# Basic Science: The Foundation of Science-Led National Development - Pursuing the New Nigeria Vision through SETI

By Anya O. Anya*


The world we live in has changed dramatically. At the beginning of the 20th century we saw the emergence of some countries of the world as industrial societies in which a nation's endowment of natural resources conferred some comparative advantages that enabled it to produce goods and services that improved the quality of life of its citizens. In 1900, for example, it took half a hectare of land and more than one year of human labour to produce enough food to feed one person. In the year 2000, that same half hectare can now feed 10 persons with an input of one and a half day's labour. What has made the difference is the scientific knowledge embedded in better fertilisers, machinery, better seeds and crop varieties that is the foundation of modern agricultural practice. This difference is emblematic of the emergence of the knowledge economy in the knowledge societies.

The bedrock of this transformation is the science, engineering, technology and innovation (SETI) systems that characterise some of the societies of the modem world. Equivalent transformation in quality of life can be seen in the health sector, in industry, in education and in the general economic wellbeing of some societies of our modem world. Thus, we can see the co-existence of pre-industrial, industrial and post-industrial (knowledge) societies in our modem world. The difference between them lies in the quantity and quality of scientific knowledge available and utilisable by each society. Hence, while in the traditional (pre-industrial) societies knowledge in the form of accumulated experience drives the production factors, in the emerging knowledge societies science-based knowledge (rational and systematic) is regularly transfused into the production system. Human capital with its stock of skills and knowledge is the driver of the knowledge economy rather than natural resource endowments.

## Globalisation and the Emer-

**gence and Structure of the Knowledge Economy**

Two developments in the last quarter of the 20th century have enabled us to clarify the cogent factors in the emergence of the knowledge economy and the institutional structure that drives it: namely, the phenomenon of globalisation and the emergence of the so called Asian tigers, particularly the dramatic entry of China into the world economic scene. Globalisation has brought about closer integration of the countries and people of the world as a result of the drastic reduction of costs in transportation and communication, which facilitated the flow of goods, services, capital and knowledge, especially technology across borders, often inducing a concomitant movement of people - the brain drain. This has often come with trade liberalisation, deregulation and the facilitation of market-driven development characterised by competition, emphasis on fiscal austerity, privatisation and market liberalisation - such as in the lowering of tariffs and the elimination of protectionist policies.

Unfortunately, for countries to take advantage of these new developments, a new institutional framework that can aid governments in creating, shaping and guiding markets, including the stimulation of new technologies, while creating a conducive environment for the operation of firms in the private sector, is necessary. Countries that have not pursued the development of the new institutional framework such as in Africa, as exemplified by Nigeria, have paid a high price for globalisation as their environments have often been destroyed, their political processes corrupted, while the pace of change has not allowed time for cultural adaptation that can stabilise the society. This has led to high unemployment and social anomie reflected in increase in violence, as well as ethnic and sub-national conflicts. The Asian tigers, as particularly exemplified by China, have relentlessly built the infrastructure for a knowledge economy at breakneck speed, while they also pursued their own alternative strategies of development as they built the institutions required.

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The Asian countries recognised early that no country will be able to achieve and sustainably maintain prosperity and a high quality of life without using the results of research and ensuring a well educated population. For example *South Korea, Singapore and Taiwan* devote more than *2 per cent* of their GDP to research and development *(GERD/ GDP)*[1] *(*See Table 1), while *China* targeted the achievement of *1.5 per cent (GERD/GDP)* by 2005. Indeed the pace of promotion and institutionalisation of S&T in China is best illustrated by the fact that in 1997 China contributed 3.9 per cent of the world's GERD, but 5 years later by 2002, this had gone up to 8.7 per cent of world GERD. Table 2 shows the relative distribution of research workers in selected countries of the world.

The increase in GERD is reflected in an increase in the number of publications and in patents granted. For example, in Russia there are 3,400 research personnel per million of the population; in Japan the figure is 5,100 per one million inhabitants; and in the U.S it is 4,400 researchers per one million inhabitants. Table 3 illustrates the share of scientific publication and patents for selected countries, China's share of publications has increased from 1.4 per cent of world total in 1991 to 4.1 per cent in 2001.China's performance in patents is less dramatic but this can be explained by the fact that patents are also indicative not only of the vitality of the S&T system but of the strength and maturity of the business environment, which provides strong incentives for innovations and, hence, patents. An additional parameter that indicates the maturity and viability of a nation's S&T innovation system is the level of imports and exports of high-tech equipment. China, for example now imports more scientific instruments, electronics and telecommunications products and electrical machinery than Japan!

