email, computer-aided design, and computer-aided manufacturing to consulting firms or service vendors that are specialized in such operations. This development might have a negative consequence on the success and competitiveness of the subsector

Table 5. Firms' ICT Adoption.

Information communication technology (ICT)	In-house	Outsourced	No
Global System for Mobile Communication (GSM)	133(100)	-	-
Internet/e-mail	40(30.1)	16(12.0)	77(57.9)
Management Information System (MIS)	29(21.8)	-	104(78.2)
Computer-aided Design (CAD)	14(10.5)	73(54.9)	46(34.6)
Computer-aided Manufacturing (CAM)	-	5(3.8)	128(96.2)

Note: Figures in parentheses are row percentages

In this study, the external factors focused on the types of collaborations that exist between a firm and other economic actors in the NIS, and the frequency of such contacts. Table 6 shows that technical collaboration occurred mainly with customers and suppliers. Other forms of collaboration occurred between the firms and the Nigerian Welders Association (60.9%). These include settling of trade dispute and financial issues between members and customers or suppliers. However, none of the sampled firms received any assistance or is collaborating with educational institutions (universities and polytechnics) as well as government research institutes especially those concerned with metallurgical and technological research such as the National Metallurgical Development Centre (NMDC) and Project Development Institute (PRODA). This particular finding is not surprising as a similar trend was reported by NISER [29] in their study of Nigeria's Technological Capacity. The report revealed a sharp decrease in the number of collaborative efforts from about 75.9% in 1996 to 16.7% in 1997 between the engineering firms and government research institutes and Nigerian universities. The continuous trend of this disconnect could be attributed to the unwillingness of the operators in sharing trade information with relevant actors, the rigor of formal processing involved, cognitive and social distance to some of these actors as well as lack of information on the advantages of such interactions. Nevertheless, more innovative ways and proactive approaches will be needed to bridge these gaps especially from the part of the government research institutes and various universities' technology

transfer and patent offices. Table 6 further shows that contact with customers and suppliers occurs only when there is a project (occasionally) while contact with Manufacturers Association of Nigeria (MAN), financial institutions and the welders' association is relatively more frequent.

Table 6. Firms' Collaboration with Actors within the NIS.

National Innovation System Actors	Interaction Types			Interaction Frequency				
	Technical	General	No	Occasionally	Weekly	Monthly	Quarterly	Yearly
Customers/Suppliers' Association	93(69.9)	3(2.3)	37(27.8)	74(55.6)	-	-	-	-
Educational Institutions	-	-	133(100)	-	-	-	-	-
Govt. Research Institute	-	-	-	-	-	-	-	-
Manufacturers Association of Nigeria	5(3.8)	42(31.6)	86(64.7)	5(3.8)	-	-	3(23.3)	6(4.5)
Nigerian Welders Association	-	81(60.9)	52(39.1)	5(3.8)	72(54.1)	-	-	4(3.0)
Financial institutions	-	39(29.3)	93(69.9)	28(21.1)	8(6.0)	-	3(2.3)	-
Standard Organization of Nigeria	5(3.8)	-	128(96.2)	-	-	-	-	5(3.8)

Note: Figures in parentheses are row percentages.

The mean and standard deviation of firms' TCI is presented in Table 7. Before running the mean and mean difference, we checked for the relationship between the variables of TCI and firm size. The measure of their association showed R^2 value of 0.755, suggesting a strong relationship. Medium-sized firms had the highest average level of technological capability (0.7703) and the micro-sized firms the lowest (0.4104). The mean differences are significant at the 0.05 level. This hints at the differential endowments of the three firm groups. In general, the medium-sized firms may have better access to capital which enables them to recruit and train more and better qualified staff. They also tend to invest more in sophisticated equipment and sometimes go as far as the international market to purchase fairly used machinery. These activities pay off in the long-run as they help to increase their capability when compared with the smaller firms.

Table 7. TCI descriptive statistics (Tukey HSD).

No. of employees (I)	Mean	Std deviation	No. of employees (J)	Mean Difference (I-J)	Std. Error
1-9	.4104	.05950	10-49	-.13909*	.01214
			50-249	-.35993*	.01752
10-49	.5495	.07638	1-9	.13909*	.01214
			50-249	-.22085*	.01763
50-249	.7703	.03759	1-9	.35993*	.01752
			10-49	.22085*	.01763
<i>R</i>	.869				
<i>R</i> ²	.755				

*. The mean difference is significant at the 0.05 level.

