A Bibliometric Analysis of the Dispersion of Research Performance within and between Universities as an Indicator of Competitiveness in Higher Education?

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ABSTRACT: *This paper examines selected hard sciences research output in South African universities with special reference to the dispersion of research performance within and between universities as a potential indicator of competitiveness in higher education systems. The subject fields surveyed are Physics, Chemistry, Biology, civil engineering and architecture, Earth sciences, Mathematics, Computer Science and Medicine in seven top universities. The study endeavours to see if these top institutions present levels of concentration of performance within universities that are high or very high and greater than that between them. We investigate the level of correlation between performance in research and its dispersion in the universities. The field of observation is made up of all the South African universities active in the hard sciences. Research performance is evaluated using bibliometric analysis, through publication indexed in the Web of science between the years 2005 and 2013. Relevant data for the study was downloaded from web of Science using largely Science Citation Index (SCI) but also Social Sciences Citation Index (SSCI) and Arts and Humanities Citation Index (AHCI). From several bibliometric indicators of research performance evaluation (such as publication output, trend, citation analysis, impact factor and Hirsch Index), we used publication output by the scientists. The citation count and impact were used to indicate the research output and performance of researchers and what differentiates them from others. We observe that the South African education system presents levels of concentration of performance within universities that are high and at times greater than that between them. This situation to a certain extent allows the search for a competitive advantage with the resulting production of outstanding research institutions, which are capable of attracting and retaining the top scientists both nationally and internationally. This in a way brings about dispersion of performance and indicates the intensity of competitiveness in research institutions and universities. We also notice that in the competitive system, the variability of performance within is much less compared to between universities. The results of the research shows that two universities with the same average research performance could have altogether different impacts on national economic development. As far as competitive systems are concerned, dispersion of performance within universities is so high that it is very difficult to perceive strong differences in performances between universities. The results obtained can be used as indicators for policy making and examine the effectiveness of selective funding of universities based on national research assessment exercises.*

Keywords: Bibliometric Analysis, Research Assessment, University Research, Research Policy

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1. Introduction

The fundamental social process of science is communication and exchange of research findings and results. The principal means of communication is the publication process, which allows scientists to verify the reliability of information, to acquire a relative sense of importance of a contribution. It is through publication that scientists receive professional recognition and esteem as well as promotion, and advancement in future research. Publication is so central to productivity in research that the work becomes "a work" only when it is published so that it can be received, assessed and acknowledged the scientific community.

The last few decades have witnessed a restructuring in scientific research. Increasingly, it is becoming a collaborative endeavour (Subramanyam, 1983). According to Qiu (1992), there is also a strong trend towards sharing and interpretation across disciplines. As a result of these trends, there is a rise in collaboration both within and between scientists. Both national and international research collaboration has been increasing and there is a rising interest both among researchers and policy makers. International collaboration has been increasing interest in recent years due to the higher quality of collaborative papers as shown in higher average impacts when compared to solely national publications (Van Raan, 1998) and an increment in the benefit gained by peripheral countries from international collaboration for integrating their national publications on to international scientific network (Russell, 1995).

Research collaboration is a rapidly growing component of core research activity for all countries. It is driven by a consonance between top-down and bottom-up objectives. Collaboration is encouraged at a policy level because it provides access to a wider range of facilities and resources. It enables researchers to participate in networks of cutting-edge and innovative activity. For researchers, collaboration provides opportunities to move further and faster by working with other leading people in their field. It is therefore unsurprising that collaborative research is also identified as contributing to some of the highest impact activity.

Bibliometrics/informetrics are increasingly used for research measurement, evaluation and policy studies. The concept bibliometrics is one of the oldest quantitative method of analysing documents or recorded information sources and therefore is widely defined and possibly known as reflected in studies focusing on the history and development of bibliometrics (Singupta 1992, Hood and Wilson 2001 and Jacobs 2010). Bibliometrics is a quantitative content analysis method widely applied to analyse recorded knowledge, largely scientific or scholarly publications or literature mainly through publication count or citation analysis(see Hetzel 1987,Singupta 1992, Daidato 1994, Kostoff 2001 and Jacobs 2012) for a variety of reasons including research evaluation performance measurement. Modern bibliometrics as a research tool has been largely inspired by Derek de Solla Price and theseminal work carried out by him in the middle of the 2oth century. In his book "Little Science-Big Science" published in 1963, he analysed research communication and presented a number ofquantitative evaluation techniques. Bibliometrics, explains Mattison (2008), is used as amethodology in many other fields of science, mainly