## The Dynamics of the Knowledge Economy

An important characteristic of knowledge economies is the heightened level of innovations which often translates into a higher level of publications and, particularly, patents as we saw earlier. Here innovation is defined as a new idea "that has proven successful as a product on the market, as a therapy applied in the health institutions, or as a new policy arrangement adopted by governments..." In much of the 20th century, it used to be assumed that basic research provides the inputs to applied research, which in turn drives the development of technologies resulting in innovations. This linear model has proved simplistic and inadequate to aid our understanding of the dynamics of the relationships underpinning the knowledge economy. On the one hand, there are the different but interlocking processes that characterise the *development of science,* the *development of technology* within the defining rubric of problem-solving and the *development of innovation.* On the other hand there is the web of relationships and interactions between institutional operators of the knowledge economy as between the knowledge creators - such as the universities and research institutes - and the knowledge users - such as industries and enterprises, including chambers of commerce, venture capitalists, schools, banks etc. - and the government as the regulator and lubricator of the environment and milieu in which the creators and users of knowledge operate effectively and efficiently.

This interactive matrix results in a network or *system of innovation* on the one hand, and *clusters of economic activities* on the other. It is out of this interactive matrix that knowledge economies are continually pushed upwards. Societies that are impatient to understand or develop this web of institutions and activities such as ours are doomed to wander in an endless jungle of stagnation and underdevelopment. To break out of this vicious cycle is the challenge.
In a nutshell the diamond core of the knowledge economy is defined by the interactive hexagon at the core of two interlocking triangles.

Thus, what Peter Tindemans has characterised as a triple helix consisting of the way in which cooperation between companies, knowledge institutions and government bodies interact is, in my view, but one entity; the dynamic core of interactions that drives the system of innovation is another triple helix which co-exists with the first triple helix. The second helix defines the relationship between science, technology and innovations which generates *the production system* characterised by *clusters of economic activities.* The superposition of the two triple helices on each other - here represented as triangles - is what drives the knowledge economy (see Figure1). It should also be clear that what drives the dynamics of the 'diamond' core of the interlinked twin triple helices is the process of innovation.

While the output of the SETI system is measured by the output of research in publications and patents, it is innovation which captures the mechanism through which SET ultimately delivers to the economy the levers for the upward climb in quality of life and sustainable prosperity, through increased production and value addition. Thus the institutional

**Figure 1:** The evolution of the two sub-systems that drive innovation and productivity with enhanced value

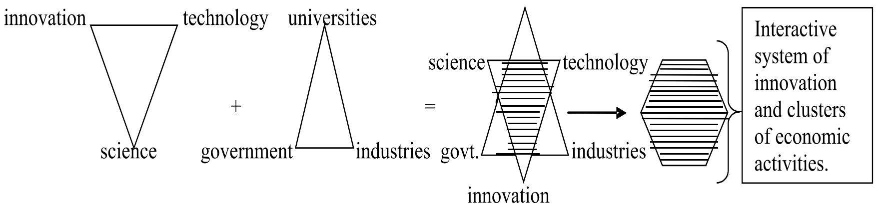
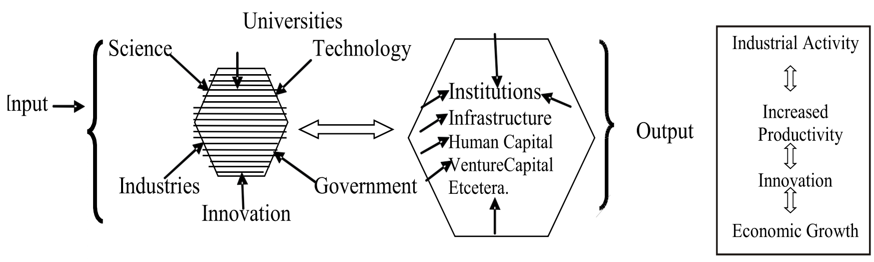



**Figure 2:** The interactive matrix that generates innovation and clusters of economic activities



matrix of the interaction between science, technology and innovation as processes, on the one hand, and the organisational framework and interaction of governments, universities and industries, on the other hand, is fundamental to the development and operation of the knowledge economy (Figure 2). So the question arises: how can we measure the innovative capacity of the S&T system of a country, as a basis to anticipate the trajectory of its evolution into a production system underpinning the knowledge economy and society? Obviously it is by the depth and intensity of the interaction in the 'diamond' matrix.

