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Learning new technologies by small and medium enterprises in developing countries

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Abstract

This paper, based on new field data, examines the ways in which small and medium enterprises in selected developing countries learn to use and augment their core capabilities with new technologies. This paper presents three findings. First, there is clear evidence of increasing complexity in the adoption and use of Information and communication technologies (ICTs) among developing country firms. Second, climbing the technological ladder requires skills upgrading through explicit learning of the new technologies. Third, firm performance is highly associated with learning capabilities, levels of technology, and a host of firm-level knowledge, skills and experience. The study found that across countries and sectors, non-formal learning is the dominant form of mastering new technologies. However, formal local and overseas training is positively associated with increasing technological complexity. There is also a close correlation between technical complexity of firms' internal ICT tools and available telecommunication infrastructure.

Keywords: Learning; New technologies; SMEs; Developing countries; ICTs

1. Introduction

In successful firms, firm level capabilities would comprise core and 'general-purpose technologies' (GPTs) competencies. The corollary is that successful firms would in turn possess both GPTs and firm-specific skills. The range of GPTs include mechanical engineering, and arguably the most pervasive to date, Information and communication technologies (ICTs) (Rosenberg, 1994) These technologies are required for and in fact are indispensable to the operation of the core routines of organizations. For instance mechanical engineering is as crucial to the automobile industry as biotechnological skill is key to pharmaceuticals and foods industries. The advent of microelectronics has not only deepened the systemic complexity of all industries; it has revolutionized the nature of industrial organization. The major technological advances in ICTs has been a major cause of the deep changes in manufacturing and underlie much of the observed patterns of process and product innovation across industries. At the center of the manufacturing changes with significant implications for processing speed, flexibility of production and high precision is the progressive inclusion of microelectronics. While much of these advances have originated in advanced industrial economies, other developing countries have taken advantage of these new technologies by building up industrial capabilities through sustained and explicit learning.

Complementary to widespread computerization and the adoption of internal electronic tools within firms is the rising skills level of the workforce in what has come to be known as the technology-skill complementarily (Goldin and Katz, 1998). In the United States, Author, Katz and Houndmills (1987) found substantial shifts towards tertiary education graduates in industries is strongly associated with more rapid growth rate in computer usage and computer capita per worker. Right from the advent of electricity, an equally 'wired' technology like ICTs, there has been an observed and persistent rise in the skill intensity of manufacturing. According to (Goldin and Katz, 1998, p697), 'technological shift from factories to continuous-process and batch methods, and from steam and water power to electricity, may have been at the root of an increase in the relative demand for skilled labor in manufacturing in early twentieth century'.

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Digital technologies have led to the lowering of costs, and higher quality products, particularly in small and medium firms that could not previously compete on the basis of scale. For instance the use of computer-aided designs (CAD), computer-aided manufacturing (CAM) has revolutionised production in both the machinery sector as well as in process industries. The continuous penetration of electronic instrument in traditional sectors has led to renewed interest in, and greater competitiveness of these sectors. The use of computer integrated manufacturing (CIM) has induced greater speed of production as well as production flexibility in product and process. These changes demand complementary knowledge and skills.

The adoption of internal electronic business (e-business) technologies employing high-speed computers coupled with advanced telecommunications technologies has not only resulted in relatively lower transactions costs but also promoted increasing intra-firm and inter-firm integration functions. Firms earn high profit margins not only through low wage and low skills production but also through fast delivery of customized products and services to customers. The scope advantage of small firms has been significantly enhanced by new technologies be they manufacturers of batch orders or subcontractors to larger firms. These changes have led to significant shifts in the skill composition of labor and heightened the debate on technology-skill and capital-skill complementarily, (Bound and Johnson, 1992; Goldin and Katz, 1998). By this term, the authors mean that 'skilled or more-educated labor is more complementary with new technology or physical capital than is unskilled or less educated labor' (Goldin and Katz, 1998, p.694 footnote).

Given the technology-skill complementarities, the introduction of IT has significant skill implication for developing countries' firms learning to produce for domestic and external markets. The successful adoption of e-business tools is likely to enhance individual worker's productivity in the so-called modern sectors such as electronics and general machinery sector. In the more traditional sectors such as textiles, clothing and foods, there is a propensity for significant rise in product quality and more precise processing. To achieve the goal of better quality products, firms are obliged to undertake greater training and investment in skills and knowledge upgrading. The implications for long term industrial competitiveness in developing countries is thus evident no matter the sectors in which countries have comparative advantage.

This paper presents evidence of learning processes and investment in selected developing countries. We advance three main theses. First, there is clear evidence of increasing complexity in the adoption and use of ICTs among developing country firms. Second, climbing the technological ladder requires skills upgrading through explicit learning in the new technologies and for this reason rate of adoption had been highly differentiated. Third, firm performance is highly associated with learning capabilities, levels of technology, and a host of firm-level knowledge, skills and experience.

The remainder of the paper is organized as follows. Section 2 presents a partial survey of the literature. A theoretical framework is presented in Section 3 while hypotheses are formulated in Section 4. Data sources are also discussed in Section 4. Statistical results are presented and discussed in Section 5 whereas Section 6 presents summary and conclusions.

