A Longitudinal Assessment of Nigeria's Research Output for Evidence Based Science Policy Development.

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Abstract

The study measured the trend of science and technology research output and investigated the pattern/breath of collaboration among actors of Nigeria's research and development system. Based on the results obtained, it considered its implications for science policy development. The study purposively selected the 148 Science and Technology Journals out of the 221 Journals queried over a 5-year assessment period from 2012 to 2016 to elicit metrical data from the publications. Data harvested was analyzed using percentages, relative growth rate and doubling time on a year-wise basis from 2012 to 2016, to identify the positive or negative growth trend of research outputs. VOS viewer was further used to examine the pattern of collaboration. The analysis from the study provided information on the extent of research that has been carried out in the various thematic areas in Nigeria's new Science Technology and Innovation (STI) Policy.

Keywords: STI Policy, Research outputs, Researchers, Thematic areas, Collaboration, Productivity, Scientometrics

1. Introduction

Growth and development for any given national economy relies upon her ability to harness and leverage on the utility derived from established linkages between various Science, Technology and Innovation (STI) actors (namely government, private sector, research institutes, and society (Ogundeinde & Ejohwomu, 2016). To stimulate any kind of socio-economic development, it requires a systematic process that involves collection of data, its scientific analysis that leads to empirical outcomes. These results serve as the basic tool for further action to be taken by government or the required authority in any policymaking or reviewing process (Uneke, *et al.*, 2012). While policy analysts are at liberty to adopt a variety of methods to ultimately reach the objective of reviewing a process or policy, certain methodologies standout given the directness of approach and applicability in terms quantifiable numeric values which can easily be computed and comprehended.

Given the subject matter for this study is research output linked with evaluating STI policy in Nigeria, a scientometric assessment will certainly shed light on key parameters especially as regarding scientific literature and S&T researchers. According to Tague-Sutcliffe (1992), Scientometrics is an important measure for the assessment of scientific publications. It focuses on the quantitative aspects of science as a discipline or economic activity. Thus, this study evaluated scientific literature based on the key thematic areas of research identified in the 2012 Nigerian STI policy document.

The 2012 STI policy pinpointed certain weaknesses in the Nigerian R&D system. Particularly relevant to the scope of this study was its identification of high-level isolated research efforts dispersed across nation. As a combative measure, the STI policy aimed to promote the concept of tying research agenda to national priorities. Hence, this study served as tool to evaluate compliance. The policy also identified a clear objective to encourage university-industry-government linkages. This was crucial to achievement of the policy objectives invariably making it an indicator to measure policy effectiveness.

The aim of this study was to systematically analyze existing scientific literature (research papers) with the purpose of creating evidence to inform future science policy development in Nigeria.

Hence, the objectives of the study were:

1. To examine the year wise volume of research output in science and technology between 2012 and 2016 based on the AJOL.
2. To measure and calculate the Relative Growth Rate (RGR) and Doubling time (Dt) of science and technology research output.
3. To examine the year wise volume research output of science and technology between 2012 and 2016 available to address the identified thematic areas in the National STI policy.
4. To measure the degree of collaboration across all identified thematic areas in the STI Policy.
5. To investigate the nature of linkages in the most productive area of science and technology research in Nigeria.

2. Science and Technology Policy for Development.

Given the plethora of overwhelming issues the African continent faces: socio-political differences, cultural or tribal clashes, lack of infrastructure, limited access to basic amenities by the vast majority, poor power supply, widening inequality gap, rising rate of unemployment, increased cost of living to mention a few (Siyanbola et al, 2016), as a matter of urgency there is need to identify and implement key strategies to promote socio-economic development. From a more optimistic perspective, the very existence of these challenges presents the opportunity for development to be achieved. The real question becomes what needs to be applied to engender sustainable development?

Science and Technology (S&T) has been identified as a primary driver of development especially for Sub-Saharan African (SSA) Countries (FMST, 2012; Siyanbola et al., 2016). This explains the partnership between UNESCO and many African Countries Nigeria, Ghana, Benin to mention a few to develop frameworks for building sustainable National STI Policies. In the Nigerian context, the erstwhile President was quoted as follows,

"***We are going to run our economy based on Science and Technology…. because nowhere in this World now that you can move your economy without science and technology. For the next 4 years we will emphasize so much on S&T because we have no choice, without that we are just dreaming…."*** **– Dr. Goodluck Ebele Jonanthan, 2011. (FMST, 2012)**

From the view of continuity in governance and buttressing the global shift in paradigm towards STI as the bedrock for in achieving development, the focus on Science, Technology and Innovation Policy did not dwindle in the newly led Buhari Administration either. The current Minister of Science and Technology, Dr Onu was quoted to have said that