The EU has attempted to develop an innovation index (SII) which is made up of various parameters for measuring human capital, such as the quantity and quality of science and engineering graduates, the level of investment in lifelong learning as reflected in the level of development of the high tech sectors of the economy etc. The quantum of knowledge creation captured in R&D expenditure (GERD) and patents and the effectiveness and efficiency of the transmission and application of knowledge, as reflected in the number of innovating small and medium-sized enterprises, are all relevant parameters, in addition to the systems for financing innovative ideas, such as venture capital and the share of high tech products in the manufacturing industry.

## The Universities and the Relevance of Basic Research

In much of the knowledge economies of U.S., U.K., Japan, France and Germany, much of the R&D is predominantly funded by industry. In the US, between 1953 and 2000, there was a tenfold increase of private sector funding for R&D, from USD3.6 billion (18.9 billion in 1996 dollars) to USD186.7 billion. In 2000, US industry performed 72 per cent of the R&D and funded 66 per cent of the R&D. In Japan, U.K., Germany and France industry performed over 63 per cent of all R&D. This throws up the question of the relevance of basic research. In all these countries, basic research is predominantly done in the universities. Indeed of the 3,400 degree awarding institutions in the US only 127 - mostly universities - are involved in research. Nevertheless, basic academic research is recognised as:

> *"a source of technological opportunity; a source of new interactions, networks and technological options and, hence, broadening of technological diversity; and a source of skills to translate knowledge into practice, enhance the ability to solve complex technical problems and an entry ticket to the world's stock of knowledge..."*

Without basic research both applied research, technology and innovations will be severely constrained. The relevance of basic research is emphasised by the realisation that it confers the human dimension to the progress of science. The best of science brings to bear the very human qualities of serendipity, creativity and intuition. This fact is underlined by the signal failure of attempts to replace the human input in research as seen in 'combinatorial chemistry'! In the mid-1990's pharmaceutical companies used robots to create huge numbers of chemical combinations that were then tested by robots to see which ones showed promise with biological specimens. By 2002 combinatorial chemistry had failed to create a single drug approved by the US Food and Drug Administration. As Arvid Carlsson, the Nobel laureate observed: "it replaced intellectual creativity with a robot - a highly sophisticated robot, admittedly - but a robot can never have intuition." It is the human quality of intuition and imagination that drives basic research in addition to the syllogism that underpins the pursuit of excellence in the scientific endeavour. Thus, it seems that basic research will continue to be funded by the public sector and pursued by the universities. While much of the innovation that underpins R&D efforts in industrial economies and drives the upward swing to economic prosperity and quality of life remains critical to the economy, it is still basic fundamental research - thanks to the very human inputs that it engenders - that remains the foundation of all scientific and technological effort and the basis of national development. It is clear that our universities must be equipped to remain the centers of excellence in basic research if we are to join the emerging knowledge economies. To plagiarise the standard cliché of the purveyors of the Washington concensus in the 1990's: "There is no alternative to basic research". In discussing basic research, the issue of multidisciplinarity - the interface of disciplines thus creating new frontiers of knowledge - is germane. This critical aspect of knowledge creation is driven mainly by basic research.

## Building the Infrastructure of a Sustainable S&T System

It would seem obvious that if we are to pursue the long-term objective of building a knowledge economy, we need to pursue the building of the infrastructure for a sustainable S&T system - both physical and intellectual. But we need to understand what the impediments are in the path of a developing country determined to build the infrastructure and chart its future course. China has in many ways pointed the way.

It should be understood that unless there are clearly defined strategic goals, the market economy poses danger to a developing economy. In the first place, the market in such an economy is not formed by creative and innovative national companies but it is essentially defined by the conditionalities of aid donors, aid programmes and multinational companies. Thus, the first challenge is to build endogenous capacity, otherwise the exogenous agents create powerful incentives for local researchers to pursue extraneous agenda not consistent with the national interest, especially if the national S&T system cannot provide careers, professional standards as well as a vision and direction for its own development.

Additionally, and this is a more general problem: The quest for

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publications and patentable research results or the pursuit for income from clinical studies, for example, has led many a researcher or even entire departments into a "grey area where values, such as independence, integrity, collaboration, openness (all values critical to research effectiveness) and the public availability of results acquired by public money, are put at risk."

