Review paper

Patenting and Technology Entrepreneurship in Nigeria: Issues, Challenges and Strategic Options

Abstract

Patent is a useful indicator of scientific outputs and techno-economic activities of countries. It can be used to provide opportunity for linkages between research and industrial organisations in an economy. However, it has not been adequately utilised by several developing countries in Africa, including Nigeria. Commercialisation of research results could be done through diverse means including technology licensing and spin-off activities. Nevertheless, Nigeria with several universities and research institutes has developed few inventions without deriving much benefit from them. This could be as a result of low investment in innovation infrastructure such as technology incubators and science parks, and low patent culture among researchers. The commercialisation process is also impeded by lack of venture capital, poor entrepreneurship culture among researchers, and poor linkage among the elements of National Innovation System (NIS). This article proposes deliberate efforts by the government to create platforms for interaction between research institutions and industries through science parks, technology incubators and increased venture fund. It is concluded that full implementation of the new science, technology and innovation policy is a necessary condition for addressing innovation gap and the challenges of technology commercialisation in Nigeria.

Keywords: **Patenting, technopreneurship, STI, science parks, incubator, and Nigeria**

1.0 Introduction

It is pertinent to note that development of any nation does not hinge only on the natural resource endowments but rather on the stock of knowledge available and how such knowledge is deployed to solve practical developmental problems. Relying simply on rich endowments of natural resources and cheap labour, without any contribution of 'intellectual added value', has been and continues to be a dead end for development (Sutz, 2005). Furthermore, education and skill levels are recognised as one of the key sources of growth and competitiveness in the global economy (Dahlman and Utz, 2005). Consequently, countries' competitiveness depends, more than ever, on their abilities to access, adapt, utilise, and create new knowledge. It has also been established that the contribution of knowledge to economic competitiveness and social welfare in countries that have adopted scientific stance for development, experience sustainable growth than others. Therefore, knowledge is a crucial tool for overcoming underdevelopment. This is because the application of knowledge in research and development (R&D) activities can lead to the development of inventions, which entrepreneurs could turn into innovations. Hence, knowledge economy cannot be separated from Science, Technology and Innovation (STI) management. For instance, Singapore moved from 'third' country to 'first' within three decades as a result of strong leadership and strong emphasis on the application of scientific endeavors to development. Similarly, S. Korean commitments to S and T engagements transformed the

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country from imitator to innovator in less than three decades. These two examples show how active and serious engagements in scientific endeavour, over time, could bring socio-economic and technological development to nations. Our argument in this article is that for Nigeria, and indeed developing countries to achieve industrial development, investment in education, skill development and R&D activities, and more importantly, exploitation of ensuing inventions are key to socio-economic development. This article reviews extant literature and examines government initiatives on STI, national competitiveness and other efforts. Some of these efforts include development of roadmap to overcome development challenges and ensure research commercialisation within the innovation system. Challenges of patenting and the need to grow pools of technology entrepreneurs, nurture them and create conducive business environment for start-up business to thrive are also discussed in this article.