2. Learning, knowledge and technical change in development

Technological learning is the way organizations such as firms accumulate technological capability (Malerba, 1992). Technological capability is the knowledge, skills and experience necessary in firms to produce, innovate, and organize marketing functions (Lall and Wignaraja, 1998; Ernst et al., 1998). Much of the technological knowledge required by small and medium firms in the early stages of development in say developing Africa is incremental and could often be acquired through what (Lall, 1982) described as 'elementary learning' although there are exceptions within firms that have moved up in the supply chain. As firms climb the ladder of manufacturing complexity, the types of knowledge it requires, the nature of its organization and the forms of institution to support it become increasingly complex. In the last decade we have come to know much more about the nature of learning and capability acquisition in firms and in what follows, We provide a brief overview. First, learning in firms is a major source of incremental technical change and as such a firm is learning organization, and through the knowledge it accumulates, continually transform its knowledge assets to foster higher orders of operation (Lundvall et al., 2002; Malerba, 1992).

Secondly, following from above, a firm is characterized by a certain level of technical and organizational knowledge base. Third, a firm draws upon a wide variety of knowledge sources (suppliers, subcontractors, machinery suppliers) that may be within its locale and often outside the national boundary (Lundvall, 1988; Von Hippel, 1988). Fourth, there are different modes of learning and the widely known learning-by-doing, and learning through research and development (R&D) are only some of these sources. Learning-by-doing is by definition a costless, effortless process, which does not often lead to innovation. However, the sort of learning efforts that lead to dynamic productivity gains require explicit investments to alter the technical and organizational assets of the firm.

Fifth, learning processes are linked to specific sources of technological and productive knowledge such as apprenticeship, equipment manufacturers and others. Six, learning does not take place in a vacuum and firms do not innovate in isolation. External actors with whom firms interact are crucial to learning in firms. The sources of external knowledge by which firms internalize new capabilities range from equipment suppliers, input suppliers universities, and research institutes; while the role of private business associations has become crucial. Learning processes are linked to the trajectories of incremental technical change through the accumulated stocks of knowledge in firms (Malerba, 1992). In other words the direction of technical change is related to the types of learning process. The different types of learning identified in the literature are: learning-by-doing (Arrow, 1962), learning-by-using (Rosenberg, 1982), learning-by-searching and R&D (Dosi et al., 1988), learning-by-interacting (Lundvall, 1988; Von Hippel, 1988); learning by operating (Teubal, 1987; Scott-Kemmis and Bell, 1988); by changing (Katz and Ablin, 1987); system performance feedback (Bell et al., 1988); by training (Dahlman and Fonseca, 1987); by hiring (Katz and Houndmills, 1987) and finally, learning by searching (Dahlman and Fonseca, 1987).

3. Knowledge, skills and new technologies

For a number of developed and developing countries, empirical literature shows evidence of growth of skilled workers, particularly those with tertiary education, over time. Again contrary to conventional wisdom underpinned by the demand and supply argument that wage inequality will be attenuated by rising skilled workers, there seem to be growing wage inequality between skilled and unskilled workers (Piva et al., 2003). This assumption might well have been extrapolated from the historical evidence dating from the industrial revolution when machines and low skilled labor replaced the artisan. Underlying these changes is the emergence, diffusion and use of knowledge, particularly scientific and technological knowledge that has reached its full manifestation in the new technologies of ICTs and biotechnology.

The form (for instance, digitally coded information), content and the way we utilize different forms of technological knowledge have been transformed by rapid changes brought about by new technologies while the mechanisms of skills transfer have been altered significantly particularly by advances in microelectronics. The new competition Best (1990) as well as the changes in the economic contexts particularly the liberal regimes of trade and production are equally significant factors (Lundvall and Johnson, 1994; Johnson et al., 2002; Ducatel, 1998). There is renewed debate on the most appropriate mix of skills and the most important sources of knowledge accumulation in a new knowledge-driven economic context. For instance, discussions are likely to continue in the foreseeable future on how to assign relative weights to formal and non-formal knowledge in firms, and the underlying conceptual dichotomy of tacit and codified knowledge.

While there is empirical evidence from the highly advanced countries, we are far from a full understanding of the most important determinants of the 'skill bias effect' often associated with both technological and organizational changes. According to this proposition, the reason for the rising skill content of the labor force is due to the accelerating rate of technological change. Technological change induces the demand for better-educated and skilled workforce (Arrow, 1962; Nelson and Phelps, 1966).[1] Sectors that experience rapid technological progress would be inclined to hire more educated workers because this group have far less need for training in basic skills and as such constitute a ready innovation asset within firms. The corollary is that technological change will in turn stimulate the demand for more knowledge intensive and skilled labor. There is preponderance evidence of a positive association between the rate of technological progress and the demand for an educated workforce. (Berman et al., 1994) working at the sectoral level, found positive correlation between R&D and skilled labor in the United States. (Bartel and Lichtenberg, 1987) also showed, using industry level data, that manufacturing industries in the 1960–1980 period exhibited greater relative demand for educated workforce in sectors with newer vintages of capital.

In addition to technology induced skill effect, organizational change would seem also to underlie the changing skill composition of firms. For example, the introduction of ICTs tend to change the ways decision are made within organizations by 'flattening' hierarchies and promoting greater involvement of the workers in management (Caroli, 2001). Facilitation of greater interaction as well as information exchange at the factory level would tend to promote worker productivity. However, while the evidence is mixed regarding the productivity-enhancing impact of ICTs, there is greater evidence of the nexus of new technologies and the emergence of new forms of organization[2] (Brynjolfsson and Hitt, 1998). What this implies is that firms would have to deal with technological and organizational changes simultaneously, putting a demand on their resources for technical, skill and organizational upgrading at the same time. As Guellec (1996) observed, "human capital and technology are two faces of the same coin, two inseparable aspects of knowledge accumulation. To some extent, the same can be said for physical capital. Accumulation of these factors goes hand in hand with innovation: one does not accumulate billion dollars of wheelbarrows or train millions of people as

[1] According to these authors, experience gained in the process of operating a given technology or new technology results in increased efficiencies and as such an educated workforce will be more amenable to learning complex technologies.

