R&D and the Challenge of Wealth Creation in Nigeria

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Abstract

In today's increasingly knowledge-driven world, science and technology (S&T) are the inseparable twin keys to progress and industrial growth as against the resource endowment of the past. Apparently, without scientific knowledge and its application the economy of a nation or an organisation either remains stagnant or declines. Consequently, most countries of the world now devote an increasing proportion of their resources to S&T and associated research and development (R&D), in an attempt to build competitive advantage or to catch up with others who have already done so. This paper assesses the Nigerian situation in this regard. Drawing from recent research and first-hand observations, the paper discusses the relationship between R&D and wealth creation in Nigeria; and offers a recipe to enhance the relationship and overcome identified R&D challenges.

Keywords: Research and development, Nigeria, wealth creation, science and technology, national innovation system

1. Introduction

In today's increasingly knowledge-driven world, science and technology (S&T) are the inseparable twin keys to progress and industrial growth as against the resource endowment of the past. It is apparent that without scientific knowledge and its application the economy of a nation or an organisation either remains stagnant or declines. S&T creates new knowledge; and knowledge is self-replicating as the more people have access to knowledge the more knowledge is produced. Most countries now devote an increasing proportion of their resources to S&T and associated research and development (R&D) in an attempt to build competitive advantage or to catch up with others who have done so. Today, R&D is one of the main thrusts of activities of western universities. This is quite understandable and appreciable because R&D, most especially in S&T, has become one of the most enduring and effective means of improving sustainable economic development and re-enforcing competitiveness in industries in a rapidly changing world. Productive R&D is expected to lead to new products or improvement of existing products, new process development or improvement of existing processes and generation/creation of new knowledge, patents, copyrights and publications. Publications are an indicator of quality invention and research outputs while patents, copyrights, and funding from companies are an indicator that those inventions have market

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potential (Carneiro, 2000; Werner and Souder, 1997; in Numprasertchai and Igel, 2005).

However, global experiences have shown that the conduct of scientific R&D does not robotically translate into development. For R&D to have any economic impact; R&D activities must be creative, innovative and exist within a strong national innovation system (NIS). Furthermore, it is necessary that scientists and engineers possess entrepreneurial skills with a focus on market-driven research. This paper examines the concepts of research and development as well as wealth creation. The relationship between these two concepts is then discussed; and a recipe is offered on how to forge that relationship. The paper also presents interesting statistics on the current status of R&D in Nigeria and its attendant challenges.

2. The Concept of Research and Development

R&D is a post Second World War phenomenon, and absorbs a sizeable proportion of corporate and public funds in the developed countries. It is largely carried out by researchers in higher educational institutions (HEIs), research institutes (public and private), and industrial firms. R&D comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of individuals, culture and society, and the use of this stock to devise new applications (OECD, 2002). It involves three main activities: basic research, applied research and experimental development (Figure 1).

Basic (fundamental or pure) research refers to experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts without any particular application or use in mind. It analyses properties, structures and relationships with a view to formulating and testing hypotheses, theories or laws. The basic researcher may not be aware of actual applications when carrying out the research. Results of such research are not generally sold but published in scientific journals or circulated to interested researchers. Basic research can also focus on some broad fields of general interest, with the explicit goal of a broad range of applications in the future, e.g., public research programmes on nanotechnology which many countries have made a research priority. This is defined in the Frascati Manual as "oriented basic research" (OECD, 2002).

Applied research is also original investigation undertaken in order to acquire new knowledge (OECD, 2002). It is, however, directed primarily towards a specific practical aim or objective and undertaken either to determine possible uses for the findings of basic research or to determine new methods or ways of achieving specific and predetermined objectives. Applied research involves considering the available knowledge and its extension in order to solve particular problems. Results of applied research are intended basically to be valid for a single or limited number of products, operations, methods or systems. In short, applied research provides operational form to ideas and the knowledge or information derived from it is often patented but may be kept secret.

Experimental development concerns systematic work, drawing on existing knowledge gained from research and/or practical experience, which is directed toward producing new materials, products or devices, to installing new processes, systems and services, or to improving substantially those already produced or installed (OECD, 2002). In the social sciences, experimental development may be seen as the process of translating knowledge gained through research into operational programmes, including demonstration projects undertaken for testing and evaluation purposes. An example distinguishing between these three types of research is as follows:

"The study of a given class of polymerization reactions under various conditions, of the yield of products and of their chemical and physical properties is basic research. The attempt to optimise one of these reactions with respect to the production of polymers with given physical or mechanical properties (making it of particular utility) is applied research. Experimental development then consists of "scaling up" the process which has been optimised at the laboratory level and investigating and evaluating possible methods of producing the polymer and perhaps articles to be made from it" (OECD, 2002).