"Science and technology would be utilized to unlock the nation's potential and drive the sustainable economic development plan of the current administration." "The road map is set out in the short-term to help achieve the Economic Recovery and Growth Plan of 2017 to 2020, which stated clearly that science and technology would be effectively harnessed to drive national competitiveness, productivity and economic activities in all sectors." (FMST, 2017)

In effect, the Buhari led administration approved a 13-year National Science, Technology and Innovation roadmap starting from 2017 to 2030 (FMST, 2017). Clearly, Nigeria has moved beyond considering the adoption of S & T as an option in her quest for sustainable development – which essentially preempts policy formulation, however what remains unclear, as with many other African countries is enforcing formulated policy strategies – policy implementation. More so, given the lack of % GERD data for a country with over 200 million people and over 70% living below the poverty line, one strives to understand what mechanism is put in place to learn how to better formulate or readjust existing STI policy strategies to suit the ever dynamic requirements of sustainable development especially within the Nigerian context. Essentially, it is critical to establish that emphasis needs to be laid on the importance of collecting historical data as a periscope for shaping the future of STI policy. First, this makes it easier to predict future trends based on existing data and subsequently forecast. Secondly, it aids effective planning of resources to meet targeted objectives and finally it creates a benchmark to measure subsequent performance year in year out or as the case may be.

2.1 Science, Technology and Innovation Indicators in Policy-Making: The Nigerian Experience

Siyanbola et al, (2016) identified that the major challenge with policy development in Nigeria was her non–exploitation of scientific evidence citing disposition towards application and utilization of scientific and technological knowledge as the major culprit. Agreeably so, this is a major reason why sustainable development has eluded the nation. Attitudinally, there is a poor culture of preserving history through proper record management. More interestingly the global north through its international multilateral agencies (World Bank, IMF etc.) are heavily relied upon to supply economic and demographic data for African countries. In many cases even when indigenous organizations or government establishments collect data, they are often funded by these donor organizations at different levels of strategic partnerships often with diverse rules of engagement - which are not necessarily devoid of ulterior motives or ploys to push alternate agendas as a matter of interest. Hence, the onus lies on the ability of African countries to look introspectively, develop or strengthen capacity and adopt innovative models to produce data by us and for us.

According to Siyanbola et al., (2016) evidence is any scientific output, which has been collected through a systematic process aimed at increasing the stock of knowledge on a subject matter. This forms the premise of this study's argument as research output is considered valuable stock to support evidenced based policy development. Hence, policy development in a Nigerian context should focus on addressing local challenges by learning from previous experience and leveraging data facts - evidence (Lehtonen, 2004; Siyanbola et al, 2016; George et al, 2016). Scientific research output which is an indicator of STI plays a critical role in providing the necessary information for policy development, when this is absent policy development becomes arduous (Padilla-Pérez & Gaudin, 2014; Chaminade & Padilla-Pérez, 2017). These STI Indicators are used to evaluate effectiveness and efficiency, benchmark, set targets and forecast or predict based on historical data.

2.2 The Historic State of Science and Technology in Africa

A Scientometric Assessment Scholarly reviewing the methodology adopted for this paper, a precursory look it taken at the study of Pouris & Pouris (2009) and Pouris (2012) where it is purported that scientometrics is an essential part of science and technology policy monitoring and assessment studies (Jeenah & Pouris, 2008). Both studies conclude that scientometric indicators offer an efficient and objective method of assessing research and innovation performance. This study also builds on previous scholarly work that employed scientometric analysis of research output. For instance, scientometrics has been used in literature to study diseases such as diabetes. The work by Rasolabadi *et al*. (2015) explored diabetes research in Iran using scientific publications. While in India, scientometrics analysis was used to map different diseases research such as: diabetes research (Gupta et al, 2011a), tuberculosis research (Gupta and Bala, 2011b), Parkinson's disease (Gupta and Bala, 2013), amongst others. Another application of Scienctometric in literature was in the measurement of productivity of organizations e.g. the work by Jeevan and Gupta (2002) measured productivity of an Indian Institute of Technology using their research outputs.

According to Pouris & Pouris (2009), scientometric assessment involves the focus on research output and patent analysis. The measurement of research output is referred to as bibliometrics representing the number of publications in a field and thus an indicator of research activity. The study further argues on the reliability of these research activity indicators, as they are clear-cut and unambiguous. Scientometric indicators enable detailed categorization and hence make possible the study of scientific and technological fields and sub-fields facilitating comparative analysis across different levels.