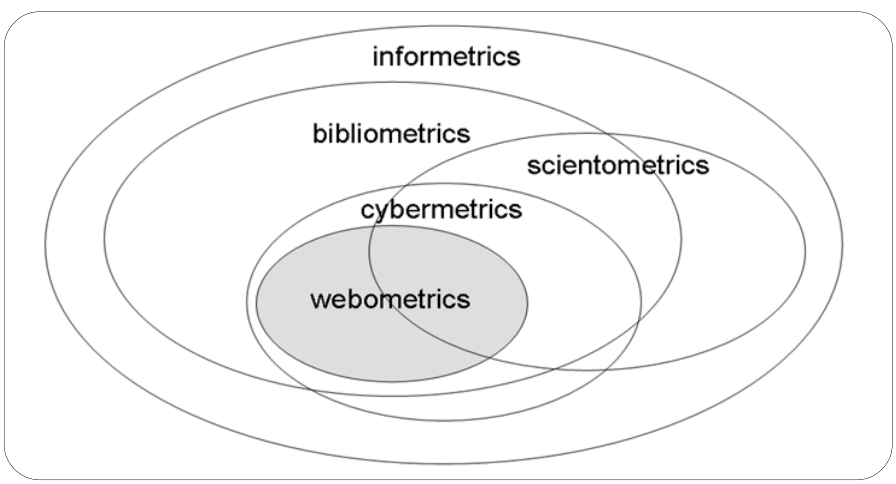

Figure 1. The overlaps between Informetrics, bibliometrics, scientometrics, cybermetrics and Webometrics (Björneborn & Ingwersen, 2004)

to map the publication pattern in differentdisciplines, such as publication behavior in economics and sociology, science policy and management and research evaluation. For example, notes, Mattson, the development of performance indicators to respond to science policy questions has been the most common application. Indicators used for this purpose include: productivity analyses measuring the output and volume share of a specific actor, e.g. a country's world share of publications or citations; research impact analysis using citations, and relational indicators studying heterogeneity of collaboration patterns between different actors (Mattson 2008).

Bibliometrics is closely linked to other metrics such as informetrics, that measures patterns of information flow; scientometrics focusing on quantitative analysis of science and science policy, webometrics that focuses on measurements of web based documents/information, cybermetrics focusing on analysis and measurement of recorded knowledge in the cyberspace and more recently altmetrics (see Priem 2010, McFedries 2012, Haustein et al 2013, Piwowar 2013, Lin and Fenner 2013) focusing on impact of papers/postings in terms article/paper/posting views, downloads and mention largely through social media. Egghe (2005) view informetrics as a broad concept embracing other metrics studies related to information science,

Bibliographic element	Equivalent Elements in Research	Informetrics/bibliometric application or measurement
Author	Researcher	Research productivity and impact per individual researchers
Author's institutional affiliation	Researcher's institutional affiliation	Research productivity and impact per institution
Author's country of origin	Researcher's country of affiliation	Research productivity and impact per country or geographic region
Journal name	Journal in which research was published	Impact factor of journals (to measure prestige, popularity, influence, quality etc)
Title of document	Topic of research	Analysis of subject focus of the research using title words
Keywords	Topic of research	Analysis of subject focus of the research using title words
Indexing subject terms	Topic of research	Analysis of subject/discipline focus of the research using title words
Year of publication	Year when research was published	Trend (i.e. growth) of research per individual researcher, institution or country
Language of publication	Language in which research is dissemi nated	Language in which research is disseminated/ communicated
Patent number	Patented research	Research productivity and impact per individual researcher, institution or country
Citations	Use of research	Influence, relevance, importance, impact or quality of research

Table 1. Application of Bibliometrics for research measurement

including bibliometrics (bibliographies, libraries etc.), scientometrics (science policy, citation analysis, research evaluation etc.), and webometrics (metrics of the web, the Internet or other social networks such as citation or collaboration networks). The overlap between Informetrics, bibliometrics, scientometrics, cybermetrics and Webometricscs and other closely related metrics was modelled by Björneborn & Ingwersen (2004) and widely supported in the scientometrics community. An extension of Björneborn & Ingwersen (2004) model to accommodate altmetrics with overlaps within cybermetrics and webometrics is being suggested (e.g. Onyancha 2013).