[2] According to Piva et al. (2003) new forms of organization include decentralization and delayering ('lean production') examples including just-in-time management; collective work such as 'quality circles'; and multitasking which requires workers to master and perform a wider variety of tasks.

stonecutters. Only the appearance of new devices makes it worthwhile to invest and train".

Developing countries are not insulated from, and indeed have much more to lose if, they do not engage in the debate to find ways to survive in the new environment of rapid technological and organizational changes. There are two reasons for this. The first is that all societies no matter their level of development need to process and use knowledge of one kind or another. As Metcalfe (2003) observes, "every economy, always and everywhere, is a knowledge economy; for social systems and economies as social systems, could not be arranged otherwise". The second reason stems from the well-debated notion that knowledge growth, validation and transfer is a socially distributed process, mediated by institutions (Lundvall and Johnson, 1994; Metcalfe, 2003; Ducatel, 1998). However, institutions of knowledge in developing Africa is weak and in most cases absent, while small firms often lack resources for innovation and tending to concentrate instead on achieving nominal production capacity with which daily routine is ordinarily concerned.

In transforming codified global digital knowledge to local use, only a proportion can be transferred by formal technology transfer mechanisms, while the rest would often require a long heuristic process of imitation, reverse engineering, learning-by-doing and apprenticeship. Stiglitz (1999) termed these processes of learning 'horizontal methods of knowledge transfer', while the formal, codified storable mode is called 'vertical transfer'. On the one hand, these largely practical informal methods take several forms.[3] Despite the increasing propensity to codify technical functions, tacit knowledge remains an important component not only in the context of traditional sectors and small firms, but a necessary cognitive basis for interpreting codified knowledge including digital and mathematical functions. On the other hand, formal learning is characterized by five distinct characteristics, namely: (1) it has a prescribed framework; (2) an organized learning package or events; (3) the presence of a designated teacher or trainer; (4) the award of a qualification or credit; and (5) the external specification of outcomes (Eraut, 2000). However, building institutions for formal knowledge accumulation is not only costly and time consuming, the resources for sustaining them are often not enough in poor countries.

The clear importance of tacit and codified knowledge highlights the dichotomy of formal and non-formal institutions. As Stiglitz (1999) argued, developing countries need to formulate effective ways to promote *local knowledge institutions* because evidently 'the overwhelming variety and complexity of human societies requires the localization of knowledge'. There is a clear distinction between global public goods and local knowledge and for this reason, every society should be active in strengthening local knowledge institutions to drive the local learning process.

4. Theoretical framework

From the foregoing, the observed pattern of shifts in the relative mix of skills in manufacturing, the increasing emphasis on knowledge and on innovation-driven rather than price-based competition, suggest to an equally imperative need for new thinking about economic development in developing countries. These changes are not new but qualitatively, they are more intense and arguably occurring more rapidly[4]. We employ a framework drawing on the concepts related to learning processes and technological trajectories followed by firms, that we reviewed in Sections 2 and 3. The recent and burgeoning literature on technological capability building suggests that knowledge sources that contribute to capability building are external as well as internal to the firm. A theoretical framework based on these arguments is depicted in Fig. 1.

As suggested by Lundvall (1988) and Von Hippel (1988) the accumulation of knowledge takes place not only by developing and employing internal capabilities but through learning by interaction with a wide variety of sources. For example, firms interact with several external organizations such as technology producers and suppliers. They also gain knowledge through interaction with their customers. In fact dominant designs and ability for greater flexibility in product designs are often achieved through interaction with product users. The different forms of interaction with technology producers, suppliers, and customers are considered extremely important to the technological acquisition process in firms. The internal processes that lead to technological capability building are training, learning-by-using and learning-by-searching (Rosenberg, 1982; Dosi et al., 1988). Learning by searching includes technological improvements achieved though R&D. A recent empirical study Oyelaran-Oyeyinka (2004) suggest that internal training opportunities greatly contribute to the workers productivity which in turn influences the technological trajectory of firms in Africa. The contribution to knowledge accumulation through internal training is more relevant and prevalent in Small and Medium-sized Enterprises (SMEs) because they are less able to organize costly and formal external training. In addition, firms tend to follow certain stable and predictable direction of search processes that

[3] Among these are: study tours to other countries, cross-training which is a form of 'learning-by-observing' in other countries, an implicit knowledge acquisition process that is different from explicit training on how to do things, twinning or seconding which pair together institutions in a horizontal knowledge exchange process, (Stiglitz, 1999).

[4] According to Goldin and Katz (1998 p704), "The increased reliance on electricity as a source of horse-power and the introduction of unit-drive appears to have had effects similar to the movement of continuous-process methods…. The role played by skilled labor in machine-maintenance means that capital and skilled labor are relative complements within any given manufacturing production process."