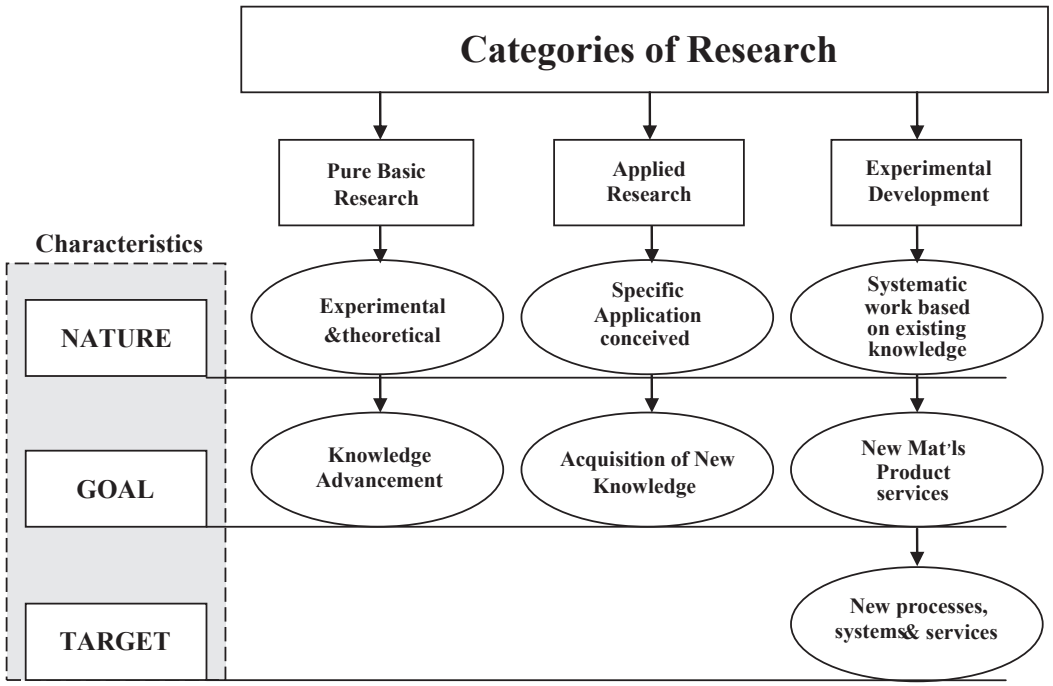
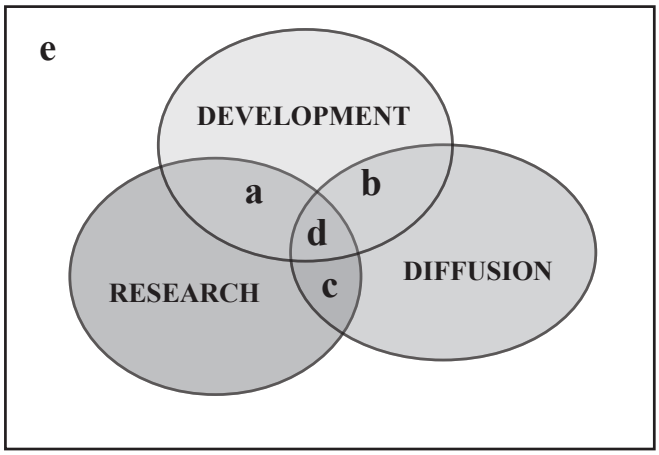


Figure 1-1 The three categories of R&D



a − Research and Development

b − Commercialisation

c – Publication, etc

d − Research, Development and Diffusion

e − NIS, the domain in which all activities take place

Figure 1-2 Model for the relationship among research, development and diffusion

3. R&D and National Wealth: how and when does it happen?

Table 1 presents some basic indicators of national wealth for a selected group of countries including Nigeria. One important fact from the table is that however wealth is defined Nigeria is not one of the nations considered to be wealthy. Besides low GDP per capita, only 1 out of every 5 Nigerian can boast of earning even 2 US dollars per day despite the country's heavy crude oil endowment.

The prosperity of many developed nations and the expansion in the economies of the Asian tigers (in the past two decades) have been largely determined by their ability to transform their economies through research in S&T and industrial production (Bamiro et al, 2008). Numprasertchai and Igel (2005) opined that R&D units in developing countries (particularly Africa and South America) have many disadvantages compared to newly industrialised countries (NICs) and developed countries in terms of base knowledge, experts, researchers and infrastructure. This is illustrated in Tables 2 and 3. Table 2 shows, inter alia, that Nigeria does not compare favourably with several other nations in terms of key R&D inputs.

Besides being ranked as one of the least competitive nations in the Global Competitiveness Ranking[1)], Nigeria is presented as having some of the weakest institutions and training systems. Table 3 shows how Nigeria compares with four other countries in terms of key R&D indicators: R&D expenditure as percentage of GDP, researchers in R&D per million people, royalties and license fees and patents to residents. Nigeria again has some of the lowest figures among the countries compared. It is worth noting that these countries generally share similar development profiles with Nigeria and they have effectively demonstrated how science and technology can be harnessed to drive national development in record time.

Economic benefits from R&D largely depend on the interaction of three key components: research, development and diffusion (Figure 1) within the National Innovation System (NIS). Today, economic globalisation has changed the world economic order, bringing new opportunities and new challenges (Commission of the European Communities, 2006) with dire consequences for developing countries. In this new economic order, developing nations can no longer compete on the basis of their natural resource endowments and locational advantages alone. For a nation to withstand competition in this era of globalisation there is need to identify niche areas and build on it by the application of scientific methods. The experiences of Brazil with sugarcane (Goldemberg, 1998), Malaysia with oil palm (Adebowale, 2008) and Ethiopia with cut flowers have shown that building scientific capacity and competences in the fields of natural resource endowment and locational advantages is a surer way to development.

Meanwhile, there are no economic gains from R&D unless the outputs (including patents) are exploited. Translation of R&D to innovation occurs through entrepreneurial activities that deal with marketing needs.

R&D is profitable when it is innovative and solves real life problems. The stages of innovation are not necessarily step-wise with a phase commencing after a preceding phase has been completed, as presented in Figure 2 Model A. In the prevalent competitive environment where speed and flexibility are critical success factors, a holistic or 'rugby' approach as suggested by Takeuchi and Nonaka (1986) is more appropriate (Figure 2 Models B&C).

4. Status of R&D in Nigeria

The key players in R&D in Nigeria are the higher educational institutions (HEIs), the research institutes (RIs), the private research establishments, government agencies with R&D mandates, etc. Presently, there are:

1) The Global Competitiveness Ranking is compiled annually by the World Economic Forum. It assesses countries using a set of 12 pillars comprising over 117 component indicators altogether. In this paper, we have only selected some of these components that are relevant to our discourse.