It is axiomatic to state that there is a crying need in a developing economy for the government to invest in basic science and the building of necessary infrastructure for high quality education. In particular, it is essential that governments have a vision of what institutional building is necessary and mould its industrial policies accordingly, including those policies which define the nature of international collaboration and international donor involvement. Caution needs to be exercised particularly to ensure that the collaboration goes beyond technology transfer to include capacity building and skills acquisition. It should be noted, nevertheless, that increasing openness of the world's trade regime, and the evolving need for governments to provide flexible economic conditions will make it much more difficult to maintain such policies. But China has done it regardless.

What is obvious also is that governments need to have a clear and longer term vision of the various components essential in a functional S&T system - private companies, universities, public research institutes, including the supportive machinery for technology transfer, quality and safety control, and the evolution of a national agenda for S&T. We need to have a clear view of what needs to be done to stimulate the growth and interaction of all stakeholders through strong incentive systems that encompass an appreciation of the problems and needs of each stakeholder.

## The Challenge for Government

In the light of all that has been said, it is clear that the challenge for government is to embrace its new but challenging role as an *enabler* and *facilitator* rather than an active doer. We should note that in the future, countries will still go through the natural succession of industrial stages, often simultaneously, given the inherent dynamics of the new global environment, driven by a combination of the natural endowments and more general comparative advantages. But here there is a reprieve: the fast pace of diffusion of 1CT offers new opportunities which cut across the natural sequence, thus enabling countries to “leapfrog” the stages. The challenge is to identify the critical drivers of the system and enhance their effectiveness. Of particular relevance are governments’ regulatory functions, which must be flexible and proactive rather than prescriptive. In particular, as we noted earlier, in all emerging knowledge economies private industry provides the greater proportion of GERD, but this will not happen until government provides the enabling environment. It is therefore necessary that governments establish the environment for private industry that is conducive to investment in technology and development to achieve the following:

- enhance the transparency of markets
- establish solid intellectual property protection regimes
- create conditions of economic stability
- create financial markets in which trust and openness rather than corruption and clientilism supervene.

That journey as challenging as it is can be accomplished in a decade given a visionary, knowledgeable and committed leadership. But the work must start now!

## The Criticality of Human Capital

In all this the quality and quantum of human capital is critical. There is an emergent national concensus that the Nigerian educational system is currently “not fit for purpose”. At all levels of the educational system, less than half of those who should be engaged in educational activities within each age cohort are actually receiving any education. The quality is often variable, from the clearly inadequate to the indifferent. What is more, it is not often clear what the purpose and goals of the educational system are at any of the levels. What kind of society are we educating the younger generation for? The failure of the system has led to a new tendency towards privatisation co-existing with the public system and more dangerously the proliferation of foreign oriented educational establishments in Nigeria.

We have seen that one measure of a fast paced industrialising economy is the relative numbers of scientists and engineering students produced by the educational system. In the U.S., in the year 2000, 33 per cent of all graduates were in science and engineering. An indication of the relative state of S&T in emerging knowledge economies is given by the number of researchers (science and engineering) per 10,000 of the population which are as follows: Japan 53.1, USA 45.3, Germany 31.4, France 28.4, and U.K. 26.6. For comparison, researchers per million of the population in developing societies are South Africa 350, India 143, China 554. The equivalent figures for African countries are Nigeria, 40, Cameroon 60, Morocco 120, Tunisia 350, Cote d’lvoire 55 and Egypt 230. Proportionately, Tanzania, Botswana, Ghana, Kenya, Madagascar, Benin and Zambia have higher percentages of their students in tertiary institutions enrolled in science, mathematics and engineering than Nigeria. With regard to internet penetration per 1000 of the population - which is now a relevant parameter for measuring the pace of diffusion of knowledge - South Africa (68.2), Zimbabwe (43.0), Togo (41.0), Botswana (29.7), Namibia (26.7), Swaziland (19.4), Gambia (18.8), Kenya (12.7), Senegal (10.4) and Ghana (7.8) are well ahead of Nigeria (3.5). Once upon a time the policy existed for a 60:40 per cent enrolment as between the sciences on the one hand and the social science, arts and the humanities in our universities. Presently, it does not seem that anybody in the educational policy establishment of Nigeria remembers this policy!

The challenge in the educational sector is two pronged: to rapidly increase the level of literacy and numeracy in the general population and to produce the high level specialist scientific/ engineering and management personnel required for an industrialising and knowledge-driven modern economy. So it is not only in the power sector that we need to declare a national emergency: the education sector of our national economy cries out urgently for such drastic treatment.