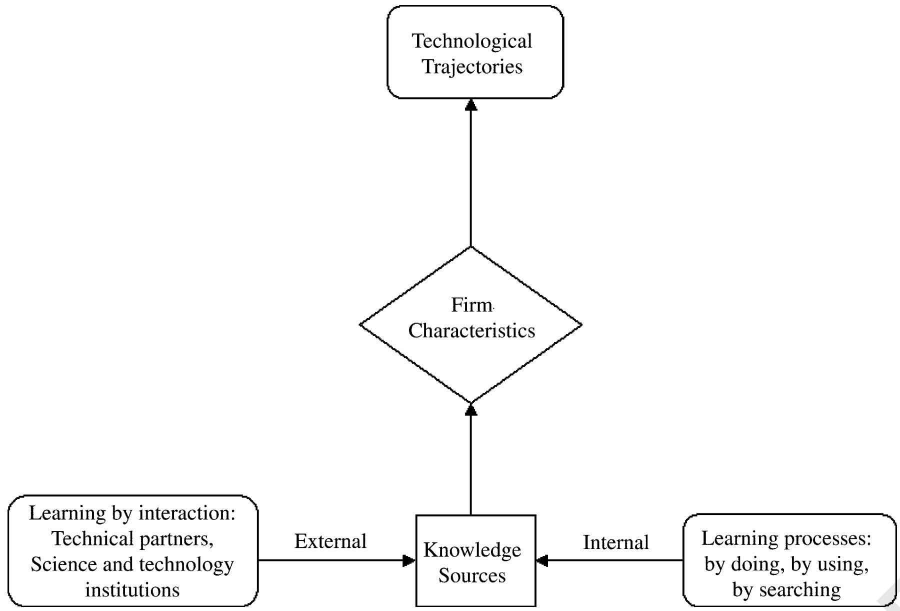

Fig. 1. Skills effect of learning new technologies.

draw on their past experience and build on their competencies over time and for this reason, learning at the firm level takes on a path-dependent character (Nelson and Winter, 1982). Where path-dependence generates inertia, old firms may lose out to new ones whereas where it helps to stimulate innovation, there might be need for learning and forgetting old skills. Encompassing the external and internal knowledge sources coupled with other firm specific factors, our analytical framework is used to explain the technological trajectories followed by sample firms.

The analytical framework is underpinned by the notion of organizational learning. Several definitions of organizational learning have been used in the literature. For instance Morgan (1986) defines it as follows: "…there is organizational learning when administrative or production unit acquires knowledge that is recognized to be potentially useful to the organization". Whereas Huber (1991) argues that learning results from four processes, namely; knowledge acquisition, diffusion of information, interpretation of information, and organizational memory (for future use of the knowledge). Two important elements differentiate measurements of firm-level activities in developing and developed countries. First, much of the improvement efforts that firms carry out in developing countries are incremental in nature and cannot be captured with the conventional R&D counts of expenditure and the number scientists and engineers. To this extent, the skills profile of firms in the two contexts differ widely with less importance given to research scientists and much more to technicians and generalists (Huiban and Bouhsina, 1998). This is in consonant with the level of technology in use and the more formalized system of research supporting industry in advanced economies, as different from the informal factory wide nature of innovative activities in the developing context. Secondly, the sources, nature and processes of learning vary with sectors and national resources and to this extent, the complexity of use of ICTs will exhibit variation with sectoral, and for our analysis, firm-level capability. Industry is relatively underdeveloped in poor countries and traditional sectors such as textiles and clothing and foods constitute the national systems. The so-called hi-tech sectors are only emerging.

5. Data sources and hypotheses

Data were collected from three countries, namely: Uganda, Nigeria, and India. Firm-level information was collected through a semi-structured questionnaire during June 2002 and January 2003. SMEs, by and large, dominated sample firms. Indian sample firms are drawn from garments manufacturing, electrical and electronic goods manufacturing, and auto-component manufacturing sectors while we could cover auto-component manufacturing, and food and beverages firms in Uganda. The Nigerian sample firms are drawn from the electronic goods and engineering manufacturing sector. Data for the three countries have been analyzed separately because of non-comparability of Managing Directors' (MDs) education and other firm specific factors such as firm size and type of e-business technologies adopted by firms in the three countries.

Since the main objective of the study is to investigate the relationship between the learning processes and the technological trajectory of firms, we have formulated the hypotheses in relation to various types of learning modes prevalent in SMEs. E-business technologies adopted by firms have been used as a proxy of technological trajectories. This is because e-business technologies cut across the production processes and adoption of new technologies has been dominated by ICT led technologies. It was found during the survey that firms were in the main using the following technologies: Flexible Manufacturing System (FMS), Computerized Numerically Controlled machines (CNC), Computer-Assisted-Design/Computer-Assisted-Manufacturing (CAD/CAM), Electronic messaging systems (Email), Management Information System (MIS), web and portal enabled technologies.

As mentioned earlier, SMEs dominate the sample firms. Hence we examined the association of two crucial firm specific factors on the training modes adopted by sample firms. These factors are the academic qualification of MDs and the size of firms. Finally we investigated the effect of mode of knowledge acquisition on the intensity of e-business technology adopted by firms. The intensity of e-business technology adopted by firms can be used as the proxy of performance in the domestic as well as export markets. Several studies (Lal, 2004; Hodgkinson and McPhee, 2002) found that users of advanced e-business technology perform better than non-users in the export markets. The following hypotheses are formulated.

5.1. Hypothesis I: MDs qualification is associated with type of learning processes

Decision making processes are very different in SMEs and large corporations. No single individual is responsible for decisions taken in large firms. This is because the decision making process is very formal and decisions are taken by a group rather than by individuals. Whereas in SMEs, almost all the decisions are taken by owners or MDs. Hence decisions made in small firms are highly influenced by the knowledge and academic qualification of MDs (MDEDU). In matters that relate to the skill upgrading of workers are very critical due to high turnover of employees in SMEs. However, skill enhancement[5] activities are very relevant for small firms because they have the tendency to employ less qualified persons and subsequently plan to provide on-the-job training. There are several kinds of on-job training such as learning by doing, sending workers for training provided by technology suppliers, and in-house training. However, the crucial question relates to the type and the adequacy of training provided. A relatively more qualified manager is in a better position to decide on the suitability of a particular training for workers. We hypothesize that MDs having engineering degrees will prefer Internet based learning processes, and would favor training workers in advanced ICTs.