2.0 Position of Science Technology and Innovation in Economic Development

Science, Technology and Innovation (STI) constitute a very important factor with great potential to galvanise economic growth and development in any nation. The need for STI in bridging the gap between resource ownership and resource development for accelerated growth becomes critical for economic development and national wealth, particularly in resource-rich African States. Prusak (1996) identified the disparity in the development of STI as one of the major factors responsible for the gap between the industrialised nations and the developing economies of the world. While resource endowment is good for a nation, the potential to exploit and transform such resources into valuable and exportable products can only be achieved through the deployment of appropriate scientific and technological knowledge. This gives birth to innovative products or services in an economy. Also, it explained the emphasis of Joseph Schumpeter on innovation as the only source of industry and economic renewal. Schumpeter was among the best known economists with an interest in entrepreneurship, and perhaps, the first major economist to analyse the role of entrepreneurship in economic development, whose interest and writing on entrepreneurship in the twentieth century is much relevant to innovation studies today. In his economic theory, Schumpeter (1934) treated innovation as an endogenous process and the entrepreneur as an innovator and prime mover in the economic system who introduces innovations in the form of new products, methods of production, markets, investment goods or re-organisation of industries. He posited that economic growth resulted not from capital accumulation, but from innovations or new combinations, hence innovation and entrepreneurship are the engines of change in the economy. Furthermore, in defining technological entrepreneurship, emphasis was placed on the possession of innovative skills for the creation of new products; new processes; markets and new forms of organisation. For instance, developed economies like United States of America, United Kingdom, Germany, France and Japan were able to achieve global competitiveness and rapid industrial development by harnessing science and technology (S&T) in their developmental efforts (Bayh, 2006). Recent accelerated development experience of the Asian Tigers like South Korea, Malaysia and Taiwan also reflects the application of modern S and T in their economies. Based on these experiences, many developing countries are becoming increasingly aware of the need to dedicate their efforts to acquiring requisite S and T knowledge and the development of indigenous capability, to fast-track the economic growth and developments in their nations.

For the underdeveloped economies to move up the development ladder, they need to pursue a rigorous acquisition and application of S&T knowledge that could transform the different sectors of their economies, especially the industrial sector. In addition, a realisation of the importance of innovation in bringing the improved products and services to the market is also required for rapid economic growth. This view was strongly supported by Sharma (2006) assertion that innovation and technology are indispensable for the transformation of countries from mere reliance on the exploitation of natural resources to technological innovation as the basis for development. Oyelaran-Oyeyinka (2006) also recommended that to achieve increased efficiency, growth and sustainability, there should be continuous improvement in all the sectors of the economy.

3.0 Technological Entrepreneurship: Definition, Concept and Benefits

Technological Entrepreneurship (TE) is synonymous to the commercialisation of technological discoveries or the establishment of new business ventures based on new technological discoveries. According to Bailetti (2012), TE involves investment in project that assembles and deploys specialised skills and heterogeneous assets that are intricately related to advances in S and T knowledge for the purpose of creating and capturing value. Therefore, TE involves the use of S and T knowledge to create value. In fact, this differentiates TE from mere trading activities or ordinary entrepreneurship. Also, Therin (2007) noted that technology entrepreneurship, technical entrepreneurship, technopreneurs (techno-entrepreneur) had been used synonymously in scientific articles to represent TE. The emphasis of TE in this article is taken to mean establishment of firm(s) to commercialise inventions or technological breakthroughs from universities or research institutes.

Comment [A4]: TE involves an investment in a project

The emergence of knowledge economy has also contributed significantly to the necessity for utilising TE as an avenue for industrial development. Critical to generating commercialisable research outputs is the huge R&D funding which must be properly directed, focused and managed. In addition, a robust system of innovation is essential for technology commercialisation to occur and in most Developing Countries, especially in Nigeria, the system is weak. Detail of how TE can be accommodated within the national innovation system is discussed in the section 4 of this article.

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4.0 NIS and Technological Entrepreneurship

Comment [A6]: NIS: where is the full name?

Technology entrepreneurs play significant roles in technology commercialisation process in an innovation system. The NIS of any country consists of distinct institutions, which individually and jointly contribute to the development, and diffusion of new technologies (OECD, 1999a). The System, through its activities and interactions, initiate, import, modify and diffuse new technologies (Freeman, 1987). The NIS as a concept is used to evaluate innovativeness of a country, and it provides the framework on which governments form and implement policies to influence the innovation process (Metcalfe, 1995). Four key elements are identified within the NIS; they are Education and Research, Industrial Production, Finance, and Public Policy and Regulation. Each of the elements of NIS has some organisations or institutions that perform specific tasks towards the actualisation of the overall objectives of the entire system.

