ISN'T THERE A BETTER WAY? THE CASE FOR A PARADIGM SHIFT IN R&D IN NIGERIA

Willie O. Siyanbola
Director-General/CEO
National Centre for Technology Management (Federal Ministry of Science and Technology)
PMB 012, Obafemi Awolowo University Ile-Ife, Nigeria
Dg.ceo@nacetem.org,www.nacetem.org

Abstract
In today's globalised world, the role of Science and Technology (S&T) in national development cannot be compromised. Several nations of the world have demonstrated how quickly S&T can bring about transformations in national status. However, the impact of S&T on development in Nigeria is not yet pronounced. Indeed, research and development (R&D) efforts within the country do not sufficiently translate into needs-based solutions. It is within this context that this paper reviews the present status of R&D in Nigeria in what we call the old paradigm. A new paradigm which is based on the joining of science, technology and innovation is presented. We argue that until S&T capabilities are effectively diffused through innovation, the benefits derivable from S&T are not actually realised in an economy; and that an effectively wired National Innovation System (NIS) is required for this to happen.

Introduction

Science and Technology (S&T) have acquired increasing attention in the new world order. It is now well-known that Science and Technology (S&T) are the inseparable twin keys to progress and industrial growth in today's increasingly knowledge-driven world. Because science leads to invention, consequently impacting greatly on the development of a nation, and, by extension, development; a nation with no basic scientific research capacity effectively excludes itself from having any real influence on the future directions of science. The role of science in development has long been recognised. Today, even economists have agreed that without scientific knowledge and its application in the use of the other factors of production (land, labour and capital); the economy either remains stagnant or deteriorates. However, global experiences have shown that the conduct of science does not robotically translate into development. As a matter of fact, huge expenditures in science do not equal knowledge-intensive activities and industries; just as scientific knowledge generation does not imply knowledge application.

According to Goldemberg (1998), development does not necessarily coincide with the possession of advanced scientific capability to produce nuclear weapon or launch satellites. Rather, in today's knowledge driven economy, development requires the use of scientific knowledge to create modern agriculture, industrial systems and education. Prusak (1996) made this more explicit when he explained that the only thing that endows a competitive edge on an organisation or a nation, is what it knows, how it uses what it knows and how fast it can know something new. This brings to the fore the importance of a union between science (continuous search for new knowledge and refinement of what is already known), and technology and innovation (applying what we know to create economic benefits and promoting the acquisition of new knowledge through learning-by-doing).

It is within this context that the role of research and development (R&D) cannot be overlooked. The main aim of this paper is to examine indigenous scientific efforts in Nigeria and the paradigm behind them. This is done with a view to recommending a paradigm shift which will ultimately translate to sustainable national development. First, the nation's development aspirations as well as her current performance as far as the attainment of these aspirations is concerned are briefly discussed. Then, the context for the discussion is extended by examining the concept of research and development (R&D) and why it is useful for national development. This is followed by a critical examination of the old paradigm in R&D in Nigeria. The elements and specific requirements of the new paradigm being advocated are then discussed before the paper concludes.

NIGERIA AND DEVELOPMENT: ASPIRATIONS AND PRESENT LEVELS

In the Nigeria of today, unlike it was in the pre-independence and early independence eras, most citizens do not have a feel of national prosperity. For instance, the nation now produces close to 20 million barrels of crude oil per day and sells at over 60 USD per barrel. In spite of that, a vast majority of the populace live below the poverty line. In

2005, GDP per capita was just 560 USD which is very low compared to that of most other countries with similar development profiles (Table 1).

Table 1: Selected Development Indicators for Selected Economies

Country*	Per Capita GDP	% population below poverty line	% population below $1/day	% population below $2/day
Japan	36501	-	-	-
South Korea	14265	..	<2	<2
Chile	5838	17.0	<2	9.6
Malaysia	4731	15.5	<2	9.3
South Africa	3489	..	10.7	34.1
China	1283	4.6	16.6	46.7
Nigeria	594	34.1	70.2	90.8

* Data for most recent available year

Source: Human Development Report, 2001; 2005; 2006

Furthermore, between 1999 and 2003, 34.1% of the nation's population live below the poverty line and over 70% live below 1 USD per day. A total of about 90% of Nigerians live below 2 USD per day (Table 1). Thus, the task of development for Nigeria is obviously huge.

In apparent realisation of the foregoing, the Federal Government of Nigeria has articulated key development agendas which include Vision 20/2020 and the 7-point Agenda. The focus of Vision 20/2020 is to position Nigeria as one of the top 20 economies in the world by the year 2020. As articulated by O'Neill *et al* (2005), Nigeria, alongside a set of 10 other countries have the potentials to attain this status if current trends are either maintained or improved upon. The 7-point agenda focus on key areas of national development that include human capital development and critical infrastructure, among others. In achieving these goals, however, there is no gainsaying the fact that Science and Technology (S&T) – particularly research and development (R&D) has a central role to play.