Table 1 Some basic indicators of national wealth for selected countries

Country	Human Development Index rank	Per Capita GDP (PPP USD)	% population below $1/day	% population below $2/day
Singapore	23	49,704	-	-
South Korea	26	24,801	-	-
Chile	44	13,880	<2	2.4
Malaysia	66	13,518	<2	7.8
South Africa	129	9,757	26.2	42.9
China	92	5,383	64.4	36.3
Nigeria	**158**	**1,969**	**70.2**	**83.9**

Source: Human Development Report 2009

Table 2 Selected global competitiveness indicators for selected countries

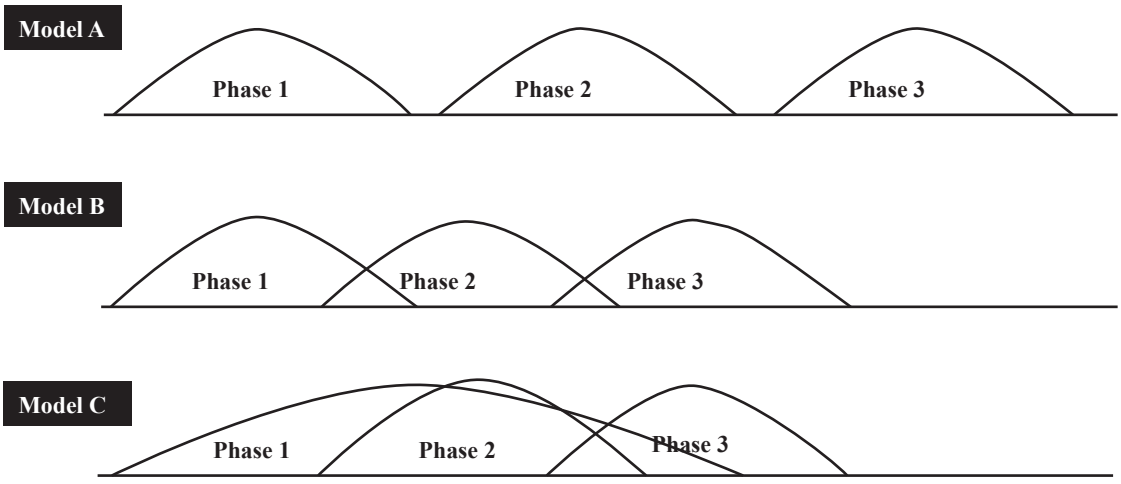
GCR	Country	Research Training	Quality of Scientific Institutions	Available Scientist & Engineers
3	Singapore	5.5	5.6	5.2
19	South Korea	4.6	5.0	4.9
24	Malaysia	4.9	4.7	4.7
29	China	4.4	4.4	4.6
30	Chile	4.6	3.9	4.9
45	South Africa	4.6	4.7	3.1
49	India	4.7	4.9	5.6
56	Brazil	4.8	4.2	4.2
99	**Nigeria**	**3.9**	**2.9**	**4.5**
114	Ghana	3.4	3.7	3.6
	Average	**4.5**	**4.3**	**4.5**

Source: Global Competitiveness Ranking (GCR), 2009

Table 3 Selected R&D indicators for selected countries

	South Korea	China	India	South Africa	Nigeria
Population in millions (2007 est.)	48	1,329	1,165	49.2	148
R&D Expenditure as % GDP (2000-2005)	2.6	1.4	0.8	0.8	0.20*
Researchers in R&D per million people (1990-2005)	3,187	708	119	307	126*
Royalties and Licence Fees in USD per person (2005)	38.2	0.1	-	0.9	-
Patents to residents per million people (2000-2005)	1,113	16	1	-	-

Source: Human Development Report, 2007/2008/2009
* NACETEM /NEPAD STI Indicator Survey



Phase 1 – Pure Research, Phase 2 – Technological Development, Phase 3 – Production and Marketing

Figure 2 Models of S&T development for industrial production (Goldemberg, 1998)

1. 104 universities with varying capacities for pure and applied R&D
2. 71 Polytechnics with modest capacities in applied research
3. 22 Colleges of Agriculture and specialised technological institutions
4. 27 Monotechnics
5. 66 RIs with R & D programmes targeted at the different sectors of the economy with a few recording some measure of success in product and process innovation (Bamiro et al., 2008) ;and
6. Very limited private sector R&D outfits (for example, Nigerian Breweries Plc Research Centre, Lagos).

In spite of this somewhat extensive institutional framework, cases of specific potentially effective R&D breakthroughs are rather few and far between (Siyanbola, 2008).

It has been established both empirically and qualitatively that R&D in Nigeria is well characterised by the schematic diagram in Figure 2, Model A. There is an inherent discontinuity among the research activities in institutions, the development activities required to produce artefacts and subsequent manufacturing and marketing of these artefacts. Contrary to the current global vogue, researchers in Nigeria still tend to adopt a 'linear' approach to their research without due recourse to the complementary activities that will guarantee the social usefulness of such research results.

Resources available for R&D are too thin and are spread on numerous independent research projects running concurrently. For instance, at Obafemi Awolowo University (OAU), records show that grants were allocated to about 46 research projects between 1998 and 2002, and 87 research projects between 2003 and the first quarter of 2007. Unfortunately, most of the projects were either surveys, impact analyses, appraisals, evaluation studies or analytical studies, while only about 1% were innovative and/or interdisciplinary (Akinsola, 2007). In terms of institutions, only six Nigerian universities (compared to four in 2007) ranked among the top 100 in Africa at the end of July 2010 (Table 4). While this number represents a modest improvement in number of entries, it is instructive to note that the best ranked Nigerian institution in 2010 ranked 61, as against 44 in 2007; and that all top ten African universities are from South Africa!