## Going Forward: A Critical Path Analysis of Nigeria’s Future Development

The political vision has been proclaimed that Nigeria should be among the top 20 economies of the modern world by year 2020. This is a simple and fascinating vision which requires a more than normal level of political will, strategic planning, total mobilisation of resources - human and physical - and beyond political rhetoric. Given our past history and present position and disposition, it would be easy to dismiss this as an unachievable vision. But as I showed in my year 1997 Award Winner's Lecture, "Rebuilding the Foundations: Science, Human Capital and Sustainable Development in the 21st Century", the critical Chinese transformation which the world now celebrates took precisely eleven years, and we have 13 years! Nevertheless, the work that needs to be done is Herculean!

For a start we need to develop urgently 'An Agenda for Science in Nigeria' alongside 'A Plan of Action for Science and Technology in Nigeria up to 2020'. These should be integrated through a process of intussusceptions into the national economic plan with all the consequent institutional infrastructure. For example, we need S&T Planning Machinery alongside the National Planning Commission, and the President needs a Science and Technology Adviser to interface with his Economic Adviser. In addition just as the Economic Team has been found vital and needful, we also need a Science and Technology team alongside the economic team. What is being suggested is neither radical nor novel. South Korea, Taiwan and China went through equivalent institutional engineering in the 1970s and 1980s. In reality our willingness and ability to undertake this necessary institutional re-engineering will be the true measure of how serious we are with the 20:2020 Vision. The total transformation of the economy that we aim for is stillborn unless the current effort undergoes a massive total transfusion of science and technology: in short we must undertake the total *scientification* of Nigeria. The real test of the political will of the new Nigerian political leadership will be the speed with which they can embrace and pursue these vital national goals.

Alongside these steps, it is necessary to institute an S&T audit of all ministries and major development projects. What is the S&T content in the work of each of the Federal Ministries? What is the cost and benefit analysis in S&T terms of investment in each major project? What is the capacity building potential of each project? Unless we can insist on answers to these questions and similar ones in our development planning process, we can neither instill the discipline and rationality of S&T into our economic development process. The Chinese had a national policy in which no turnkey projects were encouraged, and the building of industrial infrastructure, whether of refineries or manufacturing industrial complexes, started with the systematic dismantling of an existing plant - usually from the US, Germany and UK - and the translocation of such plants to China. Both dismantling and reconstruction must involve Chinese personnel, particularly engineers. The logic was simple: the individual can only learn to do by active participation in a functional industrial system and the nation can only develop by harnessing and developing its human capital potential. The fastest way to learn is by doing! In the Nigerian situation, it is appropriate to ask: How many engineers and technicians has the much trumpeted GSM revolution added to the Nigerian stock of knowledge and expertise if we ignored the army of recharge card sellers? Is there a national plan of action to *Nigerianise* the skills, expertise and knowledge inherent in the transforming and awesome potential of this technology? In the 30 years or more that Julius Berger has been active and prospering in the Nigerian construction industry what stock of engineers and technicians has been added to the national stock? Until we can ask such uncomfortable questions and insist on answers to them we will not in 2020 or soon thereafter become a thriving or modem economy!

In the new international environment of competition driven by technology and trade, in what areas of industrial and technological endeavour can Nigeria best develop a competitive advantage?

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We need to ask this question in order to prioritise them. Nigeria is rich in oil and gas as well as in various solid minerals, metallic and non-metallic. Can we parlay this God-given advantage into technological leadership in materials science? Our vast biological diversity encourages the expectation that we can be a leader in biotechnology - But what kind and what area of biotechnology?

Finally, we must understand that S&T cannot play the role we expect of it in our industrial and economic development unless we sign on to the dictates of a merit-driven but just society. How are we building-in merit and competence in our educational system? Perhaps, this is the opportune time to implant the decision to establish a National Science Foundation to infuse competition, merit and excellence into the national research agenda. In a nutshell, whatever may be our vision and ambitions for Nigeria; until we can embrace the total *scientification* of Nigeria as a cultural imperative, we are unlikely to fulfill our vision, mission and ambitions as the giant or heart of Africa. ■

## Notes

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[1]GERD (Gross Expenditure on Research and Development), GDP (Gross Domestic Product)

[2.] CBC Business Environment Survey: (Commonwealth Business Council Report: 2005)