It has indeed been argued that critical action must be taken in specific areas if S&T must help us to deliver on our national aspirations (Ekpiwhre, 2008). It is known, for instance, that a country's innovation capacity – that is, the ability to create and/or apply new knowledge to solve practical problems – greatly depends on four indices: the country's level of technological capability; the formal and informal institutions as well as their supporting systems; physical infrastructure; and an advanced knowledge infrastructure. Using these criteria, Nigeria currently stands at 71st position out of 75 countries in a recent rigorous assessment reported as shown in Table 2 by Oyelaran-Oyeyinka (2008). In terms of GDP per capita, we are ranked 12th among the top-rated potential top 20 economies by 2025, and in terms of GDP growth, we are ranked 8th (Table 3). The need for us to pay attention to the key areas that determine our national capacity for S&T-driven growth, as earlier mentioned, is now urgent. The rest of this paper narrows the discussion down to the issue of R&D. How is this presently being carried out in Nigeria? How should it be carried out to guarantee maximum results? What management strategies are necessary to ensure that the nation derives sufficient benefits from R&D? The rest of this paper seeks to answer the foregoing questions, among a few others.

Table 2: Ranking of Countries according to Innovation Capacity

Group I **Frontier Countries**	*Group II* **Fast Followers**	*Group III* **Fast Followers**	*Group IV* **Lagging Followers**
1.United States	21.India	36.Ukraine	61.Kazakhstan
2.Japan	22.Portugal	37.Croatia	62.Moldova
3.Sweden	23.Ireland	38.Pakistan	63.Kyrgyz Republic
4.Germany	24.Poland	39.Malaysia	64.Guatemala
5.Switzerland	25.Hungary	40.South Africa	65.Peru
6.France	26.Slovenia	41.Bangladesh	66.NIGERIA
7.United Kingdom	27.Turkey	42.New Zealand	67.Panama
8.Canada	28.Australia	43.Belarus	68.Azerbaijan
9.Italy	29.Czech Republic	44.Thailand	69.Syrian Arab Republic
10.Finland	30.Mexico	45.Estonia	70.Ecuador
11.Israel	31.Slovak Republic	46.Tunisia	71Gabon
12.Korea, Republic of	32.Greece	47.Philippines	72.Benin
13.Austria	33.Romania	48.Russian Federation	73.Congo Republic
14.Hong Kong, China	34.Brazil	49.Lithuania	
15.Belgium	35.Bulgaria	50.Latvia	
16.Spain		51.Jamaica	
17.Netherlands		52.Jordan	
18.China		53.Argentina	
19.Norway		54.Egypt, Arab Rep.	
20.Denmark		55.Indonesia	
		56.Costa Rica	
		57.Vietnam	
		58.Colombia	
		59.Chile	
		60.Venezuela, RB	

Source: Oyelaran-Oyeyinka, 2008

Table 3: Basic Facts about selected entrants into the top 20 economies by 2025

	Population	Literacy	Poverty	GDP	GDP Growth	Teledensity	Power Generation
	Million	*(Adult %)*	*(Level %)*	*$ per cap*	*%*	*%*	*bnkwh*
China	1,330	91	8	5,300	11.4	63	3,260
India	1,150	61	25	2,700	9.2	23	662
Vietnam	86	90	14	2,600	8.5	51	596
Philippines	254	97	30	3,400	7.3	20	542
Egypt	81	71	20	5,500	7.0	36	103
Kenya	38	85	50	1,700	7.0	18	5.5
Pakistan	168	50	24	2,600	6.4	41	90
Nigeria	140	68	70	2,000	6.4	30	23
Ghana	23	58	28	1,400	6.4	24	7
Malaysia	25	89	5	13,300	6.3	95	83
Indonesia	238	90	17	3,700	6.3	33	126
South Africa	44	87	50	9,800	6.1	101	264
Iran	66	77	18	10,600	5.8	54	170
Bangladesh	153	43	45	1,300	5.6	13	21.4
Brazil	191	87	31	9,700	5.4	72	400

Source: Adapted from Maduka (2008)

THE CONCEPT OF R&D

R&D generally refers to creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications (OECD, 2002). According to the Frascati Manual (OECD, 2002), the term R&D covers three activities: basic research, applied research and experimental development. *Basic research* is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view. *Applied research* is also original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific practical aim or objective. *Experimental development* is systematic work, drawing on existing knowledge gained from research and/or practical experience, which is directed to producing new materials, products or devices, to installing new processes, systems and services, or to improving substantially those already produced or installed.

Generally, R&D is perceived to fall within the domain of science, technology and innovation (STI) activities. It is assessed through a number of standard input-output indicators such as the gross national expenditure on R&D as a proportion of GDP; number of researchers per thousand or million citizens, patents applied for by or granted to residents/non-residents in a country and economic outputs including the receipt of royalties/licence fees arising from patents or other forms of intellectual property. In the course of this paper, some of these indicators are assessed for Nigeria, in comparison with other countries (see Tables 4-7)

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 based only on their natural resource endowments and locational advantages. For a nation to withstand competition in this era of globalisation there is need for such to identify its niche areas and build on it by the application of scientific methods. The experiences of Brazil with sugarcane (Goldemberg, 1998) and Malaysia with the oil palm (Abiola, 2007) have shown that building scientific capacity and competences in the fields of natural resource endowment and locational advantages is a surer way to development. In consciousness of this, most countries now devote an increasing proportion of their resources to Science and Technology (S&T), and to the associated Research and Development (R&D), in an attempt to build competitive advantages, or to catch up with others who have done so.