Finally, in the context of developing countries – like Nigeria, scientometric indicators provide unique insights into the strengths and weaknesses of the STI systems as other sources of information are usually lacking (Uzun, 2002; Pouris & Pouris, 2009; Kahn, 2011; Pouris, 2012).

3. Methodology

For the objectives of this study, a scientometric analysis was adopted. First to observe the availability of science and technology research at policymakers' disposal to address the thematic areas as identified in the 2012 STI policy and secondly to identify the key areas of specialization that were in dire need of intervention to bolster the overall production of scientific literature or increase research activity. The data in this study was retrieved from Google Scholar database based on Journals of Nigerian affiliation indexed in the African Journal Online directory (AJOL) for the period 2012 to 2016. The AJOL whose mission is to counter the westernization inequality of information flow by facilitating awareness and providing access to research published in Africa (Rosenberg, 2002), contains the largest dataset of peer-reviewed literature for African researchers. Hence justifying the studies data source.

3.1 Study Sample and sampling Technique

The study purposively selected all the 148 Science and Technology Journals out of the 221 Journals registered on the AJOL directory. Each one of the 148 Journals was queried over the 5year assessment period from 2012 to 2016 to elicit metrical data about academic papers. The reason for selecting the period 2012 to 2016 was to select the first five years after the new science, technology and innovation (STI) policy document was enacted. The study explores to what extent researchers have responded to the thematic areas in line with fulfilling the mandates of the new STI policy document.

3.2 Research Tools and Instruments

This study was analyzed and interpreted by using various scientometric indicators and related statistical tools. VOSviewer, an open source software was used to examine the pattern of collaboration and determine the nature of linkages by converting the sample data set into science maps to give a pictorial representation of existing collaborations among researchers. The design of the analysis includes the following categories such as year wise distribution of publications, growth of literature and doubling time, degree of collaboration, authorship pattern, linkages and institutional affiliations.

4. Results and Discussion

4.1 Descriptive Analysis of data collected

To identify exact queries for data to be extracted, the study identified the AJOL Index, which is a directory that lists available journals based on countries. The Nigerian tab contained 221 Journals. By adopting the OECD classification for science and technology fields of specialization, the study extrapolated 148 Journals with science and technology orientation representing 67% of the total number of Journals available, this renders credence to the fact that there is due emphasis laid on science and technology research in Nigeria.

To carry out a successful query, two things were necessary. First, the name of the Journal as cited by the AJOL index. Second, the International Standard Serial Number (ISSN) which is a unique 8-digit code used to identify newspapers, journals, magazines and periodicals of all kinds and on all media–print and electronic. The ISSN was used in combination with the journal name to sieve journals with the same name originating from a different country that is not Nigeria.

Query Google Scholar Database **"***Journal_ Name***" *"***ISSN***" * "***Year_Beginning***" * "***Year_ End***"**

4.2 Year wise volume of science and technology research output

Table 1 shows the number of publications produced by researchers across the different fields of science and technology as categorized by the STI policy document and the relevant shares during the five-year period 2012-2016.

It is observed that the volume of research publications remained relatively constant at approximately 20% per annum. However, a less than 1% decline in volume of research output is observed in 2014 and 2015. Judging by the data represented in this table above, this indicate that volume of research output in science and technology given the set methodological constraints did not grow. An increase in the volume of annual research output will indicate that more evidence abounds which may feed into the policy process of future policy document. Likewise, an increase in the volume of research will indicate that there has been some response by researchers to provide scientific knowledge to address the shortfall in knowledge in the thematic areas identified in the 2012 STI policy documents. The policy identified 19 thematic areas in which Nigeria researcher should focus on to strengthen the country's R&D system. The total number of science and technology publications analyzed for this study stand at 14,413 publications.

Table 1: Year -wise distribution of science and technology research output 2012-2016

S/N	YEAR	No of Publications	Total Publication (%)
1	2012	2925	20.29%
2	2013	2924	20.29%
3	2014	2878	19.97%
4	2015	2801	19.43%
5	2016	2885	20.02%
		14413	**100.00%**

4.3 The Relative Growth Rate (RGR) and Doubling Time (Dt)

The study measures research output in terms of relative growth rate (RGR) and Doubling Time. According to Devalingam, Babu & Suresh, (2015) this model is credited to Mahapatra. The Model's origin is traced to the biological sciences where it is used to measure growth rate in comparison to size. Scientometric scholars adopted the methodology to determine speed of growth of research publications. This is important as the argument of this study rides on the capacity of research data in assisting to develop science policy in Nigeria. Hence, it is expected to observe a growing relative rate in comparison to size over a specified period.