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**Table 1: Key Indicators on World GDP, Population and GERD 2002 - Selected Countries**

| *Country* | *GDP (in billions USD)* | *%World GDP.* | *Population in millions)* | *%World Pop.* | *GERD (in billions USD)* | *%World GERD* | *%GERD/ GDP* |
|---|---|---|---|---|---|---|---|
| Argentina | 386.6 | 0.8 | 36.5 | 0.6 | 1.6 | 0.2 | 0.4 |
| Brazil | 1,300.3 | 2.7 | 174.5 | 2.8 | 13.1 | 1.6 | 1.0 |
| China | 5791.7 | 12.2 | 1280.4 | 20.7 | 72 | 8.7 | 1.2 |
| Egypt | 252.9 | 0.5 | 66.4 | 1.1 | 0.4 | 0.1 | 0.2 |
| France | 1608.8 | 3.4 | 59.5 | 1.0 | 35.2 | 4.2 | 2.2 |
| Germany | 2226.1 | 4.7 | 82.5 | 1.3 | 56.0 | 6.7 | 2.5 |
| India | 2777.8 | 5.8 | 1048.6 | 17.0 | 20.8 | 2.5 | 0.7 |
| Israel | 124.8 | 0.3 | 6.6 | 0.1 | 6.1 | 0.7 | 4.9 |
| Japan | 3481.3 | 7.3 | 127.2 | 2.1 | 106.4 | 12.8 | 3,1 |
| Mexico | 887.1 | 1.9 | 100.8 | 1.6 | 3.5 | 0.4 | 0.4 |
| Nigeria | 110 | 0.2 | 140.0 | 2.2 | 0.2 | 0.05 | 0.0009 |
| South Africa | 444.8 | 0.9 | 45.3 | 0.7 | 3.1 | 0.4 | 0.7 |
| United Kingdom | 1574.5 | 3.3 | 59.2 | 1.0 | 29.0 | 3.5 | 1.8 |
| United States | 10414.3 | 21.9 | 288.4 | 4.7 | 290.1 | 35.0 | 2.8 |
| Russia | 1164.7 | 2.4 | 144.1 | 2.3 | 14.7 | 1.8 | 1.3 |

**Table 2:** **Distribution of Researchers and Research in Selected Countries**

| *Country* | *Researchers (thousands)* | *% World Research* | *Researchers per million* |
|---|---|---|---|
| Argentina | 26.1 | 0.5 | 715.0 |
| Brazil | 54.9 | 1.0 | 314.9 |
| China | 810.5 | 14.7 | 633.0 |
| Egypt | 2.0 | 0.04 | 3.1 |
| France | 177.4 | 3.2 | 2981.8 |
| Germany | 264.7 | 4.8 | 3208.5 |
| India | 117.5 | 2.1 | 112.1 |
| Israel | 9.2 | 0.2 | 1395.2 |
| Japan | 646.5 | 11.7 | 5084.9 |
| Mexico | 21.9 | 0.4 | 217.0 |
| Nigeria | 2.0 | 0.04 | 1.43 |
| Russia | 491.9 | 8.9 | 3414.6 |
| South Africa | 8.7 | 0.2 | 192.0 |
| United Kingdom | 157.7 | 2.9 | 2661.9 |
| United States | 1261.2 | 22.8 | 4373.7 |

**Table 3:** **Distribution of Scientific Publications in in Selected Countries**

| *Country* | *Total* | | *%* | *World* |
|---|---|---|---|---|
| | *1991* | 2007 | *1991* | 2007 |
| Argentina | 1,719 | 3,756 | 0.4 | 0.6 |
| Brazil | 3,105 | 8,564 | 0.7 | 1.4 |
| China | 6,340 | 2,4367 | 1.4 | 4.1 |
| Egypt | 1,651 | 1.830 | 0.4 | 0.3 |
| France | 27,335 | 40,485 | 6.0 | 6.8 |
| Germany | 37,112 | 55,212 | 8.2 | 9.2 |
| India | 9,848 | 11,620 | 2.2 | 1.9 |
| Israel | 5,409 | 7,744 | 1.2 | 1.3 |
| Japan | 42,653 | 64,655 | 9.4 | 10.3 |
| Mexico | 1,307 | 4,049 | 0.3 | 0.7 |
| Russia | 9,718 | 21,315 | 2.1 | 3.6 |
| South Africa | 2,618 | 2,657 | 0.6 | 0.4 |
| United Kingdom | 40,789 | 55,363 | 9.0 | 9.3 |
| United States | 179,615 | 195,660 | 39.4 | 32.7 |

**** Although Nigeria had a respectable showing in the 1970s, by the 1990's and at the turn of the new century, Nigeria's contribution had vanished from the publication radar- a telling index of the State of the universities.***