For instance, the economic progress recorded in the 50 leading S&T countries is much higher than in the rest of the world. While the average wealth per capita in these 50 countries grew by 1.1% between 1986 and 1994, the per capita income of the other 130 countries of the world fell by 1.5% over the same period (OECD, 1997). Unfortunately, as the rest of the world has advanced technologically, Africa has fallen relatively further behind. From 1988 to 2001, the number of scientific articles published worldwide grew by 40%. Africa not only failed to keep pace with this growth, publication counts actually declined by 12% in absolute terms. In 1988, Africa accounted for 1.26% of all scientific publications; by 2001 its share was only 0.76%. And as the technological intensity of trade has grown, Africa has seen its share of world trade decline. Africa accounted for 2% of global merchandise exports in 1990, but only 1% by 2002. Indeed, countries that have heavily invested in R&D have reaped substantial economic benefits. Table 4 details the statistics for some selected countries. Unfortunately, the statistics for Nigeria are not readily available but some of these are highlighted in the next section.

Table 4: Selected R&D indicators for selected countries

	South Korea	China	India	South Africa
Population in millions (2003 est.)	47.5	1300	1070.8	46.9
R&D Expenditure as % GDP (1997-2002)	2.5	1.2	0.8	0.7
Researchers in R&D per million people (1990-2003)	2979	633	120	192
Royalties and Licence Fees in USD per person (2003)	27.8	0.1	-	1.1
Patents to residents per million people (2002)	633	5	0	0

Source: Human Development Report, 2005

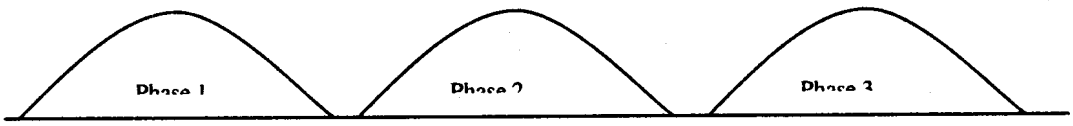
R&D IN NIGERIA: THE CURRENT AND OLD PARADIGM

There is no gainsaying the fact that certain things are wrong with the R&D system in Nigeria. It is important to note, however, that these issues have arisen from certain fundamental flaws that are not immediately obvious but can only be brought out with close scrutiny of the national system, such as is being carried out at NACETEM. For instance, NACETEM has closely monitored innovation capability in the industrial sector for about 3 years now and we have studied extensively the nation's National Innovation System (NIS) over the same period.

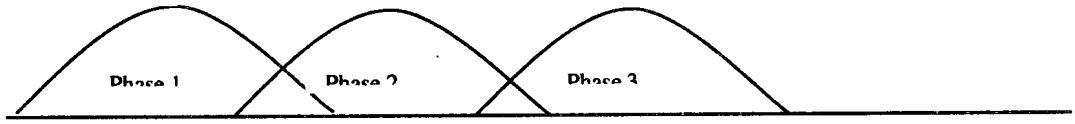
It has been established both empirically and qualitatively that R&D in Nigeria is well characterised by the schematic in Figure 1, Model A. There is an inherent discontinuity among the research activities in institutions, the development activities required to produce artefacts and subsequent manufacturing 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.

Regarding the availability of funds to prosecute research, there is an emergent awareness of the contribution of science and technology to national development in Nigeria. This is evidenced by the consistent increase in budgetary allocations to S&T, in recent times. From ₦1.5 billion in 1998, the Federal Government increased S&T allocation to a total of ₦5 billion to in 2004. This 233% increase averaged about 33% each year, over the 7-year period. By 2006, federal allocation to S&T had increased to ₦ 16.0 billion, representing a 220% increase from 2004 (an annual average of about 73 %) and a 730% rise from 1998 (annual average of about 81%). As impressive as these increases appear to be, federal allocation to S&T is still grossly inadequate when other issues are taken into account. For instance, the Nigerian GDP in 2006 was estimated to be US$116 billion which is about ₦ 14,900 billion (at the rate of ₦129 to 1 US$, 2006 est.). Working with these figures, the nation's S&T allocation in 2006 is shown to have amounted to only about 0.11% of GDP - a far cry from UNESCO's recommended 1%. In the absence of serious local funding for R&D, therefore, most researchers turn to foreign donor agencies and institutions that set the research agenda that may not necessarily address local problems. Little wonder, then, that research solutions to many of our local problems are still apparently elusive. It is inconceivable, for instance, that the development of an anti-malaria vaccine will be successfully funded with foreign funding.