[5] Siegel et al. (1997) suggest that three types of skill empowerment may result when adopts advanced manufacturing technologies which are: (a) training; (b) changing employees job responsibilities, (c) creating new jobs and career opportunities for employees.

5.2. Hypothesis II: Firm size is associated with type of learning processes

Firms with larger size of operation are generally more innovative and have the resources (knowledge and skills), to modify product specifications. Changes to product design might require changes in production technologies and processes that in turn might require training for the users of new technologies. On the contrary, training requirement is less frequent in firms where product profile remains static. Such firms operate in markets with little competition and tend to exist in the lower end of SME skills spectrum. We argue in this study that firms with larger size of operation are expected to adopt modern learning processes such as Internet enabled learning. Smaller firms with lower level of operation have neither the resources nor are they in a position to appropriate the full benefits of new technology based learning processes. The complexity of ICTs adopted is limited by the size of firm.

5.3. Hypothesis III: Technological trajectories are significantly influenced by type of learning processes

The success of adoption of new technologies depends on several prerequisites such as the ability of firms to use them effectively and efficiently, appropriability of benefits of new technologies, and the capacity utilization of new methods of production. A major factor in the adoption of new technologies is the entrepreneurial ability of MD in SMEs. Other factors such as skill intensity and appropriability are derived from entrepreneurship. Another factor that is pivotal to the adoption of new technologies is the learning process employed by the users of such technologies. Since both modern and so-called traditional technologies are being significantly revolutionized by ICTs, we hypothesize in this study that MDs who appreciate and provide Internet based learning opportunities are expected to adopt more advanced technologies.

6. Statistical results

In order to test the hypotheses of the study, we collected data on various learning processes prevalent in the firms. It is quite possible that more than one learning process were used to upgrade the skill of workers. Hence the variable, learning process, is a multi-response one. MDs responses are coded on a binary scale. Data on technological trajectories were also collected. Statistical results related to hypothesis I are presented in Table 1.

It can be seen from Table 1 that learning-by-doing is the preferred means of knowledge acquisition in all the three countries irrespective of academic background of MDs. For instance in Indian firms, 90.91% of MDs having undergraduate degrees preferred learning-by-doing as one of the options for skill upgrading of workers while all the MDs with CA and LLB preferred this mode of knowledge

Table 1
Learning Processes and Managing Directors' Education

Learning mode→ MDEDU	Training	Learning by doing	Internet searching	Learning by interaction	Overseas training	Total firms
India						
BE and MBA	48 (69.57)	63 (91.30)	58 (84.06)	46 (66.67)	39 (56.52)	69
CA and LLB	9 (81.82)	11 (100.00)	9 (81.82)	6 (54.55)	5 (45.45)	11
GD and PG	80 (62.02)	121 (93.80)	101 (78.29)	94 (72.87)	89 (68.99)	129
UG	16 (72.73)	20 (90.91)	18 (81.82)	13 (59.09)	12 (54.55)	22
Total firms	231	231	231	231	231	231
Uganda						
Engineer	7 (53.85)	9 (69.23)	3 (23.08)	4 (30.77)	2 (15.38)	13
Technical	9 (30.00)	17 (56.67)	5 (16.67)	5 (16.67)	4 (13.33)	30
Diploma						
Others	8 (23.53)	22 (64.71)	8 (23.53)	8 (23.53)	8 (23.53)	34
No response						7
Total firms	84	84	84	84	84	84
Nigeria						
Engineer	25 (66.59)	27 (71.05)	1 (2.63)	13 (34.21)	1 (2.63)	38
Technical	9 (32.14)	8 (28.57)	1 (3.57)	5 (17.86)		28
Diploma						
Others	2 (14.29)	1 (7.14)				14
No response						25
Total firms	105	105	105	105	105	105

Note: Figures in parentheses are row percentages. Percentages are not expected to add to 100% because of multi-response of MDs.

accumulation. However, the next important source is Internet searching in India while in Uganda and Nigeria, it is the in-house training of workers.

The main reason for firm preference for the Internet as a source of information for skill upgrading in Indian firms is the availability of reasonably good telecommunication infrastructure. The type of e-business technologies used by Indian firms reflects this. On the other hand the level of Internet based e-business technologies is relatively unsophisticated in the other two countries. This could be the possible reason for giving preference to in-house training as the second best mode of skill upgrading of workers. Results presented in Table 1 show that the preferred mode of learning has not been influenced by the academic qualification of MDs. The only exception is in Indian sample firms where the largest number of MDs (84.06%) with BE and MBA degree preferred Internet based learning method while a lower proportion of MDs with other academic backgrounds chose the Internet as a source of learning. One of the possible explanations could be that MDs with engineering and business management degrees are more aware of the benefits of Internet based learning processes.