In a recent assessment of R&D productivity at Nigeria Universities and Research Institutes, 337 researchers were sampled from S&T fields in 12 leading universities (NACETEM, 2011). Table 5

Table 4 World ranking of universities, July 2010

African Rank	University	Country	World Rank
1	University of Cape Town	SA	340
2	Stellenbosch University	SA	538
3	University of Pretoria	SA	539
4	University of the Witwatersrand	SA	808
5	University of Kwazulu Natal	SA	904
6	Rhodes University	SA	1,024
7	University of the Western Cape	SA	1,124
8	University of South Africa	SA	1,219
9	University of Johannesburg	SA	1,422
61 (44)*	**Obafemi Awolowo University**	**NGA**	**5,756 (5,834)***
66	**University of Jos**	**NGA**	**5,882**
68 (96)*	**University of Lagos**	**NGA**	**5,936 (7,601)***
77 (79)*	**University of Benin**	**NGA**	**6,324 (7,318)***
79 (65)*	**University of Ibadan**	**NGA**	**6,425 (6,809)***
99	**University of Nigeria, Nsukka**	**NGA**	**7,170**

Note : Figures in parentheses represent 2007 world ranking of Nigerian universities
Nigerian universities are shown in 'bold' format.

Source: http://www.webometrics.info/top100_continent.asp?cont=africa; 2010

Table 5 R&D productivity in Nigeria (2004-2008): number of publications

Output	Total	Per Capita	Per Annum	Per Capita per annum
Articles in Local Journals	1,124	**3.34**	224.80	0.69
Local Conference Papers	954	2.83	190.80	0.57
Articles in Foreign Journals	942	**2.80**	188.40	0.56
International Conference Papers	397	1.18	79.40	0.24
Books/Chapter in books	230	0.68	46.00	0.14
Total	**3,647**	**10.82**	**729.40**	**2.16**

Source: NACETEM (2011)

Table 6 Mean values of Journal publications in developing countries

R&D Output (per capita)	Nigeria ('09)	(Kerala) India ('02)	Kenya ('02)	Ghana ('02)
Articles in foreign journals	2.80	2.21	1.53	2.24
Articles in local journals	3.34	4.90	1.02	2.09

Source: Adapted from Duque et al. (2005)

illustrates the researchers' R&D output in terms of journal publications, conference papers and contributions to books over a period of five years. In all, 1,124 and 942 articles were published in peer reviewed local/national and international journals, respectively. The results also revealed that Nigerian researchers published, on average, 2.80 and 3.34 articles in foreign and local journals, respectively. When compared with similar studies conducted in India, Kenya and Ghana in 2002 (Table 6), Nigerian researchers appeared to publish more than those from the other two African countries. Nonetheless, besides the success stories of the yam pounding machine first produced in Obafemi Awolowo University and patented in Great Britain, and the sickle-cell anaemia management medications - NIPRISAN and NICOSAN – patented in the United States by the Nigerian Institute of Pharmaceutical Research & Development, there is very little inventive and patenting activities ongoing in Nigeria's research system (Table 7).

The relevance of R&D collaboration to productivity cannot be over-emphasised. Evidence from NACETEM (2011) showed that researchers collaborate more with local research agencies than any other stakeholder in the NIS. Table 8 illustrates the proportion of researchers with working collaboration and the stakeholders with which they collaborate. Only 29% of the sampled researchers collaborate with industrial firms. The essence of such collaboration include: sponsorship of workshops and conferences, travel fellowship, S&T grants, provision of R&D facilities and staff exchange programmes.

Table 9 contains information on the opinion of Nigerian researchers about factors that generally impede R&D in relation to their individual research endeavours; lack of funding, inadequate supply of electricity, lack of R&D facilities, obsolete facilities and lack of exposure to modern laboratory skills rank highest among the limitations (NACETEM, 2011). This result is consistent with an earlier study by the National University Commission (NUC), which itemised the following as factors contributing to the decline of R&D in Nigerian HEIs since 1988:

1) Constraint of equipment for carrying out state-of-the art research

2) Lack of research skills in modern methods

3) Over-loaded teaching and administration schedules that leave little time for research

4) Difficulty in accessing research funds

5) Diminishing scope of mentoring junior researchers by seasoned and senior researchers due to the brain drain (Okebukola 2002; in Bako 2005).

5. Knowledge-Based Income Generation Options and R&D Based Wealth-Creation

Intellectual Properties that are developed in institutions and industries are supposed to be demand-driven and based on knowledge, skill and experience. Such model is based, firstly, on what the market and customers actually need and not basically on what the researcher think the market needs. Secondly, it is based on working with parties who may be the actual customers in the future. Thirdly, it allows the researcher to determine whether there is a real market for their R&D before the R&D begins. Fourthly, it saves time, efforts and money in creating products/services that no one wants or is already outdated or obsolete and hence not marketable. R&D outputs or intellectual property (IP) could be exploited before or after their protection. The framework for possible exploitation paths are depicted in Figure 3, which identifies two broad paths available for R&D commercialisation. The first path is to seek protection through intellectual property rights (IPR), which might be sold, licensed or exploited by the researcher(s) through outright sale or joint-venture firms.

The second path, which is considerably shorter and has a higher potential return through multiplier effects, is to directly commercialise through organisational forms (incubations, science and technology parks, spin-offs or existing firms). The optimal route will depend on the status of the new technology and the maturity of the industry in which it is to be used.