The General Formula for Calculation;

$$R\ (1\text{-}2) = [(W_1 - W_2) / (T_2 - T_1)]$$

Where, R (1-2) is mean Relative Growth Rate over the specified period

W_1 = Log W_1 (Natural log of initial number of Publications)

W_2 = Log W_2 (Natural log of final number of Publications)

$T_2 - T_1$ = The Unit difference between the Initial time and Final time

From natural sciences, the doubling time is the period required for a quantity to double in size or value. While this function can be applied to a myriad of situations, ranging from population to volume of malignant tumors, in a Scientometric study the principle is applied and measures the growth rate of research publications.

According to Santhakumar & Kaliyaperumal, (2014) between the relative growth rate and the doubling time subsists a direct equivalence. In the case where the number of publications of a subject double during a given period; then the difference between the logarithms of numbers at the beginning and end of this period must be logarithms of number 2 (Thavaman, 2013; Santhakumar, & Kaliyaperumal, 2014; Devalingam, Babu & Suresh, 2015). If natural logarithm is used, this difference has a value of 0.693; thus, the corresponding doubling time for each specific period of interval and for publications can be calculated by the formula:

The General Formula for Calculation;
Given, R (a) = Relative growth rate per unit of time (Year)
Doubling time (Dt) = 0.693/ R
Therefore, Doubling time for publications Dt (a) = 0.693 / R(a)

A graphical upward movement from left to right indicates there is a growth in literature publication.

Table 2: The RGR and Dt of Science and Technology Research Output 2012 -2016

SN	YEAR	No of Publications	Cumulative of Publications	W1 (Log No. of Publ.)	W2 (Log of Cum. of Publ.)	RGR (W2-W1)	DT Doubling Time
1	2012	2925	2925	-	7.98	-	0.00
2	2013	2924	5849	7.98	8.67	0.69	1.00
3	2014	2878	8727	8.67	9.07	0.4	1.73
4	2015	2801	11528	9.07	9.35	0.28	2.48
5	2016	2885	14413	9.35	9.58	0.23	3.01

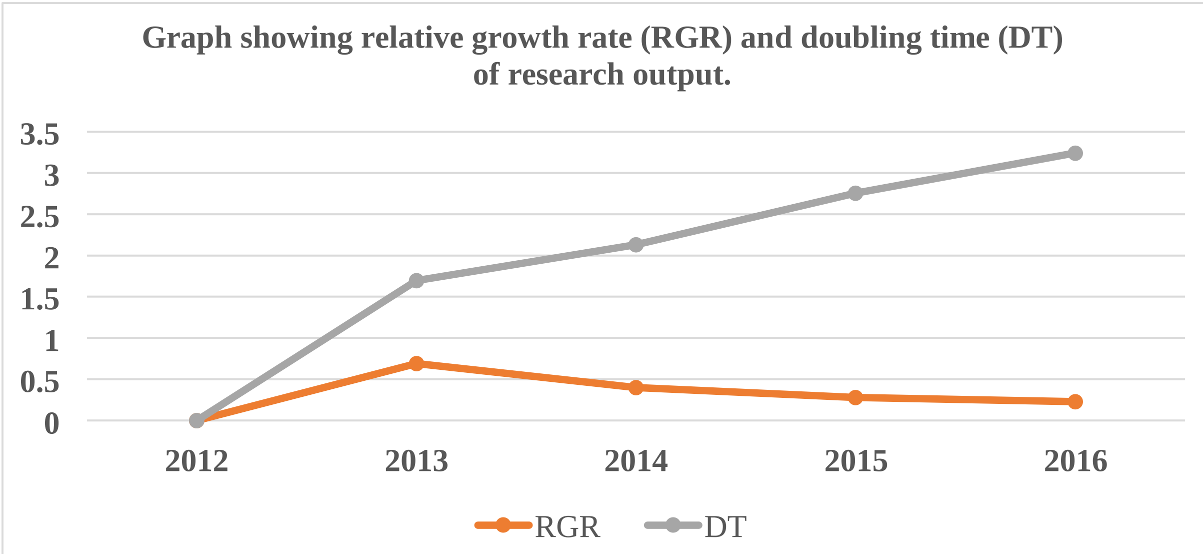

Figure 1: Graph showing RGR and Dt of Science and Technology research 2012 -2016.