The Education and Research Element of the NIS include universities and specialised research institutes, whose functions are teaching/human resource development, conduct of research and transferring the results, in form of technology, to industry for exploitation. Universities are traditionally involved in the first two activities, but the third mission was added to their mandates since after the Second World War, in recognition of their contributions to the prosecution of the war. This third mission involves community service, that is, technology transfer to business sector (OECD, 1998). Fulfillment of this mission necessitates the creation of conducive environment for university researchers to engage in industry collaboration activities, particularly to commercialise research outputs, establish spin-offs and to stimulate entrepreneurial activities among the students and the academe. These are further necessary to justify investments in R&D activities at the universities while also fostering requisite human capital development.

It has been established that universities that engage with industry have access to industry funding and are able to pool better talents than universities who do not, though, contrary arguments exist. However, for the inventions that the Education and Research Element develop to be exploited industrially, researchers and students of the element should imbibe or embrace TE culture. With adequate training in TE, the researchers and students become technopreneurs who are better able to establish spin-off firms and face the rigors of innovation process. Similarly, the researchers are prepared to present their inventions to existing firms for exploitation. It is advisable that before the inventions are commercialised, they should be protected through patent, to guarantee investments' return and avoid unnecessary intellectual property legal battles.

The Industrial Production Element of the NIS includes the public and private sector firms that produce and sell goods and provide services. The Element comprise of the multinationals or Trans-National Corporations, micro-, small-, medium- and large Enterprises. In recent years, new generations of New Technology-Based SMEs, which are spin-offs or start-ups have been established to commercialise research outputs and technologies that originate from universities, government research institutes or private laboratories called their parent organisations. Research outputs from universities and the government is normally exploited by large companies, while that of private companies are exploited by the company or employees of that company. Where the company is formed based on development of core firm's technologies, they usually have single product focus and niche market character (Hoffman et al., 1998). In addition, the firms, since the 20th Century, may establish in-house laboratories where research would be conducted to support their products, processes and services. Webstar (1991) noted that before 1900, the idea of industrial research laboratory did not exist.

The exploitation of innovations requires funding. In the case of private research, the belief that innovation can make a positive contribution to the profitability of the company will provide the necessary impetus for funding. However, where individuals will try to exploit the research, they often need venture capital. This leads naturally to the third element of NIS-the finance element. The finance element provides innovation funding in the form of venture capital, which is an investment in new, unlisted, high-risk, high-tech spin-off firms, in the form of equity, quasi-equity and/or a conditional loan. Venture capital is crucial to the innovation process. Some large companies are reluctant to undertake high-risk innovative projects, such projects are

usually undertaken by small technology-based firms, in which venture capitalists invest (OECD, 1996). The fund is usually provided at the early stage when an idea is not fully developed and research is being conducted. If sufficient fund cannot be found at this early stage, an innovating project may fail. Guild and Bachher (1996) identified Private Venture Capitalists, Public Venture Capital Funds and Business Angels as three classes of Venture Capitalists. The high returns from their investments attract the venture capitalists to sponsor the high-risk projects. However, the assurance of protection of the technology that is being developed from illegal exploitation through patenting encourages the Venture Capitalists to invest their resources in the young companies.

The public policy and regulation element of the NIS include government ministries, agencies and other bodies at various levels that are involved in regulating S and T researches and their industrial exploitation. The government uses financial and non-financial policy instruments to promote innovation. For the NIS to work effectively, governments take steps to strengthen their innovation systems by reinforcing the basic framework conditions for innovation; promote the development of highly skilled labour force and a dynamic research base; provide the right climate for business innovation by implementing stable macroeconomic policies; protect intellectual property rights; and maintain a regulatory framework that promotes innovative behavior (OECD, 1999b).

5.0 Patenting and Exploitation of New Technologies

Patent is the legal protection placed on technological activities embodied in an invention to prevent its unauthorised use or exploitation, and granted to firms, individuals or other entities by national and regional patent offices. The exclusive legal rights of industrial exploitation of patent allow the owner to exploit the invention for a period of time, generally for about 20 years (Kamil, 2003). Invention refers to the generation of an idea, or the creation of a new technology for the first time, or the improvement of an existing technology. Such invention could be a product or a process, which may be brand new, but more often, it could be a combination of existing technologies (Hauser, 1998). Thus, an invention can be a completely new product, which is based on new technologies and/or designs, or an existing product whose functions have been greatly improved by structural, material or process changes (White and Liu, 1997).