Table 2 presents the distribution of the learning mode by size of firms. We used total number of workers rather than

Table 2
Learning processes and firm size

Learning mode→ Size	Training	Learning by doing	Internet searching	Learning by interaction	Overseas training	Total firms
India						
<50	38 (63.33)	54 (90.00)	48 (80.00)	32 (53.33)	37 (61.67)	69
50–99	44 (68.75)	60 (93.75)	51 (79.69)	49 (76.56)	32 (50.00)	11
100–200	34 (61.82)	53 (96.36)	41 (74.55)	37 (67.27)	44 (80.00)	129
200+	37 (71.15)	48 (92.31)	46 (88.46)	41 (78.85)	32 (61.54)	22
Total firms	231	231	231	231	231	231
Uganda						
<3	21 (23.38)	49 (66.22)	18 (24.32)	18 (24.32)	18 (24.32)	74
3+	8 (80.00)	7 (70.00)	2 (20.00)	3 (30.00)	1 (10.00)	10
Total firms	84	84	84	84	84	84
Nigeria						
<5		2 (5.88)		1 (2.94)		34
6–9	16 (43.24)	17 (45.95)	4 (10.81)	10 (27.03)	3 (8.11)	37
10–20	12 (80.00)	11 (73.33)		5 (33.33)		15
20+	19 (100.00)	19 (100.00)	1 (5.26)	6 (31.580	1 (5.26)	19
Total firms	105	105	105	105	105	105

Note: Figures in parentheses are row percentages. Percentages are not expected to add to 100% because of multi-response of MDs.

Table 3
Technological trajectories and learning processes (India)

Technologies→ Dep. variables	FMS	MIS	Email	Web site	Portal
Training	0.033 (0.501)	0.042 (0.675)	0.114 * (1.742)	−0.056 (−0.853)	0.148 ** (2.297)
Learning by doing	0.045 (0.676)	0.274*** (4.406)	0.160 ** (2.441)	0.091 (1.396)	−0.011 (−0.171)
Internet Searching	0.069 (1.036)	0.222*** (3.550)	0.070 (1.060)	0.071 (1.081)	0.045 (0.701)
Learning by inter-action	0.079 (1.175	0.078 (1.237)	0.026 (0.384)	0.076 (1.151)	0.168 ** (2.566)
Overseas training	0.111* (1.664)	−0.004 (−0.057)	0.009 (0.131)	0.170 ** (2.591)	0.141 ** (2.191)
R^2	0.029	0.136	0.047	0.052	0.083
F	1.337	7.095	2.241	2.464	4.060
Significance	0.249	0.000	0.051	0.034	0.002

sales turnover as a proxy of size of operation because of the non-availability of sales turnover for all firms' data. We would have lost substantial degrees of freedom by considering sales turnover as size of operation.

Results presented in Table 2 are similar to the distribution of preferred mode of learning processes by academic qualification of MDs. Cutting across countries and size of operation, sample firms have used learning-by -doing as the most important source of knowledge acquisition. Searching through the Internet is the preferred second best mode of skill upgrading by Indian firms in general and in addition larger firms have assigned more importance to Internet searching compared to firms with smaller size of operations. Whereas firms in the other two countries have given more or less equal importance to the two sources of learning, namely: in-house training and learning-by-doing. In fact larger firms in Uganda and Nigeria consider in-house training more important than learning by doing. For instance 80% of firms employing more than three persons have chosen in-house training while 70% of firms in this size category preferred learning-by-doing method of knowledge accumulation. Similarly 80% of Nigerian firms employing between 10 and 20 workers chose in-house training compared to 73.3% of firms in the same category of employment preferred learning by doing. Presumably, large firms with better financial resources could organize formal training while small producers rely more on learning-by-doing.

We tested hypotheses III by using Ordinary Least Square (OLS) method and bivariate distribution of firms by the technological trajectories followed. The bivariate results are presented in the Appendix A. Regression and bivariate analysis results are similar. Hence the discussion is limited to OLS results. It was not possible to pool the data of all the countries because the type of e-business technology employed by sample firms is different across countries. Hence country-specific parameters were estimated. The type of e-business technology, which is considered a proxy of technological trajectory, has been used as a dependent variable. Parameters of regression equation for each type of technology have been estimated separately. The parameters were estimated using standardized values of variables to negate the effect of discreteness of variables. The results for India, Uganda, and Nigeria are presented in Tables 3–5, respectively.

Indian firms use cluster of five e-business technologies. From Table 3 that FMS using and web site-owning firms prefer overseas training for effective and efficient use of the new system. This is because flexible manufacturing systems are in some sense customized systems and specially designed for firm-specific needs. For this reason, general training is hardly appropriate, and not surprisingly, firms that adopted such systems would of necessity require specialized training, which is often available only overseas. Table 3 also shows that MIS using firms found learning-by-doing and Internet searching, significantly useful. Only email using firms might not have access to the Internet due to low speed and unreliable communication. Some of these firms invariably resort to using email through Public

Table 4
Technological trajectories and learning processes (Uganda)

Technologies→ Dep. variables	CNC	FMS	MIS	Email	Internet
Training	0.179*** (3.002)	0.154 ** (2.605)	0.673*** (7.623)	−0.007 (−0.067)	0.057 (0.514)
Learning by doing	0.032 (0.796)	−0.114*** (−3.007)	−0.004 (−0.066)	0.057 (0.969)	−0.177 ** (−2.317)
Internet searching			0.714 ** (2.381)	−0.092 (−0.313)	−0.092 (−0.244)
Learning by inter-action	0.023 (0.175)	−0.039 (−0.321)	0.260 (1.200)	0.001 (0.004)	−0.086 (−0.315)
Overseas training	0.811*** (5.837)	0.833*** (6.391)	−0.690*** (−3.179)	1.030*** (4.813)	0.914*** (3.365)
R^2	0.935	0.946	0.835	0.852	0.742
F	175.793	204.744	51.744	56.289	29.287
Significance	0.000	0.000	0.000	0.000	0.000