Based on the results from the graph, from 2013 to 2016 RGR there is a downward slope from left to right this is indicative of the fact that exponential growth is not experienced in terms of scientific literature. The existence of exponential growth in science and technology research in Nigeria will have been further proven by a constant doubling time rate (straight-line); however, the Dt-line is increasing at a declining pace indicating that growth in literature is not exponential. On the other hand, emerging economies like China, India, South Korea, amongst others benefitting greatly from exponential growth in research output as they journeyed towards industrialization. If Nigeria, will take similar path with these Asian countries, the research outputs must increase at an exponential rate. Before this can materialize, there must be a significant adjustment in Nigeria's R&D system. This could involve increasing the number of research personnel and/or increasing the amount of funds allocated to research.

4.4 Distribution of Science and Technology research output according to identified thematic areas in the National STI Policy

The 2012 National STI Policy document contains 19 thematic areas targeted to revive the socioeconomic development of the Nation. Based on the 14,413 publications retrieved, the papers were regrouped using keywords in the title of each paper to identify the thematic area the study belongs to query identify thematic area "Using Keywords"

Table 3: Distribution of Science and Technology research according to the 2012 National STI Policy Identified Thematic areas

RANK	Thematic Area	2012	2013	2014	2015	2016
1	Health Research & Innovation, Natural Products, Natural Medicine, Pharmaceutical Research, etc	1573 (0.5378)	1676 (0.5732)	1738 (0.6039)	1430 (0.5105)	1431 (0.496)
2	Agriculture	321 (0.1097)	306 (0.1047)	221 (0.0768)	262 (0.0935)	407 (0.1411)
3	Industrial Research, Development and Production	360 (0.1231)	261 (0.0893)	224 (0.0778)	336 (0.12)	270 (0.0936)
4	Environmental Science and Technology	157 (0.0537)	188 (0.0643)	174 (0.0605)	192 (0.0685)	170 (0.0589)
5	Science Laboratory Technology SLT	136 (0.0465)	142 (0.0486)	152 (0.0528)	176 (0.0628)	181 (0.0627)
6	Information and Communications Technology (ICT)	127 (0.0434)	141 (0.0482)	132 (0.0459)	141 (0.0503)	129 (0.0447)
7	Ferrous, Non Ferrous and Chemical Technologies Research	53 (0.0181)	45 (0.0154)	59 (0.0205)	54 (0.0193)	56 (0.0194)
8	Water Resources	34 (0.0116)	26 (0.0089)	42 (0.0146)	52 (0.0186)	58 (0.0201)
9	Raw Materials and Manufacturing	41 (0.014)	40 (0.0137)	42 (0.0146)	23 (0.0082)	38 (0.0132)
10	Mines and Materials Development	27 (0.0092)	22 (0.0075)	26 (0.009)	35 (0.0125)	39 (0.0135)
11	Energy	36 (0.0123)	17 (0.0058)	13 (0.0045)	32 (0.0114)	38 (0.0132)
12	Biotechnology Research	23 (0.0079)	34 (0.0116)	24 (0.0083)	30 (0.0107)	23 (0.008)
13	Wood Resources	17 (0.0058)	10 (0.0034)	14 (0.0049)	9 (0.0032)	19 (0.0066)
14	Youth, Sports and Tourism Development	5 (0.0017)	4 (0.0014)	3 (0.001)	19 (0.0068)	14 (0.0049)
15	Works, Land, Housing and Urban Development	14 (0.0048)	3 (0.001)	11 (0.0038)	6 (0.0021)	8 (0.0028)

16	Transport System	1 (0.0003)	6 (0.0021)	2 (0.0007)	3 (0.0011)	3 (0.001)
17	New and Emerging Technologies Nanotechnologies and New Materials	0	3 (0.001)	1 (0.0003)	1 (0.0004)	1 (0.0003)
18	Defense & National Security	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
19	Space Research and Investments	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
		2925 (1)	2924 (1)	2878 (1)	2801 (1)	2885 (1)

Table 3 above shows the distribution per annum of the researched papers elicited from the google scholar database. Results show that the thematic area on health research & innovation, natural products, natural medicine, and pharmaceutical research received the greatest attention with about 54% of all the papers oriented in this direction. Agriculture research comes in at slightly over 10% of the data used for this study. In a close third, research papers focused on Industrial research, development and production at 10%. As inferred by the 2012 STI policy, this field covers areas in the natural sciences, as well as basic and applied sciences. These 3 thematic areas account for over 70% of the research papers analyzed in this study. This signifies the strength of Nigeria's R&D system at present. These sectors/thematic areas represent the starting point from which Nigeria's economy can be built on and then gradually over time, there will be significant spill overs to other sectors/thematic areas. On the other hand, the study did not observe any paper that could be categorized as Defense & National Security or Space research and Investment and only 6 papers (Very much less than 1% contribution of the papers studied) for the New and Emerging Technologies Nanotechnologies and New Materials which represent the bottom 3 research areas. The study shows overwhelmingly large data set of publications classified under the Health Research & Innovation, Natural Products, Natural Medicine, Pharmaceutical Research, etc. Thematic Field representing over 50% of the data set. This shows that the health sector in Nigeria has received good attention in the research space. It is difficult to tell if the STI policy was entirely responsible for this high volume or the high volume of publications was more of a response to the challenges facing the health sector in Nigeria, but it does suggest that there is a dearth of information available to make informed decisions by policymakers. However, as a means of evidence-based science policy development. R&D expenditure efforts can be targeted at commercializing innovation in the health sector.