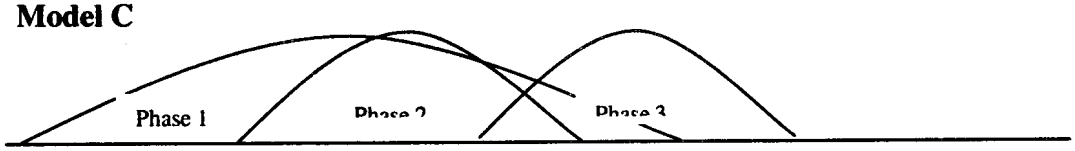
Model A



Model B



Model C



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

Science and Development

In terms of institutions, the nation has approximately 200 institutions where R&D could take place to a varied extent (Table 5). In spite of this somewhat extensive institutional framework, cases of specific potentially impactful R&D breakthroughs are rather few and far between. Essentially, R&D productivity in these institutions is somewhat low. For instance, productivity in terms of research publications appears high but it is actually low in absolute terms and compared to other countries.[1] Indeed, when other issues such as number of researchers per institution; the funds allocated to R&D and the number of patents granted in the country are considered, the inadequacy of the R&D efforts come out even more clearly (see Tables 1 and 3). In addition, the efforts invested in scientific paper publications and human resources do not sufficiently translate, first and foremost, to industrial properties and then to observable impacts of science on national development. For instance, only 74 local patents (as against 122 foreign patents) were registered in Nigeria in the 6-year period between 2000 and 2005 (Table 7). In China and India, the figures are in the range of tens of thousands (Table 6).

Table 5: Science and Technology Institutions in Nigeria, 2006

Institutions	Total number
Science Policy Making Bodies	3
National Research Institutes	63
International Research Institutes with major activity in Nigeria	6
Science and Technology Agencies	12
Higher Educational Institutions with Science-based disciplines	
Universities	89
Polytechnics	21
Colleges of Education	71
Other S&T Organisations	15
Total	196

Sources: http://nicoys.net.ng/nigeria/orgs.php?n=1, (June 26, 2007); http://www.nucnigeria.info/universities.htm, (April 17, 2007)

[1] Between 1995 and 2005, Nigerian researchers contributed to over 9,100 articles in top-class international journals, albeit, close to 6,000 0f these are from only 10 universities. When local journals are also accounted for, the figure could go as high as 15 or 20,000 – a far cry from figures in the range of hundreds of thousands recorded in countries like China and India.

Obafemi Awolowo University, 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 are either surveys, impact analyses, appraisals, evaluation studies or analytical studies, while only about 1% is innovative and/or interdisciplinary (Akinsola, 2007).

The National Universities Commission (NUC), since the early 1980s noted that:

> *"in terms of quality and quantity, the research output of tertiary institutions in Nigeria was about the best in sub-Sahara Africa up to the late 1980s (Karani, 1987). The wherewithal for research surely as good research training and motivation, availability of equipment, and good library facilities pre-dominated, with the onset and acceleration of the decay in the system, these ingredients faded away. By 1996, the quantity and quality of research had declined to an all-time low" (Okebukola, 2002: 49).*

Summarizing the factors that contributed to this decline from the late 1988 to 1996, and subsequent collapse from 1997 to date, the NUC listed the following:

1. Lack of research skills in the modern methods;
2. Constraint of equipment for carrying out state-of-the out research;
3. Over-loaded teaching and administrations schedules which thee little time for research;
4. Difficulty in accessing research funds;
5. Diminishing scope of mentoring junior researchers by seasoned and senior researchers due to brain drain (Okebukola, 2002; 4).

Putting together all the issues identified so far, the key challenges of R&D in Nigeria can be itemised as:

i. a generally poor attitude towards research in Nigeria, even among researchers. Many people were unwilling to supply necessary information;
ii. a huge disconnect between social demands and research supply which has resulted in the generation of much knowledge that are not directly relevant within our national context and gross misfit between research activities and national priorities;
iii. poor funding of research and development activities;
iv. infrastructural constraints;
v. an apparent lack of coordination in research and development activities which has brought about a situation in which meagre resources are spread too thin on several small and, many times, duplicated research initiatives.
vi. an ailing industrial sector as evidenced in high firm failure rate
vii. a generally poor attitude towards patenting and other forms of intellectual property rights

The prevalence of these issues shows that there is a great need for a change in the approach to research and development (R&D) in Nigeria. The following section discusses in further detail why there should be a shift in paradigm and what the new paradigm is all about.

NEW PARADIGM IN R&D

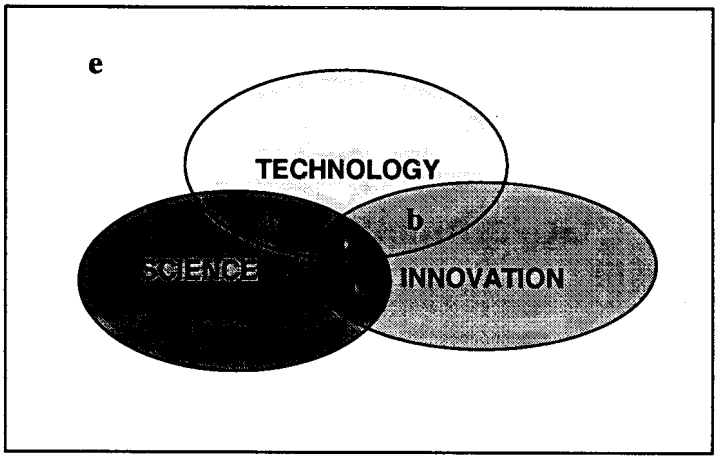
Beyond any doubts, it is now known that the connection between science and technology is neither linear nor anti-linear, but in fact highly non-linear. Indeed, the