Table 5
: Technological trajectories and learning processes (Nigeria)

Technologies→ Dep. variables	CAD/CAM	FMS	MIS	Email	Internet
Training	0.507*** (3.187)	0.161 (1.185)	0.220 (1.324)	0.365 ** (2.040)	0.427*** (2.879)
Learning by doing	−0.516*** (−3.212)	−0.245 * (−1.768)	0.288 * (1.720)	−0.289 (−1.577)	−0.410 ** (−2.706)
Internet searching	0.106 (0.664)	0.560 *** (3.952)	−0.015 (−0.088)	−0.009 (−0.050)	0.151 (0.943)
Learning by inter-action	0.060 (0.450)	0.184 (1.360)	0.125 (0.801)	0.267 (1.523)	0.149 (0.934)
Overseas training	0.272 * (1.754)	0.182 (1.346)	−0.172 (−1.055)	0.272 (1.545)	0.419*** (2.789)
R^2	0.313	0.607	0.239	0.303	0.521
F	4.465	9.874	2.633	2.873	6.948
Significance	0.002	0.000	0.037	0.029	0.000

Switched Telephone Network (PSTN), a source that is largely unreliable and often technically insufficient for browsing the Internet. Hence email-using firms did not consider Internet searching an adequate tool for skill enhancement. MDs of portal using firms attach significant importance to training (in-house as well as overseas) and learning by interaction in knowledge upgrading. This certainly confirms our hypothesis namely that portals provide a great deal of opportunities for users to interact and learn from each other. In fact portal is the most effective way for interacting with other business partners.

Table 4 presents the regression analysis results for Uganda. It shows clear differences in the types of e-business technologies used by Ugandan and Indian firms. Not a single Uganda firm in the sample had its own web site. They were also not using portal based e-business technologies.

Again, all the sample firms preferred overseas training as an important mode of learning. While in-house training was rated very important by all the firms except by email and the Internet using firms, searching through the Internet emerged significant in MIS using firm only. The relationship between learning-by-doing and FMS using firms emerged significant but negative. One possible explanation could be that MDs of FMS using firms strongly felt that learning-by-doing could not be an effective means of skill upgrading for firm-specific technologies such as FMS. Similar arguments could be extended to explain the negative but significant relationship between MIS using firms and overseas training. Evidently MIS using firms were not using e-business in production processes and hence they did not require overseas training for their workers.

Table 5 presents the parameter estimates and other statistics for Nigerian data. The Table shows that the types of e-business technology utilized by Nigerian firms are relatively more advanced (CAD/CAM) than Ugandan firms but the Nigerian firms were not using web and portal based e-business technologies, unlike some Indian firms.

Unlike Ugandan firms, the MDs of many of the Nigerian firms did not rate overseas training as an important source of knowledge accumulation, the only exception being CAD/CAM using firms which is understandable because workers would need special training that might not be available locally. The positive relationship between the Internet using firms and overseas training could also be because of the high probability that Internet using firms are likely users of CAD/CAM also. Like firms in the other two countries, MDs of Nigerian firms gave due importance to in-house training. Surprisingly the coefficient of learning-by-doing emerged significant but negative in all the regressions except MIS using firms. One of the reasons could be that MDs of advanced technology (FMS and CAD/CAM) using firms did not consider that learning-by-doing could be a very effective means of knowledge acquisition for this type of technology. This conjecture was confirmed during our interviews. Firm owners that have adopted fairly advanced e-business techniques tend to have overseas affiliation and Nigeria, on-going technical collaboration with partners.

The results presented in the above tables suggest that in general and cutting across countries, learning-by-doing is indeed an important source of knowledge acquisition and accumulation. However, this mode of learning becomes less effective in cases where a firm adopts advanced technologies. Another significant result is that in the era of ICT induced manufacturing revolution, MDs of sample firms have found searching through the Internet a very effective way of learning in India. This may well be because industrial clusters from where sample firms have been drawn enjoy fairly superior communication infrastructure. Consequently, MDs of these firms have found Internet searching a reliable and fairly rapid way of learning than organizing formal local and overseas training, important as the latter is for specific technologies. The reliable communication network promotes learning through interaction with other business partners. The emergence of learning-by-interaction as a significant mode among Indian firms illustrates the point.

The sample firms in Uganda and Nigeria, however, assigned more importance to training compared to searching through the Internet. The phenomenon can be explained by the same argument. Apparently, due to lack of reliable communication network, firms in these countries resort to organized training as a viable alternative way of learning than Internet browsing. Firms in Uganda and Nigeria although for different technologies, rate overseas training as a very important source of learning whereas MDs of Indian firms depend less on this source. This could be because in the last two decades, the Government of India has established several industrial clusters where the private sector has been allowed to provide technological infrastructure including human resource development institutions. Consequently Indian firms would have less need of overseas training in advanced technologies than the other two countries.

7. Summary and conclusions

This study investigated the differentiated effect of wider sets of firm level skill on the learning processes in SMEs in a number of developing countries. We distinguished a pattern of adoption that shows clear relationships between internal firm variables, and external infrastructure features that influence both the technological trajectories and firm-level performance. There is a certain gradation of adoption that displays skill-technology complementarily. There is net correlation between firms using advanced technologies and the education level of owners and a consistent correlation between learning modes and complexity of ICT in use. New types of SMEs, called networked enterprises have emerged during the last decade (Raymond et al., 1999). However, our study suggests that this phenomenon is not automatic; there is a strong association between the complexity of firm-level e-technologies and the level of national technological capability (Oyelaran-Oyeyinka and Lal, 2004). Several scholars (Raymond et al., 1999; Blili and Raymond, 1993) have called attention to the threat and opportunities that come with the adoption of ICTs in SMEs. There is also considerable scope for institutional learning in SMEs suggesting new and additional challenges for developing countries that for now have relatively weak institutions.