4.5 Investigate the degree of collaboration among Nigeria's science and technology researchers.

Collaborations among researchers play fundamental roles in providing access and opportunity for a cross fertilization of ideas. According to Khaparde & Pawar (2013), the degree of collaboration metric is proposed as a scientometric indicator by Subramanyam (1983). This study focuses on the 19 thematic areas identified in the 2012 National STI policy document for Nigeria, hence in addition to interpreting the results which ranges from low to high collaboration based on the metrics (0.00 - 0.99). This was applied in Rajendran, Jeyshankar & Elango (2011) study on scientometric analysis of contributions to Journal of scientific and industrial research. The general formula is given as;

$$DC = N_m / (N_m + N_s)$$

Where DC = Degree of Collaboration

N_m= Number of Multiple of Authored Papers N_s= Number of Single Authored Papers.

High or low collaboration factors speak to the quality of research papers produced as identified in each thematic field. This metric directly references the science policy for development. Hence, inferences are raised as to the existence or non-existence of quality research to tackle or proffer solutions in that field using our existing dataset.

Table 4: Degree of Collaboration among science and technology researchers 2012-2016 based on thematic areas.

RANK	STI Policy Field	Total No of Papers	Total Authors > 1	Degree of Collaboration
1	New and Emerging Technologies Nanotechnologies and New Materials	6	6	1
2	Science Laboratory Technology SLT	787	754	0.96
3	Ferrous, Non Ferrous and Chemical Technologies Research	267	245	0.92
4	Raw Materials and Manufacturing	184	169	0.92
5	Health Research & Innovation, Natural Products, Natural Medicine, Pharmaceutical Research, etc	7848	7143	0.91
6	Agriculture	1517	1370	0.9
7	Biotechnology Research	134	121	0.9
8	Wood Resources	69	62	0.9
9	Environmental Science and Technology	881	765	0.87
10	Mines and Materials Development	149	129	0.87

11	Works, Land, Housing and Urban Development	42	36	0.86
12	Water Resources	212	181	0.85
13	Industrial Research, Development and Production	1451	1223	0.84
14	Energy	136	110	0.81
15	Youth, Sports and Tourism Development	45	34	0.76
16	Transport System	15	11	0.73
17	Information and Communications Technology (ICT)	670	483	0.72
	Grand Total	**14413**	**12842**	**0.89**

Table 4 above shows the degree or extent of collaboration among authors in each respective thematic area. The ratio is based on the number of single authors to more than one author in every field. Noticeably 100% collaboration is observed in Nano technology and new materials field. ICT, Transport and Youth & Sports fields have the observed lowest degrees with 72%, 73% and 76% respectively. The other policy areas range between 81% and 96% degree of collaboration. Research in Nanotechnology thematic area is a product of 100% collaboration along all publications. This is closely followed by 96% collaboration in the science laboratory thematic area, while chemical research and raw materials & manufacturing tie in 3rd place with 92% collaboration on analyzed publications. ICT witnessed the least degree of collaboration with 72%, indicating 28% of papers published in thematic field were solo contributions (this suggests evidence that researchers in this field have a legible propensity to by solo author eroding the value of collaboration, which strengthens the quality of publications. Interestingly, this result is consistent congruent with results from Khaparde & Pawar (2013) where they understudied degree of collaboration in information technology and found low collaboration among researchers suggesting this phenomenon can transcend beyond geographical boundaries. The argument for evidence-based policy development from this study's perspective is that collaboration between researchers is the bedrock for cross-fertilization of ideas; hence, research outputs are very inclusive in content and quality when more than 1 author is involved. The study observed that thematic areas that are more technologically sophisticated (e.g. nanotechnology, biotechnology, among others) required more collaborations. Hence, collaboration could have been as a result of necessity than free will in this context.

4.6 The nature of linkages in the most productive area of science and technology research in Nigeria

In this section, the study builds on the previous objectives by presenting a graphical and pictorial perspective to the study. Primarily for understating interactions and linkages within the research and development system in Nigeria, based on the identified thematic areas in the STI Policy Document. The subsections below create a build-up activity necessary for understanding the results from the graphical representation.