However, the higher chance for success makes the second route more relevant for the Nigerian

Table 7 R&D productivity in Nigeria (2004-2007): patents

Year	LOCAL PATENTS (NON-CONVENTIONAL)	
	No. of Applications Filed	No. of Applications Granted
2004	88	40
2005	81	64
2006	95	87
2007	84	33
Total	**348**	**224**

Source: Compiled by NOTAP, 2008

Table 8 Characteristics of R&D collaboration in Nigeria

Stakeholders	% of Researchers
Local Research Agency	40.8
Industry	**29.2**
International Research Agency	17.5
University within Nigeria	6.8
University outside Nigeria	4.9
Local Financial Institutions	2.7
World Bank	2.3
NGOs	2.3
State Government	1.5

Source: NACETEM (2011)

Table 9 Ranking of barriers to tangible R&D

Limitation	% researchers
Lack of funding for research	87
Inadequate supply of electricity	82
Lack of R&D facilities	76
Obsolete facilities	67
Lack of exposure to modern lab skills	55
Inadequate water supply	54
Lack of quality research assistance	50
Inadequate access to recent journals/library materials	45
Lack of exposure to conferences	43
Inadequate time for R&D	29
Poor attitude to collaboration among researchers	29
Lack of research drive	24

Source: NACETEM (2011)

context where resources are scarce, inventive activities are rare and IPR protection is weak. In the USA, Stanford University and the Massachusetts Institute of Technology (MIT) have incubated large numbers of spin out firms. For example, the number of companies spinning out of MIT increased from 156 to 636 within two decades. In Sweden, Chalmers University of Technology created 240 companies from R&D products wit hin 30 years. It has been reported that

"If the companies founded by MIT graduates and faculty formed an independent nation, the revenues produced by the companies would make that nation the 24th largest economy in the world. The 4,000 MIT-related companies employ 1.1 million people and have annual world sales of $232 billion during 1994. That is roughly equal to a gross domestic product of $116 billion, which is a little less than the GDP of South Africa and more than the GDP of Thailand." (MIT - The Impact of Innovation,1997)

"The 25,800 currently active companies founded by MIT alumni employ about 3.3 million people and generate annual world sales of $2 trillion, producing the equivalent of the eleventh-largest economy in the world." (Roberts and Easley, 2009).

In order to maximise benefits from R&D activities the following factors, each of which is discussed separately, are highly critical:

1. Virile National Innovation System (NIS)
2. Individual re-orientation
3. Institutional re-arrangement
4. Functional Government-University/Research Institutes-Industry Linkage through Networking (GIKI model)
5. Effective Technology Transfer Model

5.1 Virile NIS

Recently, the concept of national innovation system (NIS) has provided a useful framework for technology policy formulation, since the concept makes explicit different kinds of inputs necessary for an innovative economy and hence competitive in today's increasingly globalised markets (Bamiro et al., 2008). The concept