> *"...historical study of successful modern research has repeatedly shown that the interplay between initially unrelated basic knowledge, technology and products is so intense that, far from being separate and distinct, they are all portions of a single, tightly woven fabric"* (Holton et al, 1996)

The foregoing statement is more or less an allusion to the patterns in models B and C in Figure 1, with varying degrees of tightness in the weave of the fabric. These models are more realistic and offer a promising path towards development that developing countries should follow. In these models, practical needs - that is, demand - influence supply, namely, the type of basic research that is done. In the past two decades, however, innovation has evolved to become, not just an activity under S&T but a key variable in the development equation, mainly due to the realisation that a nation becomes competitive only on the basis of knowledge, the application thereof and the speed with which

new knowledge is acquired (Prusak, 1996, 1998). Thus, the joining together, as depicted in Figure 2, of science (increasing what we know), technology (applying what we know) and innovation (turning our applied knowledge into economic benefits and promoting the acquisition of new knowledge through learning-by-doing) is more useful than the singular contributions of any of science or technology. Indeed, until S&T capabilities are effectively diffused through innovation, the benefits derivable from S&T are not actually realised in an economy.

Nonetheless, STI activities have to exist within the frame work of the National Innovation System (NIS). The National Innovation System (NIS) has been defined in different ways by various authors and is generally depicted as shown in Figure 3. Freeman (1987) defined it as "the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies." Freeman's definition emphasises the interaction between the production system and the process of innovation. Ilori (2006) defined it as a constitution of elements and the relationships located within or rooted inside the borders of a nation state, which interact in the production, diffusion and use of new and economically useful knowledge. An important advancement in this definition is the consideration that must be given to economic usefulness of STI activities.



a = Science and Technology;
b = Technology and Innovation;
c = Science and Innovation;
d = Science, Technology and Innovation, the exact place where economic benefits are optimally derived. It also takes cognisance of complementary factors that affect the ability to exploit knowledge potentials irrespective of the knowledge source
e = the National Innovation System (NIS), the domain in which all activities take place

Figure 2: Linking science, technology and innovation to development
Source: Egbetokun and Siyanbola, 2008

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, 1999). 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 her society.