The visualization map is displayed using a combination of links, clusters, authors and number of citations. Within a thematic area, linkages are established based on authors and their collaborative efforts. Clusters are identified as a set of items included in a map. Clusters are non-overlapping in items. Hence, an item cannot belong to more than one cluster. It is possible for an item not to belong to any cluster however for the purpose of this study items not belonging to clusters where treated as extraneous and not part of the core study Van Eck & Waltman (2007). Linkages in the case of co-authorship links as with this study is a focus on examining relationship between researchers, the links attribute indicates the number of co-authorship links for a given researcher with other researchers. Based on the formulated map, the study focused on the number of citations. Hence, it is possible for a thematic area to have very high cited publications, however the publication is not linked to any other research and therefore not in any cluster, such authors will not feature on the map. The map represents the total number of linked research papers in a thematic area. Invariably what this means is that, it is possible for a publication to be highly cited, yet its authors do not show up on the visualization map because they are not linked (i.e. they are isolated – no evidence of collaboration with other authors within that thematic area). Hence, the visualization map presented is a display of the longest or widest linkage (collaboration) between researchers in any given thematic area.

Table 5: Nature of Linkages among science and technology researchers 2012-2016

STI Thematic Area	**Total No of Authors**	**Authors in the Map**	**Clusters**	**Links**
Agriculture	4124	134	17	248
Biotechnology Research	361	13	5	20
Energy	328	9	4	12
Environmental Science and Technology	2262	12	3	23
Ferrous, Non Ferrous and Chemical Technologies Research	749	12	3	21
Health Research & Innovation, Natural Products, Natural Medicine, Pharmaceutical Research, etc	22223	659	36	1209
Industrial Research, Development and Production	3576	31	9	60
Information and Communications Technology (ICT)	1394	27	8	49
Mines and Materials Development	366	10	4	15
New and Emerging Technologies Nanotechnologies and New Materials	*17	*16	*3	*17
Raw Materials and Manufacturing	487	16	4	26
Science Laboratory Technology SLT	2310	71	10	123
Transport System	33	4	1	6
Water Resources	505	11	4	15
Wood Resources	176	16	5	21
Works, Land, Housing and Urban Development	98	8	3	11
Youth, Sports and Tourism Development	108	6	2	9

*Represents unlinked clusters

Table 5 above shows a summary of links and clusters plotted on the visualization map. Based on data used for this study, the transport system thematic has 12.12% authors represented on the visualization map. On the average, other policy thematic areas have less than 10% of authors represented on their respective visualization map. Despite the large number of authors in Health and Agriculture STI policy areas only about 2.97% and 3.25%, authors are represented on their respective visualization maps. While the New and Emerging Technologies Nanotechnologies and New Materials thematic area have 3 clusters it is worthy to note that neither of these clusters are linked together and are therefore isolated cases. At the base of each graph a scale ranges from 0 to maximum number of citations the colour scheme flows from deep blue to yellow (Low to High).