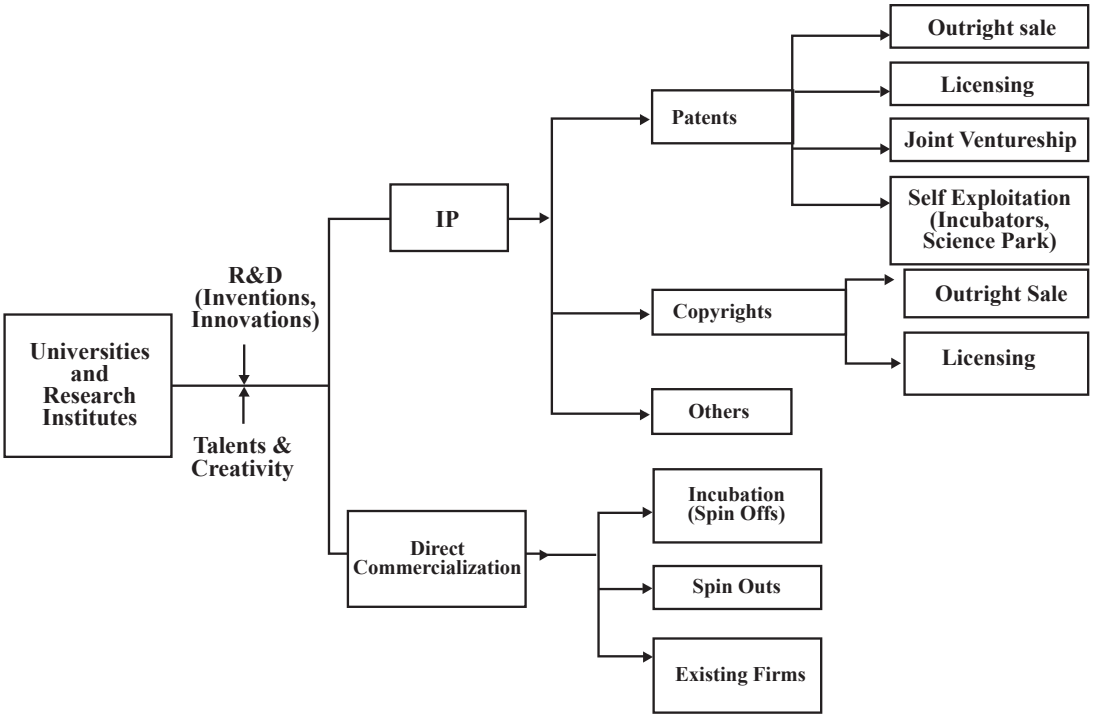
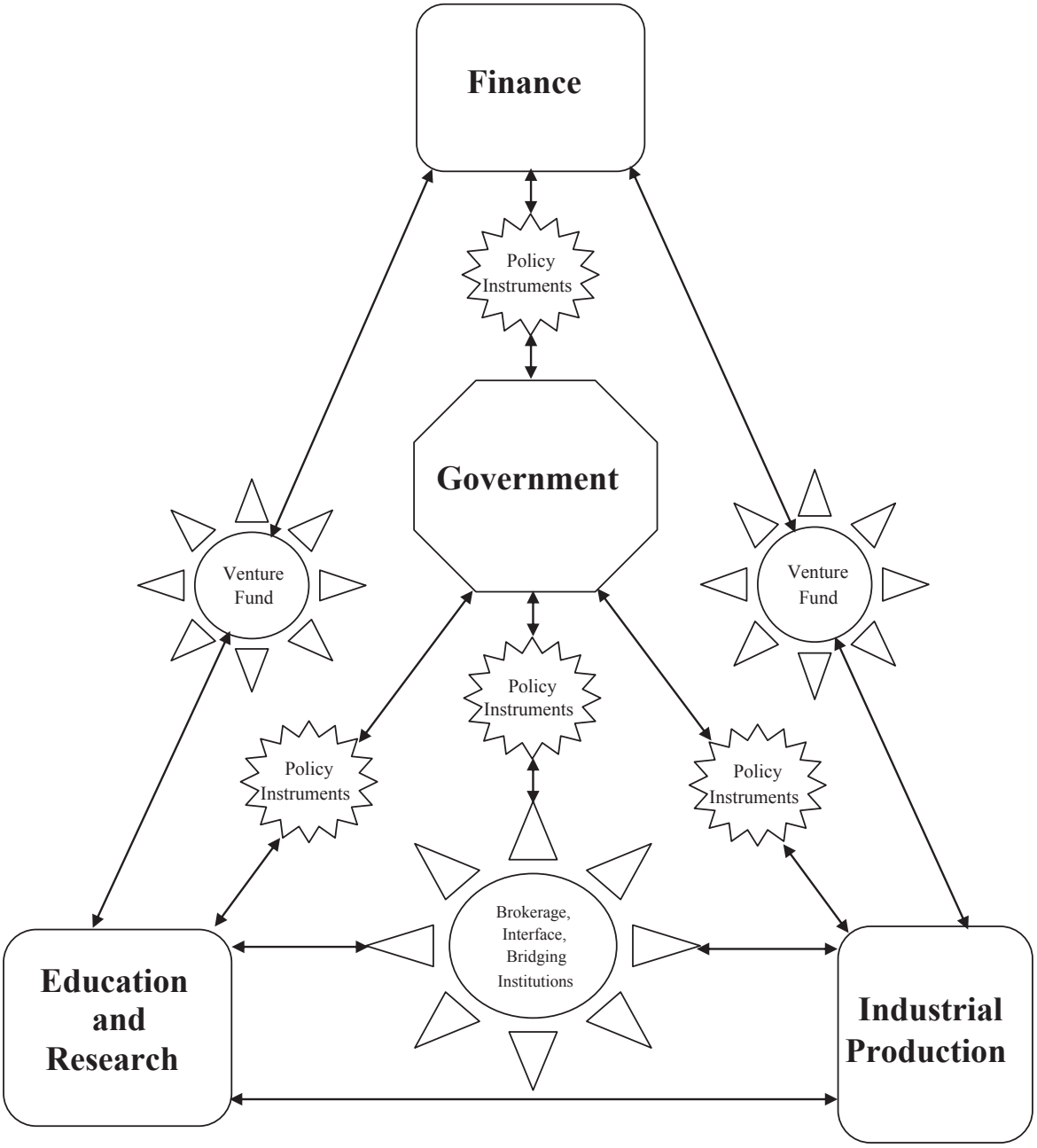


Figure 3 Options for knowledge-based wealth creation



Source: Adapted from Tiffin (1997)

Figure 4 Typical structure of interactions among the elements of the national innovation system

first appeared in the mid-1980s in the context of debates on industrial policy in Europe (Sharif, 2006). Presently, many international organisations such as the Organisation for Economic Cooperation and Development (OECD), European Union (EU) and the United Nations Conference on Trade and Development (UNCTAD) use NIS as an integral part of their analytical perspective (Lundvall, 2002 in Sharif, 2006).

Today, nations that have successfully transformed their economies to compete and thrive in technology and knowledge intensive sectors have done so by creating and strengthening their NIS. Finland was the first country to adopt the concept as a basic component of its science and technology policy, and Sweden has given the concept legitimate status in its own right by naming a new central government institution the "Systems of Innovation Authority" (Sharif, 2006).

There have been several attempts to put forward a concise definition for NIS. One such attempt provided by Metcalfe (1995; in Sharif, 2006) described NIS as a "set of institutions that (jointly and individually) contribute to the development and diffusion of new technologies. These institutions provide the framework within which governments form and implement policies to influence the innovation process. As such, it is a system of interconnected institutions (established) to create, store, and transfer the knowledge, skills, and artefacts which define new technologies". An alternative definition is: "a system of interacting private and public firms (either large or small), universities and government agencies aiming at the production of science and technology within national borders; interactions among these units may be technical, commercial, legal, social and financial, inasmuch as the goal of the interaction is the development, protection, financing or regulation of new science and technology" (Bamiro et al., 2008). One of the earliest and most popular definitions, given by Freeman (1987), is that NIS comprises a network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies (Freeman, 1987). Here the author emphasised a network or collaboration of public and private institutions/organisations for the purpose of innovation. Ilori (2006) similarly described NIS as a constitution of elements and the relationships located within or rooted inside the borders of a nation or state, which interact in the production, diffusion and use of new and economically useful knowledge. This description also agrees with an earlier definition put forward by Adeoti (2002) that the NIS represents an integrated system of economic and institutional agents directly promoting the generation and use of innovation in a national economy. An NIS consists of four main elements – government/policy; academia; the private sector/industry and the finance element (Figure 4). Each of these has its own unique roles which, however, depend on the functionality of the others for success. It has been noted that the innovative performance of an economy depends on how the individual institutions and actors (e.g. firms, research institutes, universities) perform in isolation and how they interact with each other as elements of a collective system of knowledge creation and use, and on their interplay with social institutions (OECD, 1997). Without adequate development of these actors and institutions in the domestic and regional settings the innovation system remains underdeveloped and anaemic (Juma et al, 2005). Along these lines, Egbetokun et al (2007) noted that the success achieved by any nation in exploiting new, especially scientific, knowledge for growth and development depends on the effectiveness of the nation's National Innovation System (NIS). This implies, according to them, that the NIS provides a framework for evaluating holistically a nation's attempt at generating and applying knowledge for meeting the needs of its society. In fact, global and national developmental agenda, such as the Millenium Development Goals (MDGs) and the Nigerian Vision 20/2020, among others, are much more easily achieved when S&T knowledge is created and deployed within the context of the NIS.

