Full Length Research Paper

Science and Technology Knowledge Management in the ICT Sector in Emerging Economies: Policy Options for Nigeria

Jegede, O.O* and Ojo, B.F.

National Centre for Technology Management, Obafemi Awolowo University, Ile-Ife, Nigeria

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The study showed how Science and Technology (S&T) knowledge was managed in the Information and Communication Technology (ICT) Sector of three selected countries that have been categorised as emerging economies. This was done to recommend policy options for Nigeria so as to develop the sector and improve the percentage contribution of the ICT Sector to Nigeria’s Gross Domestic Product (GDP). The Study used secondary data. Data were sourced from different published sources, internet and company records. Three Asian countries (China, South Korea and India) were selected for the study owing to their global contribution in the areas of electronics and semi-conductors. The study found out that China acquired S&T knowledge by massively investing in research and development (R&D); this was achieved by increasing the amount of the GDP allocated to R&D by 87.5% within 17 years. China also increased their scientific and technological research by 16.5% annually and also sponsored a large number of Ph.D students in the United States which increased China’s annual doctorate degree by 18.7%. South Korea companies, on the other hand, developed their S&T knowledge skills by initiating, imitating, improving and innovating knowledge gotten from external source. This helped Korean firms to overtake their pioneers in the US and Japan within twelve years in the semiconductor industry. India strategy for knowledge management was anchored on the effective collaboration between the industry and the knowledge centres (university and research institutes) and in-house R&D activities. In conclusion, the study found out that Nigeria can adopt and adapt any combination of these policies. Though some of these polices cannot be directly deployed in Nigeria owing to the peculiarity of Nigeria which is characterized by political instability which in turn aggravates policy precariousness. There are other potential limiting factors like social acceptability, infrastructure and poverty level and would influence which policy fits well. The study also recommended strategic implications for practice for the ICT companies while advising government on policy.

Keywords: R&D Intensity, Scientific Outputs, Imitation, Innovation, Collaboration.

INTRODUCTION

Knowledge management can be defined as the discipline of enabling organizations to collectively and systematically create, share and apply knowledge, to better achieve their objectives (Riege, 2005). Knowledge management is built around the cumulative experiences and practices of the individuals in a certain discipline. It relies heavily on the attitude and willingness of professionals to share their knowledge with others. In this respect, knowledgesharing practices and initiatives forms a key component of knowledge management programs, in terms of organizational and individual learning (Riege, 2005).

Knowledge is important to a country, a professional may feel that knowledge which he/she owns is his/her intellectual assets and will be too mean to spare. Therefore, government and institutions have to activate the knowledge sharing process by using the knowledge management policies (Abaaoud, 2009). This will lead to innovation and hence enhance their competitive advantages. Knowledge management is carried out in Nigeria through technology acquisition which is assisted and monitored by National Office of Technology.

* Corresponding author: jegede.seye@yahoo.com
Technology acquisition management is one of the most important determinants for the development of any country. Firms which complement technology imports with intra-firm technology transfer and in-house development are better positioned to bring about technological paradigm shifts and so increase their competitiveness (Hitt et al., 2000; Narayanan, 1998).

There are different ways through which technology can be acquired: through direct purchase, foreign direct investment, acquisition of machinery and equipment with embodied technology; but the most important approach to enable adaptation, assimilation and development of imported technology is in-house research and development.

Firms in developing countries do not only engage in research and development for process or product innovation alone but to improve and maintain their capabilities to assimilate and exploit externally available information (Narayanan, 1998). It is therefore deemed necessary for a developing country like Nigeria to engage in both in-house development initiatives and external technology acquisition in order to improve company competitiveness (Grant, 1991; Grant, 1997; Jegede et al., 2011).