As soon as a research activity results in the development of an invention, it is important to apply for a patent. In the past, the first person or organisation to invent is recognised in the United State of America (USA), but today and globally, the first to file a patent application is recognised (IPLA, 2013). However, in order to qualify for the award of patent, an invention should satisfy three key conditions: novelty, non-obviousness and industrial applicability (Arnold, 1996). The number of patents registered serves as indicators of inventiveness to a country. A patent is also used as a determinant of economic activities (Kamil, 2003).

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The process of patent acquisition is similar in most countries, however application fee differs. Upon receiving a patent application, the Patent Office conducts both formal and substantive examinations. A formal examination is conducted to verify whether the patent application complies with the formal requirements such as whether the patent was drafted in the appropriate format, and all necessary fees have been paid. Thereafter, substantive examination is conducted to ascertain the novelty of the invention. Substantive examination involves a detailed

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and comprehensive search of the prior art and comparing of the claims in the patent application with all existing patent and other relevant technical documents in database worldwide. Once the novelty condition and inventive step are confirmed and the examiner concludes on the patentability of the invention, a patent is granted. In a situation where patent office does not have the capability to conduct substantive search, some specialised institutions could be contacted but with a fee. In Nigeria for instance, patents are granted on formal examination alone. Lack of substantive examinations subjects most local patent to legal tussles, in case of dispute. In this case, patent office conduct prior art search and prepare search reports that are made available to the applicant and to the public. Nonetheless, a patent application could be rejected if the claim of novelty or inventive step or both are lacking altogether. In Nigeria, registration of patents is handled by the Patent Office at the Trademark, Patent and Design Registry that is located in the Federal Ministry of Commerce and Tourism.

A patent can be commercialised through different routes including joint venture, licensing, outright sale of the patent right, or the establishment of spin-off firms to exploit the invention. The best route to use will depend on the status of the new technology and the maturity of the industry where the invention is applicable. Lowe (1993) suggested that consultancy might be used if an invention is low-tech, but when it is progressing and not radical, licensing could be better. For both radical and less radical process innovations, the use of joint venture or licensing was suggested. However, when an invention is radical, i.e. the product and/or process is entirely new, establishing a spin-off company to exploit it would likely maximise the returns.

6.0 Establishing Spin-Off Firms

Spin-offs or new technology-based firms are enterprises that are specifically established to exploit inventions that originate from establishments called their parent organisations. Spin-off firms usually have some stakeholders, the researchers, university or laboratory where the technology is developed. Researchers who developed inventions could establish spin-off firms solely or in partnership with their institutions/institutes of employment and/or other investor(s). Existing enterprises may also be involved in the formation of the spin-off firms in order to reposition themselves in the industry where they operate. However, when newly established, spin-offs usually lack capital and other complementary resources needed for successful operations. They are unable to attract loans from bank because their assets are largely intangible. Therefore, venture capitalists come to their rescue by providing funds called Venture Capital and management support.

Venture capital is usually in the form of equity, quasi-equity and/or conditional loans that are offered to high-tech spin-off firms. Venture capital investments in the high-technology firms generally last about three to eight years (Guild and Bachher, 1996), during which spin-off firms are groomed into matured/stable companies. As the businesses become well-established, their shares are offered for sale at the stock markets to several shareholders. This ensures the survival and sustainability of the company beyond the lifetime of the initial founder(s) and owner(s), so that the knowledge, expertise, and assets of the company do not go to the graves with the founders. The valuation and sales of shares of the companies depend on an efficient and reliable financial system (Wellons, 1985) and it involves the operations of Stock Exchange and Securities

Commissions, brokerage companies, experts in legal, financial, tax, regulatory and accounting issues.