Stefaniak (1987: 151) and Onyancha (2013) reflect the bibliographic data or elements in research and the purpose into which the elements can be put in bibliometric/informetric analysis as summarized by Onyancha (2013) in the table above:

2. Research Problem and Purpose

The study endeavours to see if these top institutions present levels of concentration of performance within universities that are high or very high and greater than that between them. We investigate the level of correlation between performance in research and its dispersion in the universities. The field of observation is made up of all the South African universities active in the hard sciences. The purpose of the study is to determine dispersion of research performance within and between universities as a potential indicator of competitiveness in selected hard sciences research output in South African universities.

The study is intended to answer the following research questions:

1. What is the research output by discipline and by University?
2. What the overall and comparative publication impact by discipline and university?
3. What is the growth and development of South African scientific publications for 2005-2013
4. What is the, nature, spread and strength of research collaboration?

3. Methodology

Research performance is evaluated using bibliometric analysis, through publication indexed in the Web of science between the years 2005 and 2013. Relevant data for the study was downloaded from web of Science using largely Science Citation

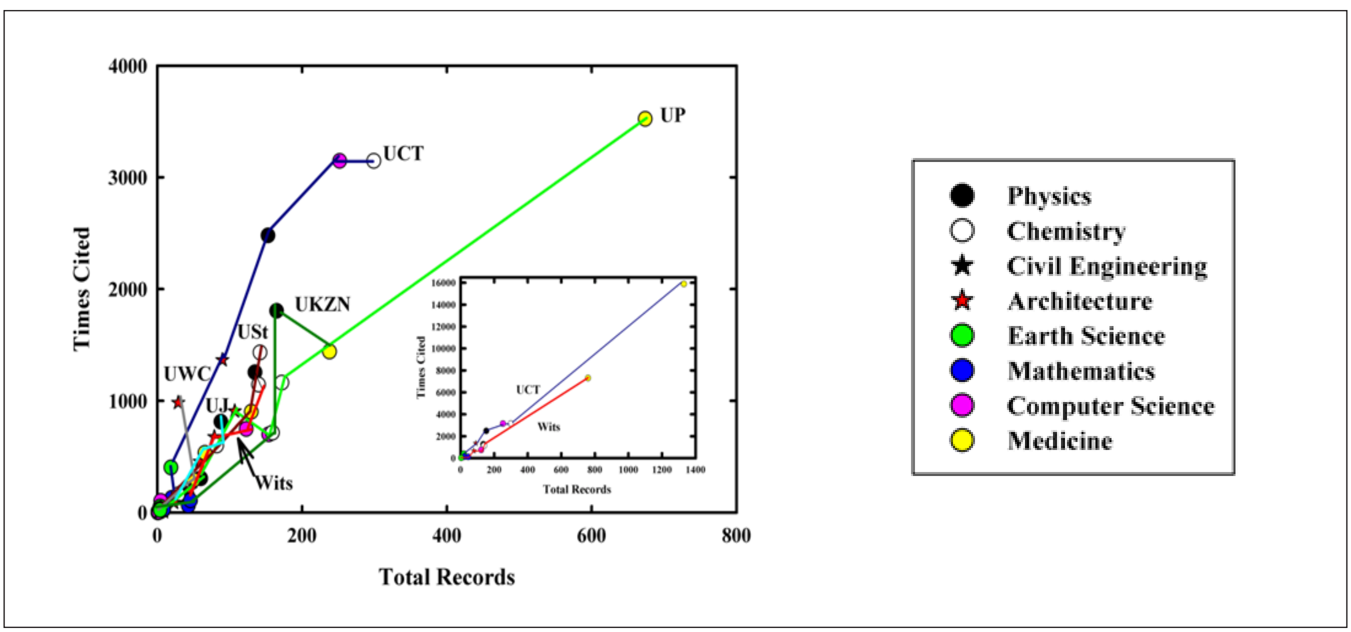

Figure 2. Citation Performance of the selected universities

Index (SCI) but also Social Sciences Citation Index (SSCI) and Arts and Humanities Citation Index (AHCI). Searches were done by University - University of Cape Town (UCT), University of stellensbosch (US), University of Witwatersrand, University of KwaZulu Nata (UKZN)l, University of Pretoria (UP), Rhodes University (RU) and University of Western Cape (UWC) which are also the top research Universities in South Africa and by discipline – Architecture, Civil Enginerring, Chemistry, Computer Science, Earth Science, Mathematics, Medicine and Physics – which are strong niche areas in some of the six universities. From several bibliometric indicators of research performance evaluation (such as publication output/count, trend and citation analysis, impact factor and Hirsch Index), we used publication output by the scientists. The citation count and impact were used to indicate the research output and performance of researchers and what differentiates them from others. This enabled the study to determine intra- disciplinary and university and inter-disciplinary and university dispersion of research as discussed in the findings.