Literature have shown that there is a strong link between a firm’s technology acquisition ability and its competitiveness (Al-Dawoud et al., 2011; Freeman, 1982; Freeman et al., 1994; Narayanan, 1998). According to Daim and Kocaoglu (2004), technology acquisition is “Obtaining and adapting new technologies through know-how, hardware, software, design and manufacturing capability for improved performance and long-term competitiveness.” Therefore technological capability of a firm is a key success factor for a successful technological acquisition to take place (Jegede et al., 2011). (Daim and Kocaoglu, 2004) In similar paper asserted that external technology acquisition can be helpful as a growth strategy to reduce the time required to commercialize a technical concept. They also argue that different technology acquisition strategies may be employed to achieve different company goals depending on the size of the company. For example, a small company that intends to improve its market share or new product development competitiveness may use in-house development or vendors as a technology acquisition strategy while a large company that intends to improve organizational and operational competitiveness may use networking, research and development as a technology acquisition strategy.

The level of development of any country can be directly correlated with the level of technology available to it (Fabayo, 1996; Oyeyinka, 1996). Due to low technological capability in Nigeria, indigenous firms have resorted to external sourcing of technology in an unmodified state. This situation has led to inadequate utilization of domestic resources, including environmental resources, and it has led to minimal linkages between different sectors of the economy because foreign technologies are designed for foreign economies (Fabayo, 1996; Jegede et al., 2011; 2012).

The Nigerian Information and Communication Technology (ICT) Industry

The ICT industry in Nigeria covers electronics, computers, broadcast, telecommunications and e-commerce activities (Adereimi, 2010). (Oyeyinka, 2007) defined ICT infrastructure as all physical facilities and technologies engaged in delivering and disseminating information and communication services in telecommunications, broadcasting, cable television service, postal service, publishing, printing, computer networks, and a wide range of terminal equipment cited in Adereimi (2010).

Since the deregulation of the ICT industry, private players have ventured into the industry thereby creating competition between the new entrant (private firms) and the former dominators. This has increased employment in the country and above all has contributed immensely to the GDP. However, majority of the ICT devices used in Nigeria are imported and there is significant knowledge gap between the firms in Nigeria and their industrial forerunners. Also there seems to be low interaction within the key actors in the industry also leading low technological and ineffective knowledge management which in turn has led to a weak innovation system (Adereimi, 2010; Olamade, 2001). More so, the level of contribution from government ministries and agencies has not materialized to significant technological competence as policies to drive learning and acquisition of skills from the multinational (technically competent) firms have not been enforced.

This paper carried out a study on how three emerging economies (China, Korea and India) acquired and managed technological knowledge and how they have used the knowledge to reposition themselves in the world, with a view to providing sound policy advice to the Federal Government of Nigeria and Ministry of Communications Technology to enable them to drive the industry with adequate policies that would help develop and increase technological capability within the indigenous firms through technology acquisition.

METHODOLOGY

The main methodical concepts adopted for this study, is based on what has been established in literature on Science and Technology (S&T) knowledge management in emerging economies who have built technological capabilities and have in turn innovated and are now globally recognized in the field of ICT. The study focused on three Asian countries (China, South Korea and India). These countries were purposefully selected because they
have the highest volume of exports in ICT products. Data were collected from published sources and were subjected to content analysis. This paper presented result that showed how these countries (so called Asian Tigers) were able to acquire and manage technological knowledge and how they have used it to be globally recognized.

RESULTS AND DISCUSSION

This section presents a detailed content analysis of secondary data that were sourced from literature.