5.2. Individual Re-orientation

The basis for any change in a systemic paradigm is a change in the individual paradigm. What this implies is that for there to be R&D-driven growth in Nigeria, every researcher must improve in orientation. Certain

key facts must now be accepted as 'gospel truth'. Chief among these is the realisation that the days of isolated, territorial research are long gone. Every serious researcher, rather than jealously concealing his or her own work, should be willing to share knowledge and work with others for the common good. Also, the perception of research as a mere means to an end, where the end is promotion-oriented publications, is not beneficial at the macro-level. While individual researchers might get promoted after many years of this research approach, the nation is left with numerous 'egg-heads' with purely curiosity-driven research results that have almost no direct social relevance. In summary, personal changes are required in individual mindset, ideology, orientation and value system.

5.3. Institutional Re-arrangement

The fact that R&D is not impacting national development, despite the extensive institutional framework, indicates that something is not right. It follows, then, that changes are required either in the way these institutions are configured or in their working – and these changes are critical. As noted earlier, R&D is under-funded in Nigeria, resulting from poorly funded institutions. The place to start, therefore, is to improve the provision of funds. This is best done through institution-based R&D grants. The benefit of an institution-based approach is two-fold. First, each institution can readily focus on areas of relative strength. Secondly, monitoring the use of such grants will be a lot easier as each institution can conveniently use its existing mechanisms to follow up on the R&D activities of its staff. Two crucial steps are recommended here. First, every research institution needs to perform an internal analysis of its strength and weaknesses and accordingly create a pragmatic R&D agenda. Such agenda should be prioritised so that any R&D activity will focus on pre-determined niche areas. Secondly, institutions need to create strong and virile research councils that will be responsible for overseeing R&D activities to ensure that they are consistent with established priorities and that they yield appropriate results for investments.

An important point to note in implementing this kind of arrangement is that full attention must be paid to areas of national priorities. Indeed, all endogenous R&D activities must be highly connected to national priorities as articulated presently in the National Economic Empowerment and Development Strategies (NEEDS I and II), the 7-point agenda and the Vision 20-2020 initiative of the Nigerian government. Given the dynamic nature of national needs, the National Research and Development Coordinating Council (NRDCC) will be required to review these national priorities in a consistent manner to ensure appropriate connectedness of all activities. From a macro perspective, institutions are required to encourage interdisciplinary and collaborative research. Several approaches can be adopted ranging from the creation of centres of excellence in multidisciplinary research to the establishment of Central Science Laboratories in institutions (as in Obafemi Awolowo University, Ile-Ife) to the creation of interdisciplinary R&D grants for the purpose of pooling resources and ensuring that researchers from varied disciplines work together. Empirical evidence from NACETEM's assessment of the Central Laboratory Facility at the Obafemi Awolowo University already shows that the Central Laboratory approach is a very good one to ensure maximum utility of meagre resources and foster collaboration. For instance, research facilities that would ordinarily be beyond the reach of individual departments are available at the facility for all disciplines to make use of; and the laboratory has attracted researchers from all parts of the country over the last 2 years.

5.4 Functional Government-University/Research Institutes-Industry Linkage through Networking: the GIKI model

The place of 'working in a net' cannot be over-emphasised. Networking is what ensures that resources are efficiently utilised and that personnel are effective. Historically, networking within Nigeria's NIS has been extremely difficult. In fact, even within single institutions, researchers often find it difficult to work together due largely to distrust, territorial behaviour and a go-it-alone attitude. Multidisciplinary research is,