4. Findings and Discussions

In this section we focus on university and discipline research output/count and dispersions.

4.1. Publication Output by University and Discipline from 2005 -2013

The scientific publication throughout the period studied (2005-2013) show that most of the South African publications came from the field of Medicine(50.57%), Chemistry, Physics and Computer (18.46%, 10.46% and 9.65%) respectively of the departments' output for the study period. The other disciplinary fields, in order of percentage contribution, were Architecture (6.80%), mathematics (2.96%), Earth Science (0.61%) and Civil Engineering 0.45%).

	Physics	Chem	Civ.Eng	Arch	Earth.Sci	Maths	Comp. Sci	Med	Total per Uni.
UCT	153 (7.04)	299 (13.76)	8 (0.37)	90 (4.14)	19 (0.87)	22 (1.01)	252 (11.68)	1330 (61.21)	2173 (33.24)
UP	60 (4.89)	172 (14.02)	9 (0.73)	107 (8.72)	9 (0.73)	42 (3.42)	154 (25.10)	674 (54.93)	1227 (18.77)
U.Stell	37 (9.30)	142 (35.67)	4 (1.00)	59 (14.82)	1 (0.25)	20 (5.03)	5 (1.26)	130 (32.66)	398 (6.09)
UWC	35 (22.58)	29 (18.70)	0	29 (18.70)	I (0.65)	9 (5.90)	2 (1.29)	50 (32.25	155 (2.37)
UKZN	165 (24.96)	159 (24.05)	2 (0.30)	46 (6.96)	4 (0.61)	43 (6.51)	4 (0.61)	238 (36.01)	661 (10.11)
WITS	135 (10.46)	140 (10.84)	5 (0.39)	79 (6.12)	4 (0.31)	46(3.57)	123 (9.53)	759 (58.79)	1291 (19.75)
UJ	88 (30.45)	82 (28.37)	2 (0.69)	23 (7.96)	2 (0.69)	4 (1.38)	22 (7.61)	66 (22.84)	289 (4.42)
Rhodes	11 (3.20)	184 (53.64)	0	12 (3.49)	0	8 (2.33)	69 (20.12)	59 (17.20)	343 (5.25)
Total per field	684 (10.46)	1207 (18.46)	30 (0.45)	445 (6.80)	40 (0.61)	194 (2.96)	631 (9.65)	3306(50.57)	6537 (100)

Source: compiled by science citation index

Table 2. Field Participation (%)

All institutions made the highest contribution to medicine except University of Stellenbosch (32.66%) in comparison to other fields of study and the highest contribution was in chemistry (35.67%). However, notable differences were found with respect to contribution made by individual institutions to the different fields of study. Rhodes University, for example, contributed heavily on Chemistry (53.64%) and lowest in Mathematics (2.33%). University of Cape Town, Wits University and University of Pretoria showed highest production in medicine.

4.2. Index of Specialisation

Normally, specialisation Index is used for normalizing research output count. It is assumed that the absolute output of publication doesnot consider the size of the institution and discipline. The specialisation Index, therefore, makes it possible to determine whether an institution is more or less specialised in a specific field compared to other institutions. If the specialisation index of an institution is less than 1 means that the institution is not specialised in this field. In other words, it is less active in this field than the average of institutions. If the index is higher than 1, this means that the institiutionis more active in a given field than the average institutions in the same field (Godin, robitaille & Cote 2001).