China

China embarked massively on knowledge management investment alongside R&D to get to where they are now because their political leaders gave priority to S&T. In 1985, the Chinese government came up with a management reform scheme on S&T; the reform was designed to build a linkage relationship between scientific research and the production unit [Lundvall, 2011]. China managed technology through 3 processes viz:

Increased Percentage of GDP Allocated to R and D

Arond and Bell (2010), posited that China increased their R&D efforts from 3% to 9% of the world’s total R&D within a seventeen year period (1990 - 2007) and also increased their research intensity (R&D as percentage of GDP) from 0.8 to 1.5 within the same period. Taking a look at table 1, in 1990, United States had 38.2% of the world R&D share; China had only 3.0%. By 2007, China’s R&D share had increased to 9.2% representing over 300% increment as against United States that had a decline in their world share of R&D by 9%. Japan, on the other hand, had a decrease of 20% in world total R&D share in 2007. More so, China’s R&D investment rose from 0.8 in 1990 to 1.5 in 2007 representing 87.5% increment within seventeen years. China’s massive investment in R&D was responsible for the 8 to 10% annual growth in its GDP (Arond and Bell, 2010).

Increased Scientific and Technologically Research

China’s massive investment in R&D in turn contributed to a proportionate increase in scientific production (Veugelers, 2010). The numbers of publications in China increase at the rate of 16% per year within 15years (1990 to 2005), while that of United States, European Union and Japan were 0.5%,1.0% and 2.0% respectively (Table 2).

Training of large numbers of PhD students

Training of large numbers of students in higher degrees in developed countries sponsoring a large number of students to study aboard was part of the reforms China embarked upon. In 2005 only, no fewer than four hundred thousand Chinese were trained in United States and this translated to exclusive growth in both volume of publications and doctorate degree holders. The annual growth rate of PhD degree holders between 1995 and 2005 was 18.7% in China while Japan recorded 2.9%, Germany 1.0% and United States 0.4 % (Table 3).

### Table 1. R and D share and R and D Intensity in US, Japan and China Source: (Arond and Bell. (2010)

<table>
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<tr>
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<tbody>
<tr>
<td></td>
<td>Share</td>
<td>R&amp;D Intensity</td>
<td>Share</td>
</tr>
<tr>
<td><strong>United States</strong></td>
<td>38.2</td>
<td>2.3</td>
<td>37.2</td>
</tr>
<tr>
<td><strong>Japan</strong></td>
<td>16.3</td>
<td>3.1</td>
<td>13</td>
</tr>
<tr>
<td><strong>China</strong></td>
<td>3</td>
<td>0.8</td>
<td>6.7</td>
</tr>
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</table>

### Table 2. Contributions to scientific production between 1995 and 2005 Source: Veugelers (2010)

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<tbody>
<tr>
<td><strong>United States</strong></td>
<td>34</td>
<td>31</td>
<td>29</td>
<td>0.50%</td>
</tr>
<tr>
<td><strong>EU</strong></td>
<td>35</td>
<td>35</td>
<td>33</td>
<td>1%</td>
</tr>
<tr>
<td><strong>Japan</strong></td>
<td>8</td>
<td>9</td>
<td>8</td>
<td>2%</td>
</tr>
<tr>
<td><strong>China</strong></td>
<td>1.6</td>
<td>2.9</td>
<td>5.9</td>
<td>16.50%</td>
</tr>
</tbody>
</table>
Table 3. Number of doctorate degrees awarded within (1995-2003) and the annual growth rate Source: Veugelers (2010)

<table>
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<tr>
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<tbody>
<tr>
<td>United States</td>
<td>41.747</td>
<td>40.74</td>
<td>0.40%</td>
</tr>
<tr>
<td>Germany</td>
<td>22.387</td>
<td>23.043</td>
<td>1.50%</td>
</tr>
<tr>
<td>Japan</td>
<td>12.645</td>
<td>16.314</td>
<td>2.9</td>
</tr>
<tr>
<td>China</td>
<td>4.364</td>
<td>18.806</td>
<td>18.70%</td>
</tr>
</tbody>
</table>

Table 4. Gap between Korea and other advanced countries in the semiconductor industry Source: Kim, (1997)

<table>
<thead>
<tr>
<th>Development Time</th>
<th>64K DRAM</th>
<th>256K DRAM</th>
<th>1M DRAM</th>
<th>4M DRAM</th>
<th>16M DRAM</th>
<th>64M DRAM</th>
<th>256M DRAM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gap</td>
<td>4 years</td>
<td>2 years</td>
<td>1 year</td>
<td>6 Months</td>
<td>3 Months</td>
<td>Same</td>
<td>Ahead</td>
</tr>
</tbody>
</table>

innovation output. This was achieved as a result of the emphasis Chinese leaders placed on learning and R&D investment.