4.2. Regression Results

Technological capability index (TCI), as the dependent variable, was regressed on both the internal and external factors. The result of the regression analysis is presented in Table 8 (which presents only the reduced form of our regression results. The full form, which includes all variables as well as alternative estimations for various aspects of TCI, is available upon request). The R^2 value of 0.926 and the F-value of 33.061 are considered satisfactory for the study. The results show that among the internal factors, prior working experience of the founder and in-house training of technical staff were statistically significant. On the other hand, only networking with Nigerian Welders' Association is significant among the external factors. The value for the prior work experience of the entrepreneur

and in-house training of technical staff indicate that work experience of the management personnel and staff training play a fundamental role in the accumulation of firm-level technological capabilities. Similarly, the significant nature of the networking with the industry association suggests that the information and services provided by this association enhanced the accumulation of the technological capability of the metal fabricating firms. These results support the findings of Wignaraja [28] who found that employee-training and collaboration with NIS agents positively influence technological capabilities of Mauritian garment firms.

Table 8. OLS estimates of the relationship between TCI and its determinants.

Factors	B	t
Constant	0.167	3.236**
Founder's education (X_1)	0.006	0.776
Production manager's education (X_2)	0.001	0.150
Prior work experience of founder (X_3)	0.143	5.519**
Prior work experience of production manager (X_4)	-0.005	-0.306
In-house training of technical staff (X_6)	0.161	5.998**
ICT in-use: Computer aided Design (X_9)	0.033	1.492
Networking with Manufacturers Association of Nig. (X_{17})	0.021	1.351
Networking with Nigeria Welders' Association (X_{18})	0.025	2.985**
Adjusted R^2	0.898	
F	33.061**	

**Significant at 0.01

5. Conclusion

In this paper, we have examined some internal and external factors contributing to the accumulation of firm-level technological capability among micro-, small- and medium-sized technology-based firms in a developing country. Our study concludes that experience gained by the entrepreneurs from their former employers and in-house training of technical employees remain the major internal factors contributing to the technological capabilities of a technology-based firm while technical collaboration with various industrial associations is an important external factor for firm success in developing countries.

For policy making, the results of our study have thrown up some important factors on which attention could be focused. Following the importance of human capital that we found, it is desirable, for instance, to begin the teaching of modern fabricating techniques to students at secondary school level as a way to prepare them for entrepreneurship and/or employment in craft-based sectors. Besides, while we acknowledge the importance of the apprenticeship system of skill acquisition, the process of apprenticeship without basic technical education should be discouraged. Moreover, if SMEs require support in the process of capability accumulation, it seems that they would benefit more from stronger networks and high quality human capital. The relative importance of interaction through the industry association casts some doubt on the relevance of university-industry interactions for these firms.

This paper is not without its limitations. Not including large firms in our sample somewhat limits the findings. Though large metal fabricating firms are not commonplace, detailed studies of the available cases hold the promise of policy-relevant results. In addition, cross-country comparative studies are desirable. The future research will focus more on the role of the educational institutions in development of human capital and employment in the sector.

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Appendix A. Questionnaire

Table 1. Questions on Technological Capability

<i>Investment Functions</i>	<i>Process Engineering Functions</i>
i. Feasibility studies for new factories, workshop or projects	i. Debugging & calibration of new equipment
ii. Search for & select technology for new projects	ii. Do routine maintenance operation
iii. Detailed engineering for new projects	iii. Replacing original equipment parts
iv. Construction of workshop facilities	iv. Quality control (Automated/Vision)
v. Recruitment & training of technical personnel	
<i>Product Engineering Functions</i>	<i>Industrial Engineering Functions</i>
i. Reproduce fixed specifications & designs	i. Operating inventory control system
ii. Accreditation/certification of product quality	ii. Scheduling production
iii. Design & introducing new products in-house	iii. Monitoring of productivity
<i>Process Innovation Functions</i>	<i>Product Innovation Functions</i>
i. Develop new production method	i. Develop new product(s)
ii. Introduce new production method	ii. Copy/imitation of imported product(s)
iii. Modification to existing production method	iii. Modification to existing product(s)
	<i>Linkage Functions</i>
	i. Networking with other firms
	ii. Association with trade union
	iii. Collaboration with educational & research institutes
	iv. Relationship with customers/suppliers
	v. Relationship with financial institution

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