The specialisation Index (Figure 4) has been calculated for selected fields using publication data for the period 2005-2013. When interpreting the indicators one should consider that specialisation of different fields varies considerably. Generally

UCT has a high publication activity in Earth Science (*SI* = 1.42), Computer Science (*SI* = 1.21) and Medicine (*SI* = 1.21). UP on the other hand, is specialised in Architecture (*SI* = 1.30), Earth Science (*SI* = 1.19), Mathematics (*SI* = 1.16), Computer Science (*SI* = 2.60) and medicine (*SI* = 1.25). University of Stellenbosch has its specialised disciplines are chemistry (*SI* = 1.93), Civil Engineering (*SI* = 2.2), Architecture (*SI* =2.18), Mathematics (*SI* = 1.69). However, Universities of Western Cape and UKZN are specialised in Physics (*SI* = 2.16) and (*SI* = 2.39) respectively and chemistry (*SI* = 1.01 and 1.3). Architecture (*SI* = 2.75, and *SI* = 1) and Earth science (*SI* = 1.15 and *SI* = 2.2) and mathematics (*SI*=1.99 and 2.19). Wits has specialisation in Mathematics ((*SI* =1.18) and Medicine (*SI* = 1.16). University of Johannesburg is specialised in Physics with a

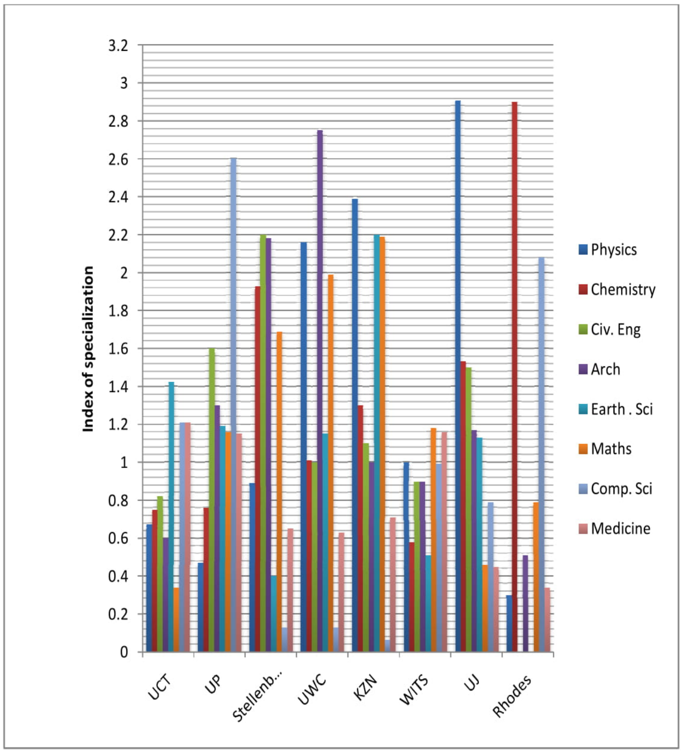

Figure 3. Index of Specialization for most productive institutions

(*SI* = 2.91) Chemistry (*SI* = 1.53), Civil Engineering (*SI* = 1.5) Architecture (*SI* = 1.17 and Earth Science (*SI* = 1.13). Rhodes has specialised in chemistry (*SI* = 2.90) and computer Science highly specialised with a (*SI* of 2.08).

	Physics	Chemistry	Civ. Eng	Arch	Earth . Sci	Maths	Comp. Sci	Medicine
UCT	0,67	0,75	0,82	0,6	1,42	0,34	1,21	1,21
UP	0,47	0,76	1,6	1,3	1,19	1,16	2,6	1,15
Stellenbosch	0,89	1,93	2,2	2,18	0,4	1,69	0,13	0,65
UWC	2,16	1,01	1	2,75	1,15	1,99	0,13	0,63
KZN	2,39	1,3	1,1	1	2,2	2,19	0,06	0,71
WITS	1	0,58	0,9	0,9	0,51	1,18	0,99	1,16
UJ	2,91	1,53	1,5	1,17	1,13	0,46	0,79	0,45
Rhodes	0,3	2,9	0	0,51	0	0,79	2,08	0,34

Table 3. Index of Specialisation

4.3. Comparative Citation Impact by Discipline and University

University	Physics			Chemistry			Civil Engineering			Architecture			Earth Science			Mathematics			Computer science			Medicine		
Indicators	Total records	Times Cited	H-index	Total records	Times Cited	H-index	Total records	Times Cited	H-index	Total records	Times Cited	H-index	Total records	Times Cited	H-index	Total records	Times Cited	H-index	Total records	Times Cited	H-index	Total records	Times Cited	H-index
University of Cape Town	153	2480	22	299	3147	29	8	62	2	90	1365	15	19	402	9	22	126	7	252	3147	28	1330	15879	58
University of Pretoria	60	305	9	172	1162	17	9	6	1	107	907	15	9	24	3	42	93	5	154	699	13	674	3523	26
University of Stellenbosch	37	145	7	142	1432	20	4	5	1	59	455	12	1	8	1	20	130	4	5	103	1	130	901	13
University of Western Cape	35	182	7	29	161	7	no records found			29	983	7	1	0	0	9	29	2	2	4	1	50	291	9
University of KwaZulu Natal	165	1805	21	159	714	12	2	0	0	46	208	8	4	52	3	43	62	4	4	33	2	238	1440	18
University of Wits	135	1255	18	140	1144	17	5	60	2	79	677	16	4	22	3	46	108	5	123	747	12	759	7305	39
University of Johannesburg	88	812	17	82	599	13	2	0	0	23	89	4	2	6	1	4	0	0	22	52	5	66	533	11
Rhodes University	11	71	5	184	1832	21	no records found			12	106	4	no records found			8	14	2	69	525	13	59	692	13