Korea

Ali et al., (2011) in their study "A case study on a process model of knowledge absorptive capacity of technological effective knowledge management: A case of Samsung electronics" reported that Korean companies were able to develop their knowledge retentive skills by initiating, imitating, improving and innovating knowledge gotten from external source. Developing countries are therefore advised to follow thus as there are statistical data that shows the positive implication it has on their economy. Samsung, a Korean company was the first in the world to exceed KRW100 trillion in sales and KRW10 trillion in net income with a revenue of US$ 119.1 billion and an operating profit of US$ 9,920 million (Ali et al., 2011). Samsung exceeded Sony (a Japanese company) in 2005 to become the world largest producer of electronics. Samsung also surpassed Motorola in 2007 to become the world’s second largest mobile phone maker. In 2009, Samsung became the world’s largest technology company with a sales of KRW139 trillion globally thereby overtaking Hewlett-Packard (US) and Siemens (Germany) while only joining the industry in the 1980’s concentrated efforts on R&D investments in electronics and building core competence in semiconductor (Kim, 1997).

There was high influx of FDI to Korean in the 1980’s which unfortunately did not translate to knowledge and technological transfer or spill over because the foreign firms were keeping fundamental knowledge (especially the technical know-how) from the indigenous firms. Koreans were spurred by this disappointment and this initiated them to start building indigenous technological capabilities.

In the early stage of their development, Samsung lacked the technical know-how since they could not learn from the foreign companies. Their strategy was to imitate products and processes from the foreign companies mainly through reverse engineering. At that time, the output was sub-standard though very cheap. Korea knew she had to improve which led to the third stage of their development. This was achieved by inviting experts (majorly Koreans who have studied abroad and have worked with some foreign companies) to lead and train the production/engineering crew. This had a multiplier effect in the industry as expertise was developed within the shortest time span. The wealth of new knowledge combined with the experience of the experts (Trainers) led to innovation in the Korean semiconductor industry (Ali et al., 2011; Chang, 2008; Kim, 1997.). The process through which Koreans managed their S&T knowledge can be analysed using Samsung Electronics as case study (Table 5).

Just before the 80’s, Korea was 4 years behind her pioneers in the US and Japan, by 1992 (twelve years later), they were contemporaries with US and Japan and by 1995, they were already ahead of US and Japan in the semiconductor industry (Table 4). This was achieved because they had built so much competence in process technology through intensive R&D (Choi, 2010). The process through which Korea evolved to build core competence in DRAM technology development is given in table 5. Samsung did not only outshined their competitors in DRAM only but they also did in NAND Flash production, LCD, active matrix OLED, and television set.
India

India strategy for knowledge management was anchored on the effective collaboration between the industry and the knowledge centres (university and research institutes) and in-house R&D activities. India invested so much in R&D as they allocated 0.98% of their annual GDP to R&D and there was a suggestion by the Minister Panaji Kumar in 2011 that it should be increased to 1.5% to 2% of GDP (NIO conference, 2011). Joseph and Abraham (2011) conducted a survey in the ICT sector by exploring the interaction between ICT industry and research institutes within India and outside the country. Their study revealed that there was a high degree of interaction between the university and the industry especially with the multinational companies whose headquarters are located in India as compared with their subsidiaries and even lower in their stand-alone firms. The nature of university interaction by the multinational companies based in India tends to suggest that the underlying objective of fostering interaction with universities at present is to ensure that graduates from the universities are industry ready such that the cost of in-house training is reduced. The industry collaborated well with universities by recruiting students to the firms. These have helped the country to produce graduates who are relevant to industrial growth cause they already possess the require skills needed to function well in the industry as a result of constant integration of knowledge acquired in school with the industrial skills that they are been exposed to the Universities adjusted well to this by updating their curriculum to meet the requisite skills required by the industry so as not to produce graduates who possess "certificates" and cannot deliver on their jobs. The Universities updated their syllabus based on feedback they got from the industries where their students were interns, because universities also came to the understanding that for knowledge to be well transferred and effectively deployed, universities and industrial sectors must argument one another.