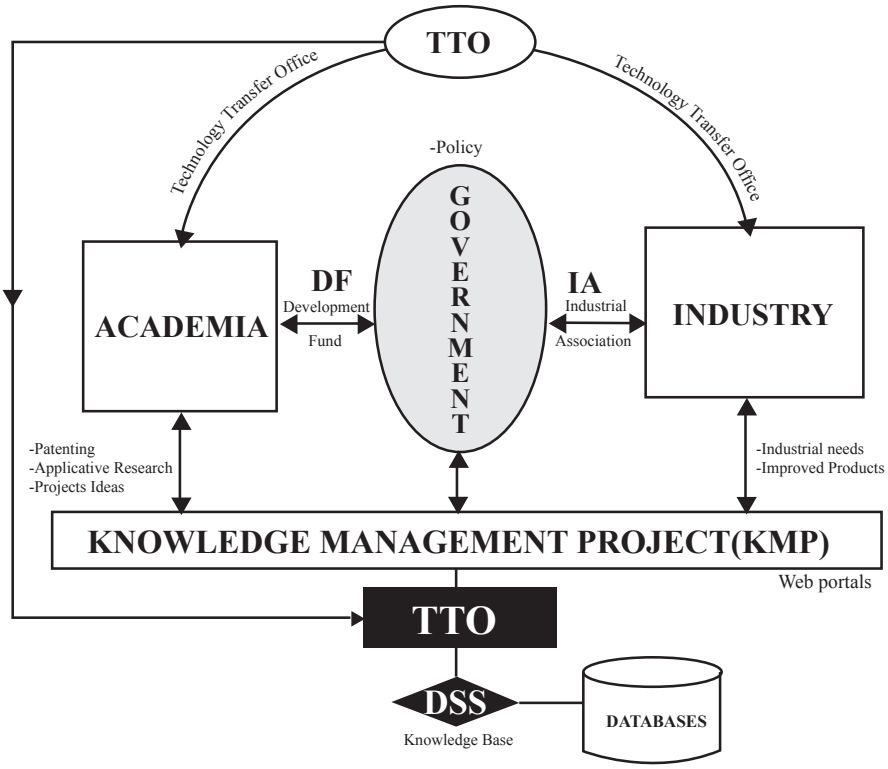


Figure 5 Model for automating interactions among government, industry and academia

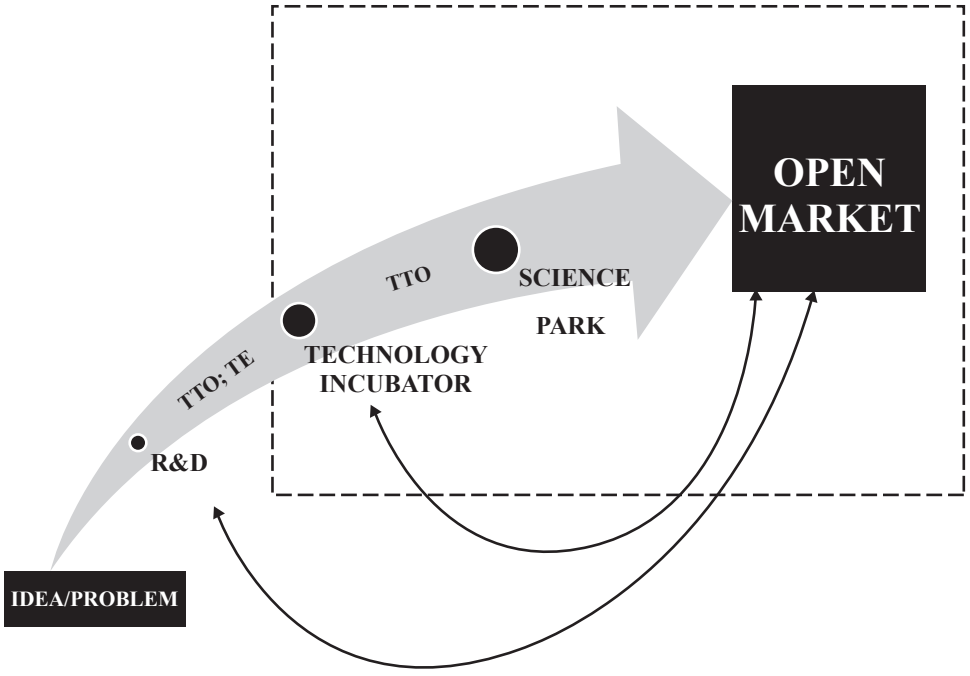


Figure 6 A new model for effective technology transfer to the market

therefore, at an all-time low in the country. Facilitating networks of researchers is particularly critical for R&D to have any meaningful impact on development in Nigeria. The model presented in Figure 5 typifies how interactions among the main stakeholders within the NIS can be automated. The underlying principle of the model is that interactions can be 'virtually' facilitated, completely overcoming the constraints of time and space. The model is essentially powered by interface organisations – Technology Transfer Offices (TTO) – through the knowledge management project. Databases of mutually beneficial knowledge are situated within these TTOs. These databases are made accessible to stakeholders within government, industry and knowledge institutions (G-I-K-I) for knowledge acquisition and sharing. It is then possible, for instance, for a researcher in a university in the northern part of the country to identify a researcher in a public research institute in the southern part who shares common research interests; or for the industry to place specific research questions to scientists in an area of need; or for researchers to jointly work on a research issue. Indeed, the potential possibilities of this model are limitless.

5.5 Effective Technology Transfer Model

R&D outputs do not suddenly appear in the marketplace; a process must be followed to ensure first and foremost that the outputs meet market expectations and secondly to improve the prospect of success. Such processes will help in moderating and removing barriers as well as amplifying the profit and sustainability potentials of any technology. The model being advanced here (Figure 6) is one that begins the technology transfer management from the idea stage to ensure that the market is considered. Through Technology Transfer Offices (TTOs) and the activities of technological entrepreneurs (TE), organisational forms built around R&D outputs can then be taken through the incubation system and subsequently through the Science Park system before they are diffused into the open market. Alternative routes leading directly from R&D to the market and from Technology Incubators to the market are also possible but much more risky.

6. Conclusions

This paper has systematically reviewed the concept of R&D and its current status in Nigeria. Key issues that militate against the developmental impact of R&D were identified as poor funding, infrastructural constraints and misdirected orientation of researchers. The consummate point of this paper is that R&D activities need to be better managed at all levels before they can lead to wealth creation. Major ways of doing this, as earlier discussed are: building a strong and virile NIS; re-orienting individual researchers; re-arranging institutions; establishing functional Government-University/Research Institutes-Industry Linkage through networking and embracing a pragmatic model of technology transfer which this paper advances. In sum, individuals, knowledge institutions, government and the productive sector all have a critical role to play in ensuring that R&D translate to wealth within the Nigerian context.

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