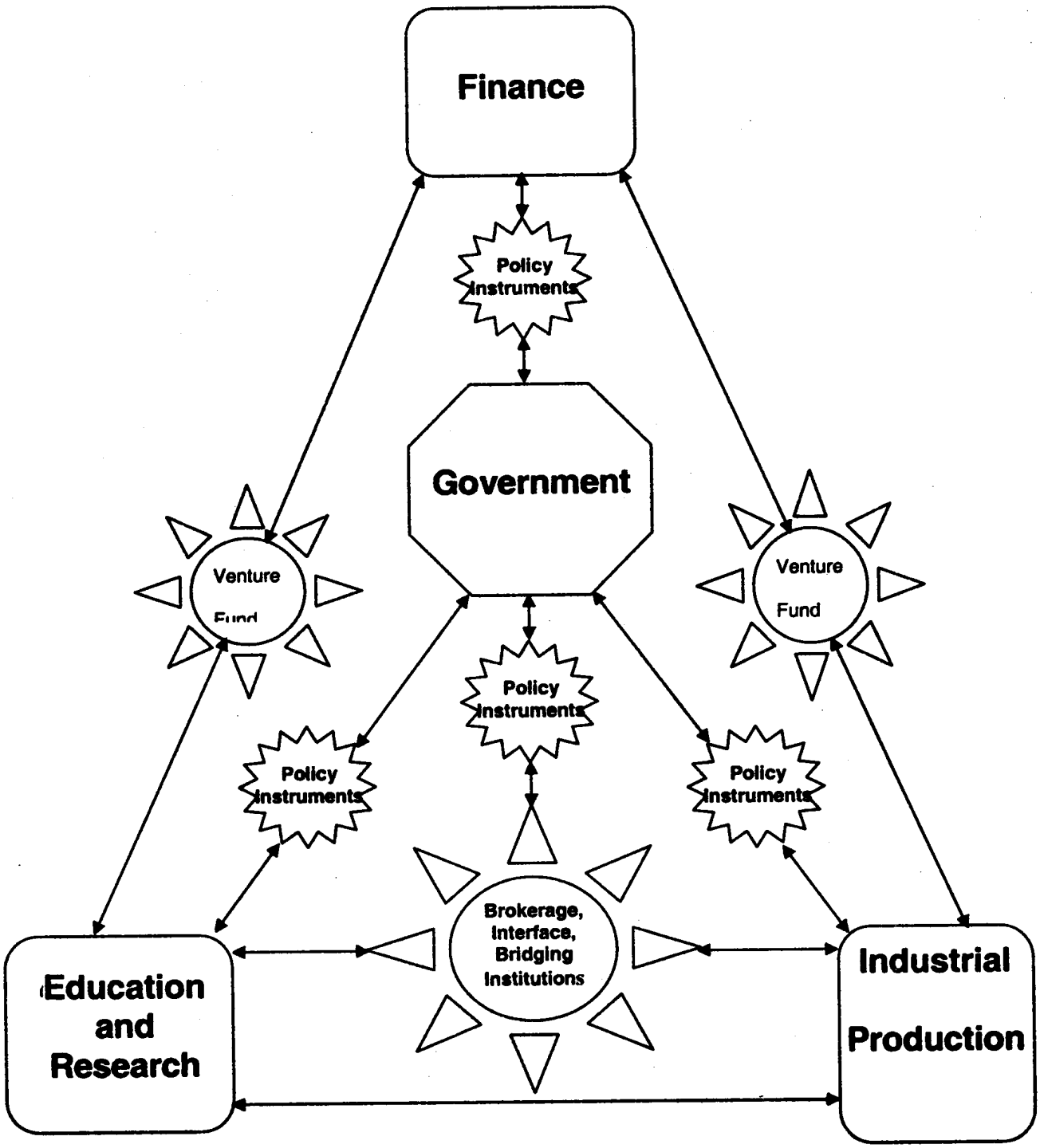


Figure 3: Typical Structure of Interactions among the Elements of the National Innovation System

Source: Adapted from Tiffin (1997)

SPECIFIC REQUIREMENTS OF THE NEW PARADIGM

Following are the key requirements of this new R&D paradigm. It is to be noted that while the items considered here are by no means exhaustive, they represent a gamut of broad, cross-cutting issues within which many more definite issues are encompassed.

i. Individual re-orientation

The basis for any change in systemic paradigm is a change in 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 lonesome, territorial research are long gone. Every serious researcher, rather than jealously conceal their work, should be willing to share their knowledge and work with others for the common good. In fact, rather than make secrets of research results, protecting these through intellectual property rights (IPRs) is exceedingly more beneficial. Intellectual Property (IP) is a legal term that refers to creations of the mind such as:

a. musical, literary, and artistic works;
b. inventions;
c. symbols, names, images, and designs used in commerce,
d. copyrights, trademarks, patents
e. and related rights

IP does not only contribute to better quality of life for inventors but also contribute to national development in both developed and emerging countries.

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 approach to research, the nation would only be left with numerous 'egg-heads' with purely curiosity-driven research results that have almost no direct social relevance.

ii. Institutional re-arrangement:

The fact that R&D is not impacting on national development in the country, 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 workings – 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 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.

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 connected in no small way to the national priorities as articulated presently in NEEDS I and II, the 7-point agenda and the Vision 20-2020 initiative of 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. In doing all of these, existing institutions will need to be strengthened and new ones may have to be created where there are none. For instance, it is necessary for every state of the federation to create a Science and Technology Ministry which can oversee all S&T activities within the state and co-ordinate with the NRDCC.

iii. Government-University/Research Institutes-Industry Linkage through Networking: the G-I-A 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 lonesome attitude. Multidisciplinary research is, 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. Several approaches can be adopted ranging from the creation of centres of excellence in multidisciplinary research (such as SHETSCO in Abuja) to the establishment of Central Science Laboratories in institutions (as in Obafemi Awolowo University, Ile-Ife).

The model presented in Figure 4 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 academia (G-I-A) 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 share 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.

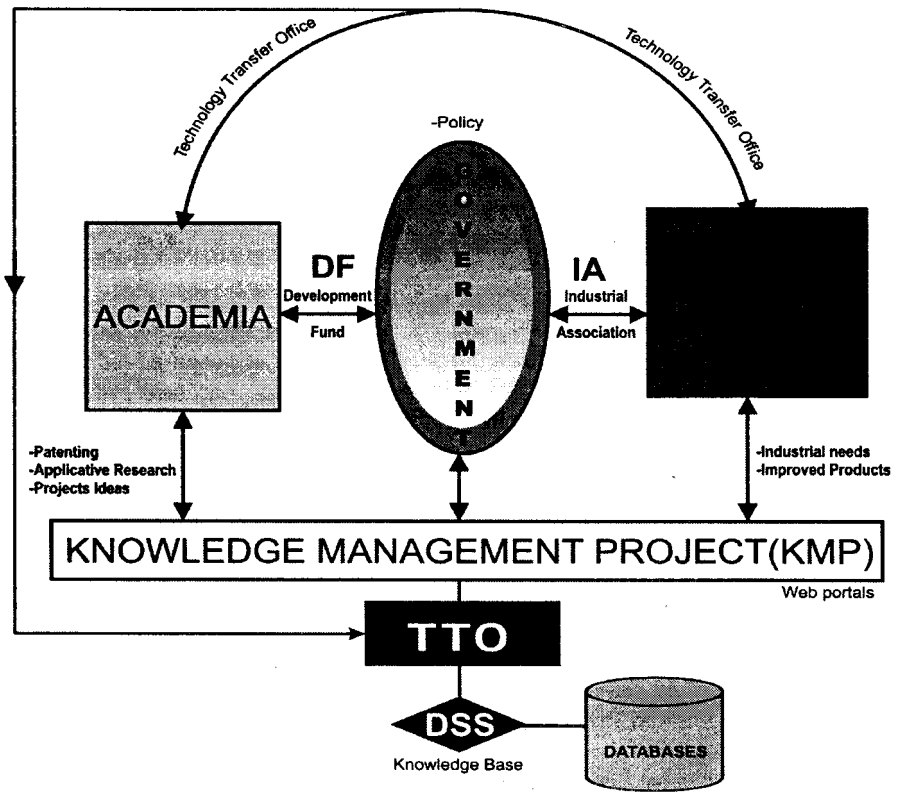


Figure 4: Model for Automating Interactions among Government, Industry and Academia
Source: Awoleye and Siyanbola, 2007