India firms internationalized their strategies and did not outsource any of its companies to another instead it was shared amongst subsidiaries of same firm [Joseph and Abraham, 2011]. They also made sure they had subsidiaries in developed counties where foreign and well experienced expatriates were employed and issues with the technical know-how were given to them to solve and even at that the technologies developed by this expatriates were firm specific and internally generated by the Indians. Collaboration was found highest with North American universities and research institutes. This needs to be seen in terms of the fact that North America accounted for highest share of IT export from India (Joseph and Abraham, 2011). They so much sought after knowledge by making their clients and suppliers as the source of knowledge for innovation. They do not outsource their R&D to other agencies; they simply buy foreign firms and turn them to a knowledge centre where the necessary foreign knowledge can be accessed by the indigenouse research centre. Meanwhile, the R&D activities of the acquired firms now focused on what the home customers’ demand (Joseph and Abraham, 2011).

Table 5. Comparative global market share (Samsung and global firms) Source: Wikipedia

<table>
<thead>
<tr>
<th>Product</th>
<th>Samsung Global M/S</th>
<th>Competitor</th>
<th>M/S</th>
<th>Year</th>
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<tbody>
<tr>
<td>DRAM</td>
<td>40.60%</td>
<td>Hynix</td>
<td>19.80%</td>
<td>Q3 2010</td>
</tr>
<tr>
<td>NAND Flash</td>
<td>40.40%</td>
<td>Toshiba</td>
<td>33.10%</td>
<td>Q3 2010</td>
</tr>
<tr>
<td>Large Size LCD Panel (Revenue)</td>
<td>26%</td>
<td>LG Display</td>
<td>25.90%</td>
<td>Q3 2010</td>
</tr>
<tr>
<td>Active Matrix</td>
<td>97%</td>
<td>LG Display Auto</td>
<td>1-3%</td>
<td>2010</td>
</tr>
<tr>
<td>Lithium-ion Battery</td>
<td>18.70%</td>
<td>Sanyo</td>
<td>19.40%</td>
<td>Q1 2010</td>
</tr>
<tr>
<td>LCD Monitor</td>
<td>18%</td>
<td>Dell</td>
<td>12.80%</td>
<td>2009</td>
</tr>
<tr>
<td>Hard Disk Drive</td>
<td>9%</td>
<td>Seagate Technology</td>
<td>31%</td>
<td>Q4 2009</td>
</tr>
<tr>
<td>Television Sets (LDC, CRT, PDP, LED)</td>
<td>17.20%</td>
<td>LG Electronics</td>
<td>14.80%</td>
<td>Q3 2009</td>
</tr>
<tr>
<td>Mobile Phone</td>
<td>21%</td>
<td>Nokia</td>
<td>32.40%</td>
<td>Q3 2010</td>
</tr>
<tr>
<td>Digital Camera</td>
<td>11.80%</td>
<td>Sony</td>
<td>17.40%</td>
<td>2010</td>
</tr>
</tbody>
</table>

CONCLUSION (OPTIONS FOR NIGERIA)

This study showed that different countries adopted different strategies to build technology capability in ICT. While China embarked on endogenous innovation which involved massive investment in R&D, increased scientific outputs (publication, patents, copyrights, etc) and advancement in professional background (doctorate degrees), Korea adopted industrial reform which was carried out as initiation imitation, improvement and innovation. India’s effort, on the other hand, concentrated on intensifying university-industry interaction and ownership of R&D departments either within India or in foreign countries.