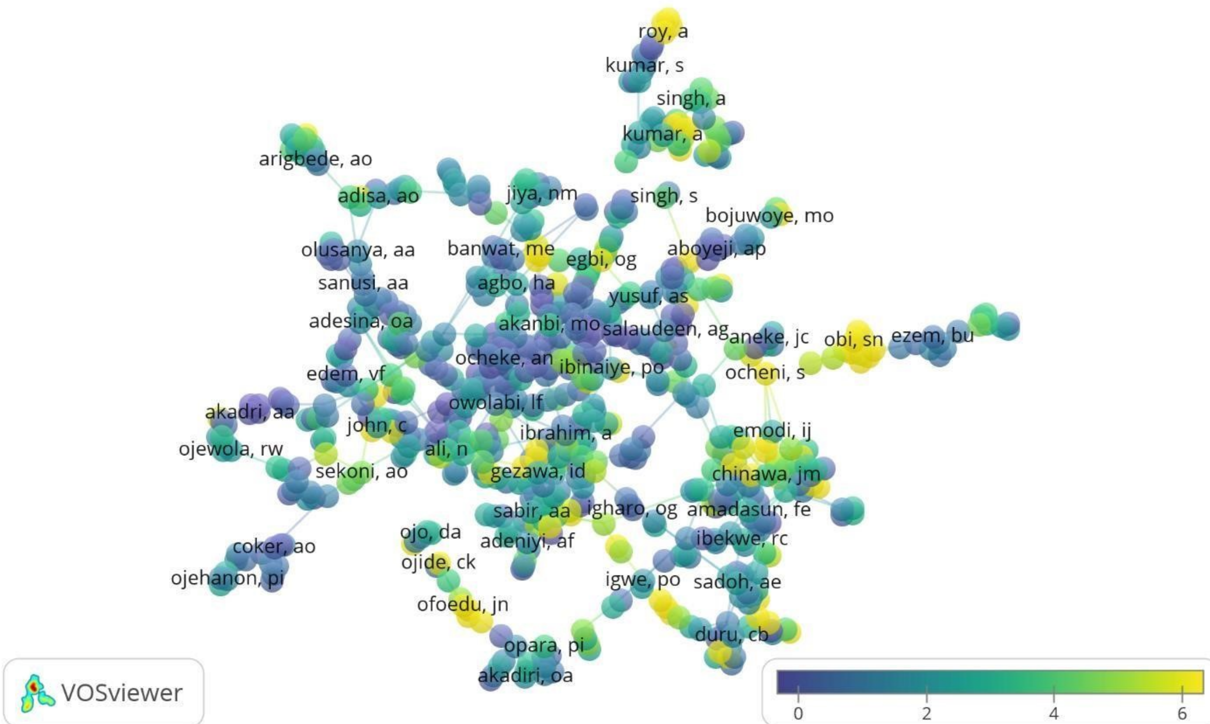

Figure 2: Linkage in Health Research & Innovation, Natural Products, Natural Medicine, Pharmaceutical Research, etc. Thematic Area

In the health research & innovation, natural products, natural medicine, pharmaceutical research thematic area; the study observed that it had 36 research clusters with 1029 links between authors in the thematic area. This was not unexpected given the plethora of data assessed under the thematic area. Based on the visualization map and a randomized selection of authors with highly cited publications the study identified the following authors; A, Roy; SN, Obi; JN, Ofoedu; JM, Chinawa; CK, Ojide and S, Ocheni. At the hub of the map, the study randomly selected LF, Owolabi as it was difficult to locate the hub given the volume of data assessed. However, it was obvious LF, Owolabi linked the major clusters on every side of the map. By querying the google scholar database, it was observed that A, Roy was a highly cited researcher for Vertex Pharmaceuticals in the US. SN, Obi was from the University of Nigeria Nsukka; JN, Ofoedu was from the Federal Medical Centre, Umuahia, Abia State, Nigeria; JM, Chinawa was from University of Nigeria Nsukka; CK, Ojide was from the University of Benin teaching hospital, Benin City; and S, Ocheni was from the University of Nigeria. The visualization map for the health thematic area suggested evidence of a highly interactive transatlantic government-institute-university collaboration between researchers in the industry.

5. Conclusion and Policy Recommendations.

The study by identifying key productivity measurements and their implications for science policy development identifies areas of improvement via recommendations and suggests alternate research focuses that will add tremendous value to the nature of research work done. For improved evidence-based science policy development in Nigeria. The following policy recommendations are advised;

1. R&D expenditure should be intensified to achieve the desired results.
    a) Commercialization of research output in the Health thematic area. This will lead to the birth of innovative products and services marketable across the African globe.
    b) Promote more research output in Agriculture. This is in consonance with the currents administration agenda to reduce over dependence on oil and its derivatives.
    c) Intensify research on the energy, as it appears that researchers who publish in university-based journals as indexed by the AJOL do not do enough energy research.
    d) Increase capacity for ICTs, the development of an economy is entrenched in its capacity to harness the dividends technology and communication
    e) Intensify through adequate funding and strategic partnerships capacity for improved Biotechnology research. Availability of the natural resources and the demographic indicator of Nigeria make it a viable option for socio-economic development.

Academia in partnership with government established research councils on science and technology should strategize on how to standardize metrical information on research output (publications) to facilitate faster data collection for easier and improved analysis. This will aid the process of evidenced based policy development in a timely fashion.

2. Government and Academia should jointly implement a strategy to encourage Nigerian researchers or authors who publish in university affiliated journals to establish visible online presence -at the simplest of levels google scholar database is advised – this is a free service whose opportunities can be immediately harnessed. This aggregates all research publications of a researcher regardless of what journal he desires to publish his/her material. It also makes research work discoverable. Discoverable research is useful for policy development.
3. Universities and research institutes should be assigned and entrusted with the role of R&D – (based on monitored and enforced policy), operating labs/incubators as well as policy think tanks to solve national problems just as we have in developed countries like the US, UK Japan, etc. The industry should rely on the university to find innovative solutions towards meeting their respective markets demands, likewise government should rely on output for policy development. These linkages need to be strengthened to improve quality.

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