This study also examines whether the introduction of ICTs has induced changes to the technological trajectories of firms with data form India, Nigeria, and Uganda. Data on various aspects of learning processes and technological profile were collected through a semi-structured questionnaire during June 2002 and January 2003. Regression analysis was used to identify the relationship between the learning processes adopted by the sample firms and technological trajectories followed by them. Several modes of learning such as in-house training, learning by doing, Internet searching, learning by interaction, and overseas training was included in the analysis.

The results of the study suggest that cutting across country and sector, SMEs have identified learning-by-doing as the most effective mode of knowledge acquisition. The choice of the second mode of learning differs among sample countries. For instance MDs of Indian firms employed Internet searching as the second best mode of learning while in-house training has been preferred in Nigeria and Uganda. One of the possible reasons we advanced could be inadequate communication network facilities for effective use of the Internet in Nigeria and Uganda. The use of the Internet is significantly determined by the availability of reliable communication network. Findings of the study also suggest that firms that adopted complex technologies had to employ overseas training for effective use of such technologies. The finding is akin to other studies (Raymond et al., 1999; Blili and Raymond, 1993).

It is also found that learning processes have significantly influenced the technological trajectories of firms. Indian sample firms have adopted ICT-led technologies in production processes. We found several firms in India that were doing business through web-enabled and portal based technologies while there was not a single firm that adopted such advanced technologies in Nigeria and Uganda. Two factors might have contributed to the adoption of advanced technologies by Indian SMEs. One, the effective accessibility of Internet connectivity and second, the availability of requisite technological infrastructure in clusters where sample firms were located. Reliable access of Internet might have encouraged firms to use Internet searching as the second best mode of learning by Indian SMEs. On the other hand, the sample firms in other two countries used technologies that did not require a strong communication network. The firms in Nigeria and Uganda adopted MIS, Email, CAD/CAM, CNC machines, and FMS. Such technologies do not require online connectivity and hence the dependence on strong communication network is not very high. This leads us to conclude that learning process significantly influenced the technological profile of firms. To this end, the choice of learning processes depends on other external factors that are beyond control of individual firms.

The study suggests several policy implications. First, SMEs need institutional support for their survival in the era of globalization. Second, human development policies aimed at SMEs need to emphasize both general and specific knowledge types and training. The adoption of advanced e-business technologies by Indian SMEs is a proof of this point. The burden and risk had been shared with the encouragement given by the Government of India (GOI) for private sector participation in providing technological infrastructure in industrial clusters. Consequently SMEs have better access to web-enabled and portal based e-business technologies in India relative to the two African countries. However, the GOI still has to take initiative for providing uninterrupted utility services so that SMEs can become more competitive in international markets. Finally, the study suggests that SMEs in Nigeria and Uganda need much greater infrastructural support in order for them to reap the benefits of ICTs and to develop the capabilities to contribute to economic development. Proper policies and programs aimed at providing required infrastructure need to be initiated in developing countries in order to make SMEs more competitive in the domestic and international markets.

Appendix A. Learning processes and type of e-business technologies

Learning mode→ E-business technologies	Training	Learning by doing	Internet searching	Learning by interaction	Overseas training	Total users
India						
FMS	4 (80.00)	5 (100.00)	5 (100.00)	5 (100.00)	5 (100.00)	5
MIS	152 (66.67)	214 (93.86)	186 (81.58)	158 (69.30)	143 (62.72)	228
Email	122 (69.71)	167 (95.43)	144 (82.29)	122 (69.71)	110 (62.86)	175
Web site	48 (63.16)	73 (96.05)	64 (84.21)	57 (75.00)	57 (75.00)	76
Portal	22 (88.00)	23 (92.00)	22 (88.00)	24 (96.00)	21 (84.00)	25
Total Firms	231	231	231	231	231	231
Uganda						
CNC	20 (95.24)	16 (76.19)	19 (90.48)	19 (90.48)	19 (90.48)	21
FMS	20 (95.24)	15 (71.43)	19 (90.48)	19 (90.48)	19 (90.48)	21
MIS	25 (89.29)	21 (75.00)	19 (67.86)	21 (75.00)	18 (64.29)	28
Email	17 (89.47)	14 (73.68)	16 (84.21)	17 (89.47)	17 (89.47)	19
Internet	19 (86.36)	15 (68.18)	18 (81.82)	17 (77.27)	17 (77.27)	22
Total firms	84	84	84	84	84	84
Nigeria						
CAD/CAM	7 (100.00)	4 (57.14)	2 (28.57)	4 (57.14)	2 (28.57)	7
FMS	6 (100.00)	4 (66.67)	3 (50.00)	4 (66.67)	2 (33.33)	6
MIS	28 (87.50)	29 (90.63)	2 (6.25)	13 (40.63)	1 (3.13)	32
Email	14 (82.35)	12 (70.59)	3 (17.65)	10 (58.82)	3 (17.65)	17
Internet	8 (100.00)	5 (62.50)	3 (37.50)	5 (62.50)	3 (37.50)	8
Total firms	105	105	105	105	105	105

Note: Figures in parentheses are row percentages. Percentages are not expected to add to 100% because of multi-response of MDs.

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