7.0 Research Output, Patent Generation and TE in Nigeria

Several authors including Oyewale (2005, 2006, 2010), Oyewale *et al.* (2007, 2008) and Bamiro *et al.* (2008) reported that Nigerian universities and research institutes develop commercialisable inventions from time to time. The Raw Materials Research and Development Council (RMRDC) and National Office for Technology Acquisition and Promotion (NOTAP), agencies of the Federal Ministry of Science and Technology, have published series of compendia on available research outputs from Nigerian research institutions (NOTAP, 2005). However, the rate of commercialisation has been very low.

In order to showcase inventions from Nigerian universities and promote their commercialisation, the National Universities Commission (NUC)[1], instituted the Nigerian Universities Research and Development Fair and exhibition since 2004. Oyewale *et al.* (2008) reported that over 70% of inventions on display at the 2004 and 2005 Fairs were not patented. Non-patenting of inventions was also revealed by respondents to the study conducted by Oyewale (2007); where about 13% of these respondents with claims of inventions also claimed to have filed applications for patents. The main reason advanced for not applying for patents for the inventions was lack of awareness of the procedure for patenting. Despite the development of inventions from the research activities in the country, it is pertinent to ask for the reasons some of the inventions were not patented. This analysis indicates that the researchers did not know much about patenting, which was a reflection of poor patent education in Nigeria (Oyewale *et al.*, 2016).

In confirmation of low patent registration from Nigerian research efforts, Okongwu (2006) reported that 74 (29%) local patents were registered out of the 259 that were submitted to the Nigerian Patent and Trademarks Office, between 2000 and 2005. Within the same period, out of the 1,775 foreign patent applications, 122 (7%) were registered. Though patent applications could be filed by inventors directly at the Patent Office, in order to encourage Nigerian inventors patent their inventions, NOTAP, by virtue of its mandates, had since 1999 been assisting local inventors to file patent applications (Ibigbami and Orji, 2009). In case of application for foreign patent, the application is submitted in line with the Patent Corporation Treaty (PCT). The authors further disclosed that NOTAP filled 86 applications between 1999 and September 2008 and obtained 61 patent grants for Nigerian inventors, while 147 applications are under evaluation/awaiting response from inventors. These efforts notwithstanding, Nigerian researchers have not been active in patenting of inventions. More recent data from the World Intellectual Property Organisation (WIPO) indicate a low level of patenting from Nigeria.

For instance, Table 1 shows a comparison of patent activities between Nigeria and four other developing countries based on data from WIPO for six years, 2010 to 2015. A summary of the table shows that patent applicants from Egypt were granted 533 out of the 3,824 total equivalent patent applications that were filed within the six years. Similarly, South African applicants were granted 6,582 out of 9,766; Brazilian applicants, 5,189 out of 28,511; while

[1] The umbrella organisation that overseers the administration of university education in Nigeria.

South Korea (Republic of Korea) applicants were granted 536,623 out of 1,022,742 applications. For the six years under consideration, 192 applications were filed from Nigeria, with 97 granted. These figures are too low for any reasonable comparison to be made. Based on the ranking of the quality of scientific research institutions for South Africa (31) and Nigeria (83) by WEF (2009), the higher number of patents from South Africa over those from Nigeria is justifiable. However, for Egypt that was ranked 96 to have greater number of patent application and grants than Nigeria show that Nigeria had been ridiculously inactive in patenting activities.