COLLECTIVE RESPONSIBILITY: THE ROLE OF STAKEHOLDERS IN THE STRATEGIC MANAGEMENT OF R&D

As it has been presented in this paper, the NIS functions like the 'master reactor' that determines the success and profitability of national R&D efforts. Therefore, every stakeholder within the NIS, beginning with individual researchers, needs to see itself as part of a larger whole. The NIS will function best when each element fulfils its unique roles as suggested in Figure 5 below.

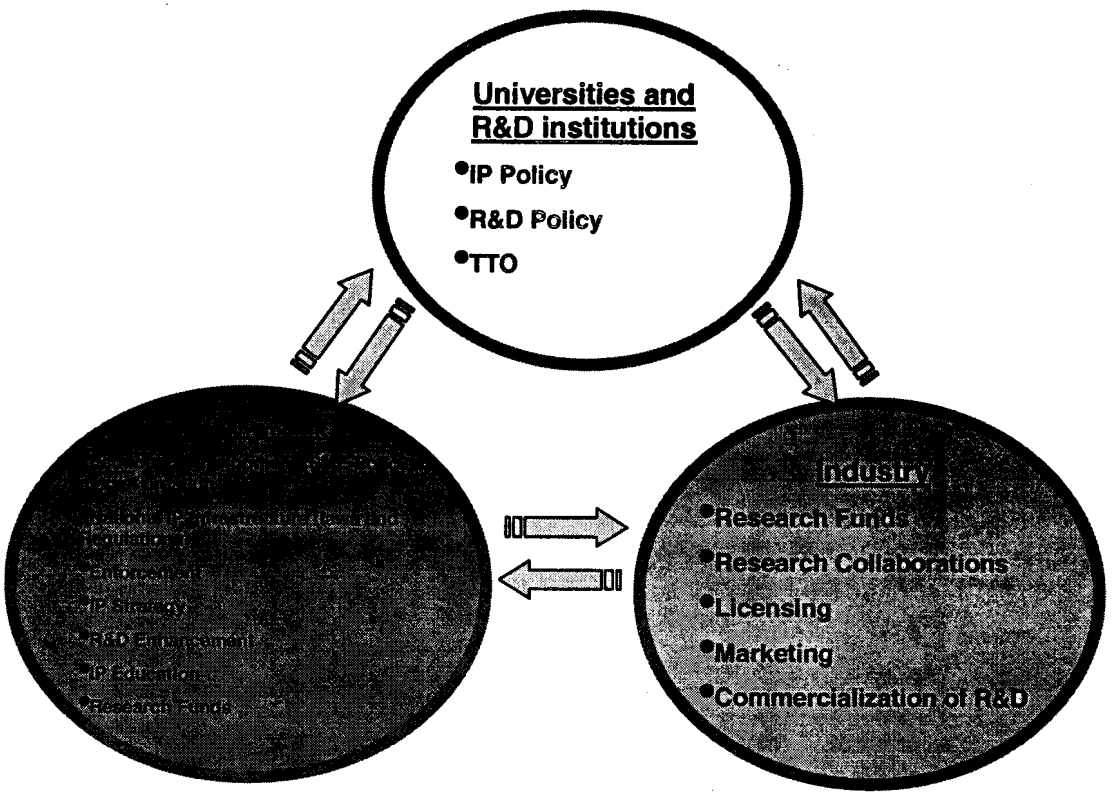


Figure 5: Structure of Government-Industry- Academia (G-I-A) Relationship
Source: Adapted from WIPO, 2008

(a) Academia

For there to be proper alignment of R&D activities and for the activities to yield maximum results, certain specific steps need to be taken by the education and research organizations. First each institution needs to set up a strong research council, the function of which will be to co-ordinate all R&D activities within its domain. Such a council will be helpful in refocusing R&D activities in each institution to ensure that they are demand-driven and based in areas where each institution has comparative strength. The council will also offer the added benefit of promoting technology transfer because the results of demand-driven R&D will always sell. For optimal benefits, a SWOT assessment will need to be carried out for each institution to identify its areas of strength and focus on those. Moreover, institutions will need to strengthen their internal systems and infrastructure. This is particularly necessary considering the fact that there is significant resource constraint within the NIS. A useful initiative would be the establishment of central laboratories where resources can be pooled and joint research activities could occur, rather than attempting to support too many 'small' isolated laboratories. Besides allowing for more efficient resource utilization, this approach will more readily facilitate multidisciplinary research than mere advocacy. Regarding their training responsibilities, tertiary education institutions will need to modify their curricula (or develop new ones, if necessary) to make them more industry-relevant and make graduates more readily employable.