Nigeria, a developing country with some level of competence in ICT knowledge can adopt and adapt one/any combination of these policies that have proven to work in these Asian countries. However, some of the policies cannot be directly deployed in Nigeria owing to the peculiarity of Nigeria which is characterized by
political instability which in turn aggravates policy instability. There are other potential limiting factors like social acceptability, infrastructure and poverty level that would influence which policy fits well.

China’s approach rests largely on government efforts. The role of government will be to increase the proportion of GDP allocated to R&D and to also improve their R&D share of the of world’s total. The current R&D intensity in Nigeria is 0.2% which is very low when compared to these modelling countries. To achieve a significant development within the shortest time frame the amount of GDP allocated to R&D should not be less than 1%. This has been adopted in some developing countries viz; Botswana, South African, Egypt e.t.c.(AIO, 2010). Nigeria government should also fund research by providing grants to researchers, educators and inventors as this will increase the overall scientific output. Researchers should be encouraged to increase their scientific outputs (publications, patents, copyrights, inventions) while Government should create an enabling environment (Incubators, Science Park, Intellectual Property and Technology Transfer Offices and Industries) where these scientific outputs can be transformed to innovations.

Korea’s approach appears to be the best for Nigeria to adopt because there has been the existence of technology market clusters in Nigeria which are actively involved in reverse engineering, repairs and maintenance of different categories of ICT product: the computer village (Otgiba Market) cluster in Ikeja (Computers and Telecommunication devices), the Alaba International Market in Lagos (Electronic and Electrical equipment) etc. Nigeria can imitate policies that would encourage in-house innovation which would be achieved by imitating products from developed countries mainly through reverse engineering (which is already taking place) and due to the firms proximity to one another, there is ample opportunity for knowledge spill over and technological learning among the firms and in the process, the firms would build some level of capabilities through interaction. At this point, the product might be substandard, and would require additional knowledge to improve on the products maybe from the knowledge centres. An integration of industry cluster with knowledge centres will lead to innovation. But the social attitude of Nigerians towards imported goods might hamper this policy because an average Nigerian has bias for imported products.

The India’s approach maybe the cheapest and easiest for Nigeria because there is already an educational policy towards achieving this. The students industrial work experience scheme (SIWES) mandates all undergraduates in the field of engineering and applied sciences to undergo industrial training in their second, third and fourth grade before they earn their degree but the major constraint is that the firms do not give the university students space to learn. Some tend to hide knowledge (competence) from the students and they give them jobs that are not relevant to their field.

**RECOMMENDATIONS**

These suggestions which are best considered as strategic implications of the study are laid out in this subheadings

**Strategic Implications for Government’s policymaking**

To enhance effective knowledge management in Nigerian indigenous ICT firms and ensure that the knowledge becomes more expressive, it is particularly important to:

i. drive interactions among educational/research institutions and industrial firms with appropriate policies;

ii. Address the challenge of infrastructural constraints as a matter of urgency. Firms would be well assisted if they can make use of highly-subsidized public utilities in their production; and

iii. Attract key actors, particularly suppliers, closer to the firms through government interventions because firms will not always have what it takes to attract these actors. Ways to do this include encouraging suppliers of materials and machinery to establish local workstations and outlets, with explicit support from government. This will reduce the cost of procurement that accrues to domestic enterprises.

**Strategic Implications for Firm’s Practice**

For the Nigerian ICT firms, the following specific suggestions are useful for the build-up of effective knowledge management:

i. Firms are required to improve their absorptive capacities by creating regular programmes for staff development, and making the necessary investments.

ii. Firms should make efforts to interact with government, knowledge institutions and other key actors of the sectoral innovation system.

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