Table 1: Numbers of Patent Application and Patent Granted to Nigeria, Brazil, Egypt, South Korea and South Africa Between 2010 and 2015

Country	2010		2011		2012		2013		2014		2015	
	No of Patent Applications	No of Patent Grants	No of Patent Applications	No of Patent Grants	No of Patent Applications	No of Patent Grants	No of Patent Applications	No of Patent Grants	No of Patent Applications	No of Patent Grants	No of Patent Applications	of Patent Grants
Nigeria	37	3	17	2	10	4	64	44	64	44	60	1
Brazil	4,134	795	4,212	805	6,603	1,027	6,850	1,243	6,712	1,319	6,554	1,385
Egypt	684	61	727	89	770	124	760	129	883	130	883	130
South Korea	177,795	75,593	187,454	97,714	203,410	112,090	223,530	123,817	230,553	127,409	238,015	109,101
South Africa	1,907	1,347	1,718	1,119	1,608	1,337	2,216	1,445	2,317	1,334	2,064	1,190

Comment [A9]: Grants: is it implied – the number of patents approved or grants to exploit patrents.

Sources: WIPO (World Intellectual Property Organisation) (2011, 2012, 2013) - Tables P1 & P2
- Ditto - (2014) - Tables A47 & A48
- Ditto - (2015) - Tables A50 & A51
- Ditto - (2016) - Tables A60 & A61

Another challenge confronting Nigerian researchers is the condition under which they operate. The infrastructure of the nation's research and higher institutions as well as of its science, engineering, and technical laboratories is far below the international benchmark, as the available laboratory equipment for the conduct of research in this system are obsolete; though they are gradually being replaced with new ones in recent time (Bamiro et al, 2008). This poor state of affairs of Nigerian S&T institutions is confirmed by the World Economic Forum (WEF, 2009), which ranked Nigeria 83 out of 134 countries in the quality of scientific research institutions, where it scored 3.6 out of 7. These imply that Nigerian S and T institutions are fairly above average. Operating with dilapidated and poorly functioning infrastructure notwithstanding, Nigerian universities and research institutes still succeed in developing some inventions from their R&D efforts.

Besides comparing the number of patent applications and grants, a comparison of the number of R&D researchers in the five countries *vis-a-vis* the number of their patent applications and grants could beam light on the reason for the poor performance of Nigeria in patenting efforts. The researchers that are reckoned with are R&D professionals (including PhD students engaged in R&D) that are engaged in the conception or creation of new knowledge, products, processes, methods, or systems, and in the management of the projects concerned (UNESCO, 2017). There is dearth of data on the number of R&D researchers in Nigeria, however, the first comprehensive data on the subject was compiled in 2006/07. The report revealed that 17,624 R&D researchers were working in Nigeria during the period (NACETEM, 2011), and UNESCO (2017) online database (1996–2016) also indicates the same figure for Nigeria in 2007. For consistency therefore, national populations and R&D researchers that were in each of the five countries in 2007 and the resident applications filed for patents in 2007 and 2008 are presented in Table 2.

Table 2: National Populations, Numbers of R&D Researchers and Patent for Nigeria, Brazil, Egypt, South Korea and South Africa

Country	Population (2007) (In millions)[a]	Number of R&D Researchers (2007)[b]	Number of Researchers per Million Inhabitants (2007)[c]	Number of Resident Patent Applications (2007)[d]	Number of Resident Patent Applications (2008)[e]
Nigeria	147.7	17,624	119.8	n.a.	n.a.
Brazil	190.1	192,081	996.4	3,810	4,023
Egypt	80.1	96,481	1,243.2	516	516
South Korea	48.0	289,098	5,997.3	128,701	127,114
South Africa	49.2	40,084	806.6	n.a.	n.a.

Sources: a - UNDP Human Development Report 2009, Statistical Annex Table L
b, c - *UNESCO Institute for Statistics, UIS online database (1996–2016).*
d - WIPO (World Intellectual Property Organisation) (2009) - Table ST.1.
e - WIPO (World Intellectual Property Organisation) (2010) - Table P1.
n.a. – not available

Table 2 shows that research inputs, in terms of researchers' per million inhabitants are fewer in the case of Nigeria compared to countries like Brazil, Egypt and S. Korea. This, in addition to funding and R&D infrastructures, determines patents generation. Similarly, the country is not investing sufficiently in scientific and technological R&D. For instance, NACETEM (2011)

reported that Nigeria had the lowest R&D intensity among African countries under the New Partnership Africa's Development (NEPAD) African Science, Technology and innovation Indicator Initiative. Research intensity is the concentration of R&D in an economy, and is defined by Gross Domestic Expenditure on Research and Development (GERD) as a percentage of Gross Domestic Product (GDP). The report indicates that Nigeria had R&D intensity of 0.2%, while South Africa that spends 8.5 times more on R&D than Nigeria had 0.95%; Brazil (0.9%) and South Korea (3.4%).