(b) Government

As a primary agent of change, the government has its own key roles to play. Provision of basic infrastructure for R&D is particularly critical. Statistics show that infrastructural constraints are exceptionally high in Nigeria. For instance, Nigerian citizens, including, of course, every researcher and scientist have an unusually low amount of electric energy at their disposal (Figure 4). It becomes imperative, therefore, that decisive action be taken in this regard. Given the central role of funding in R&D, it is important that the government pays attention to this. Beyond using public funds directly, there are a number of financing options that could be explored. These include the establishment of Venture Capital organisations and/or innovation funding organisations as well as facilitating and engaging in public-private partnerships.

Besides providing fund and infrastructure, government also has the responsibility of protecting spin-off companies, most of which are essentially small- and medium-sized firms. Beneficial mechanisms would include the establishment of S&T parks, strengthening and publicising Technology Business Incubation Centres (TBICs), creation and/or strengthening of interface organisations like the TTOs, among others. In addition, the development and implementation/enforcement of a concise IP policy falls within the purview of government. This would encompass the amendment of laws governing government-funded patents.

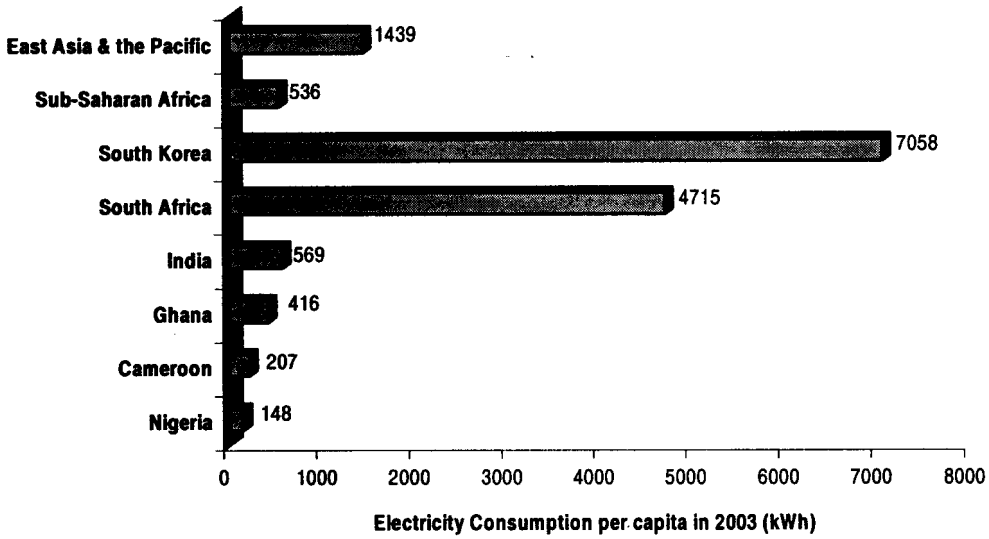


Figure 6: Electricity Consumption per capita in selected countries, 2003
Source: World Development Indicators, 2005

(c) The Private Sector (Industry)

The primary function of the private sector within a healthy NIS is to receive and commercialise technologies from knowledge centres – thereby completing the STI cycle with innovation activities. In doing this, it is fundamental that industry operators embrace the concept of open innovation. Open innovation is described as combining internal and external ideas as well as internal and external paths to market to advance the development of new technologies, with the realization that not all good ideas start at home. In a way, open innovation requires extensive networking and might therefore be alternately perceived as network innovation. Making network innovation work involves cultivating contacts with start-ups and academic researchers, constantly scouting for new ideas and ensuring that engineers do not fall prey to "not invented here" syndrome, which always values in-house ideas over those from outside (WIPO, 2008). To make this concept work even more, industry operators will be required to actively engage in research collaborations. It is, for instance, a global best practice now for the private sector of an economy to provide considerable research funding. This is an area in which Nigeria is lagging seriously behind most other nations. In South Korea, for instance, the business sector now provides over three-quarters of R&D funds (KISTEP, 2007). When these are done, it then becomes relatively easier for industrial firms to commercialize R&D outputs through licensing, IP exploitation etc. Besides offering greater returns for the firm, the economy as a whole will benefit from such strategic partnerships.

Conclusion

This paper has systematically reviewed the concept of R&D and its current status in Nigeria. The case was made for a shift in paradigm and the elements of the new paradigm were discussed in detail. Specific strategic action steps have also been suggested for each of the stakeholders within the NIS. Key issues that militate against the developmental impact of R&D were identified as poor funding, infrastructural constraints and poor attitude of researchers. The underlying principle of the new paradigm advanced herein is networking. The key requirements for the paradigm shift to occur were identified as a change in the mindset of individual researchers, a more progressive institutional structure and a network approach to R&D. It is believed that if this paradigm shift is embraced and the strategic steps recommended are taken, the impact of R&D on national development will become evident sooner than later.

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