What is more, a breakdown of investments in research shows that Nigeria spent little on experimental research that could possibly results in patent. However, high percentage of the research expenditure goes into basic research. These expenditure profiles are at variance with what operates in other countries where several resident patent applications are filed annually. For instance NSB (2014b) reports that basic research, applied research, and experimental development expenditure in the USA in 2011 were 18%, 19%, and 63% respectively. Another reason for not venturing into the development aspect of R&D by the research institutions is the poor linkage with industrial firms that could possibly utilise the research findings in their operations.

Furthermore, inability to file patent applications among Nigerian researchers could be traced to inadequate information and poor understanding on patent matters. In addition to poor patent education in Nigerian institutions, other factors identified as preventing patenting of the inventions include poor technological entrepreneurial culture, lack of institutional infrastructure and inadequate research funding. Though, efforts have been made to address these challenges over the years, these efforts are yet to show meaningful impacts. For instance, in order to promote entrepreneurial culture among Nigerian University students, compulsory entrepreneurship courses had been introduced to undergraduates in Nigerian universities, including students in science, technology, engineering, and mathematics departments (NUC, 2007). The courses were to engender entrepreneurship culture in both the students and the faculties. Furthermore, the establishment of Intellectual Property Technology Transfer Offices (IPTTOs) in Nigerian research institutions is expected to address some of the problems of poor patent education and technological entrepreneurship in the country. The offices assist researchers in the institutions to consult patent documents in the course of their R&D engagements, facilitate documentation and patenting of inventions emanating from their research activities, establish business linkages between research institutions and industry and create spin-offs from their research results (Orji, 2009). Starting with the establishment of 15 IPTTOs in 2006, the number has now grown to over thirty-nine (39) as of December 2016 (NOTAP, 2017).

Comment [A10]: The number of offices have increased by 160% but the number of patents is still poor.

The evaluation of compulsory entrepreneurship programme introduced by the NUC in 2006 was conducted by an Agency of the Federal Ministry of Science and Technology revealed high entrepreneurial propensity among the undergraduates (NACETEM, 2012). The study involved 42,800 student and 249 lecturers in 2010. The study gave further insights into the levels of entrepreneurial interest among the undergraduates; the results showed that Nigerian students have high level of entrepreneurship interest. The study also found that 24% of the students were into personal businesses alongside schooling (Adelowo et al., 2016). However, the terse socio-economic and business environment in the country may not be able to encourage technological entrepreneurship. For instance, among the teachers of entrepreneurship in the schools covered in the survey, only few of them engaged in businesses. This may not be unconnected to their level

of entrepreneurship training among other factors impeding business development in Nigeria. Other important challenges of research commercialisation in Nigeria include obsolete laboratory equipment for training and research, high brain drain, which was responsible for the departure of 5.13% of the academic staff from Nigerian universities during 2001/2002 and 2005/2006 sessions (Bamiro *et al*, 2008). Nevertheless, with establishment of the Tertiary Education Trust Fund (TETFUND) in 2011, funding of tertiary education and research has improved, though with little results (TETFUND, 2012). An additional source of funding for research is the National Research and Innovation Fund that is proposed to be established by the STI Policy of Nigeria (FMST, 2012). Adequate implementation of these research and innovation funding mechanisms are very germane to technological entrepreneurship development in Nigeria.

To jumpstart technology commercialisation and in the system, some ready-to-market research outputs ('low hanging fruits') in the research institutes could be harnessed for business in the short term while investment in S&T activities continues. Also, universities' R&D Fair annually organised by the Raw Materials Research and Development Council (RMRDC) tagged 'Techno-Exposition programme' could be used to attract interested entrepreneurs for technology commercialisation as well. In order to facilitate investing in the technologies on display during the exhibition, the Council, sometimes, publishes investment profiles on them. The Investment Profiles provides information that could guide potential investors on the requirements for the projects. The impact of the Techno-Exposition in respect of TE is yet to be ascertained. However, assessment is necessary to track the milestones of the programme and devise means of improving and attracting investors.

Nigerian S&T Policy was recently reviewed and named Science, Technology and Innovation (STI) Policy. The first S&T policy in Nigeria was formulated in 1986. The Policy had been reviewed twice, in 1998 and 2004 before the 2012 edition. Given the position of S&T knowledge in development globally, the new STI Policy devoted Section 3.4 and 3.5 to Intellectual Property Rights and technology transfer respectively. In addition, the Policy recommended the establishment of a National Research and Innovation Fund with a minimum contribution of 1% of GDP to R&D activities, to ensure adequate funding of STI activities, while the National Research and Innovation Council, headed by the Presidency as the chairman, is to be instituted to among others coordinate STI activities and facilitate fund raising activities to support innovation activities in Nigeria. If adequately implemented, the new STI policy is expected to address the some of the challenges of non-patent culture and low exploitation of Nigerian research outputs, especially as spin-off companies, thereby strengthening Research-Industry interactions in Nigeria.

8.0 Conclusion and Policy Recommendations

The article considered the issues of science, technology and innovation in industrial development, and how patent commercialisation could stimulate business development through technology entrepreneurs (technopreneurs). It described the importance of technopreneurs in the commercialization process, how their training enables them to push inventions to the market. In addition, the essentials of National Innovation Systems and the position of technological entrepreneurship as a crucial constituent of the system were also considered. The article further described the importance of technological entrepreneurs in the commercialisation process. In

addition, the paper discussed the essentials of robust interaction among the elements of National Innovation System and the position of technological entrepreneurship in the system, as a crucial element of the system. More to the discussion of the position of patents and technological entrepreneurship in Nigeria, the low level of research outputs was examined and the causes identified. We also delved into various infrastructures that can support the system to operate efficiently and bring together all the elements of the national innovation system.

Tackling the identified challenges within research system in the country requires strategic actions by the government, knowing full well that technology commercialisation creates wealth and reduces unemployment. The following recommendations therefore ensued from the article. First, there is an urgent need to address the problems of poor funding of research activities in Nigeria. It is essential for Nigerian government to implement the recommendations made in the new STI policy, particularly the establishment of the National Research and Innovation Fund recommended to promote innovation and enhance national competitiveness. Also, the low awareness of patenting in Nigerian research system should be addressed through patent education. Workshop on intellectual property rights should be mounted in the research system, particularly among researchers in science, engineering and technology fields to inculcate the culture of patent in them. Furthermore, the reward system in the university system could be redesigned to promote technology commercialisation and entrepreneurship, since distinct skill set are required for technology commercialisation. The researchers could also consider markets when conceptualising research ideas to guarantee commercialisation of the outputs. Alternatively, specific directive from government to provide funding for research that addresses national needs could be another effective means of addressing local challenges with scientific solutions, thereby increase the chances of technology commercialisation.

Comment [A11]: I think it might be better if you put the recommendations in point form:

The following recommendations therefore ensued from the article:

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In addition, the industrial sector could be incentivised to exploit the commercialisation of research outputs from the research institutions. For instance, as technology transfer offices have been established in some research institutions in Nigeria, there is the need to strengthen them to function effectively so as to foster robust relationship with industrialists for research results uptake. The entrepreneurship education in Nigerian universities should be made more practical, taught by practicing entrepreneurs and include business experimentation before graduation. The need for the governments at all levels in Nigeria to promote the creation of venture capital organisations and encourage the emergence of business angels to finance technological innovation is also suggested.

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