Table 4. Dispersion by Citations

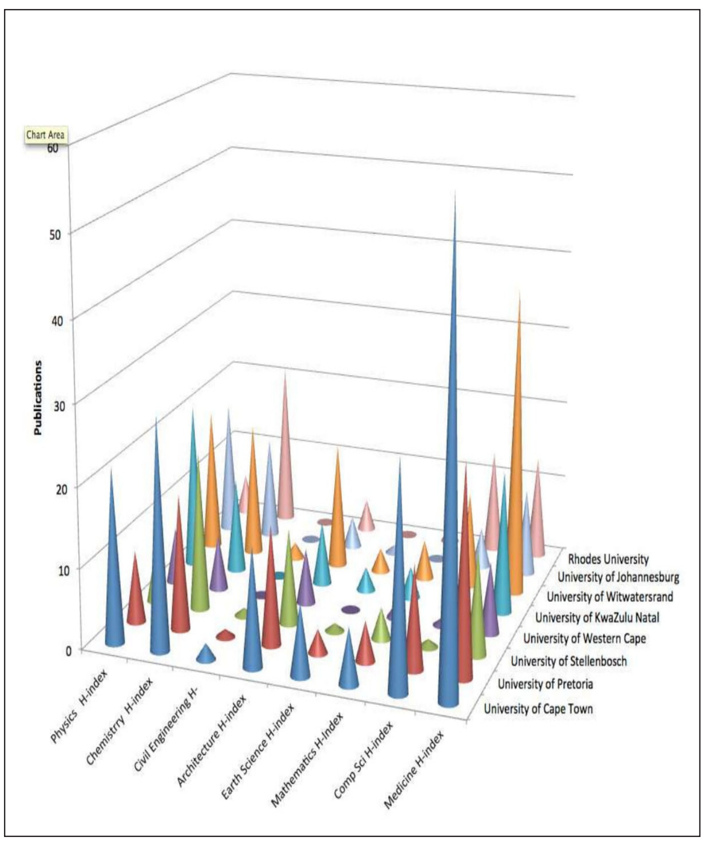

Figure 4. H-Index factor by institution/University and discipline

H-Index is a simple method to quantify the impact of a scientist's research output in a given area (Hirsch 2005). In the last few years, it has quickly become a widely used measure of a researcher's scientific output. The meaning of the h-index can be explained as follows. Suppose a researcher has 15 publications. If 10 of these publications are cited at least 10 times by other researchers, the h-index of the scientist is 10, indicating that the other 5 publications may have less than 10 citations. If one of these 10, out of the 15, publications receives, let us say, 100 citations, the h-index still remains 10. If each of these 15 papers receives 10 citations, the h-index is again only 10. The h-index will reach 15, only if each of all the 15 papers receives a minimum of 15 citations. Therefore, to calculate the h-index of a scientist, find the citations of each publication, rank them according to the number of citations received, and identify the first 'h' publications having at least 'h' citations. To have a reasonably good h-index it is not sufficient to have a few publications with hundreds of citations (Kumar 2009). The use of h-index aims at identifying researchers with more papers and relevant impact over a period of time.

In our research, it was clearly demonstrates the highest h-index received by the scientists and the fields. Both UCT and Wits have achieved the highest h-index in medicine. UCT also had higher h-index in computer science and chemistry. H-index therefore is a reliable method of measuring the high impact of a productivity of a field and institution.

4.4. Trend Analysis of Publication for 2005-2013

The graphing of article counts annually is a bibliometric technique that determines how many articles have been devoted to a given concept over time. The rationale for this method is that bibliographic records are a relatively objective indicator for measuring discourse popularity (Ponzi & Michael 2003).

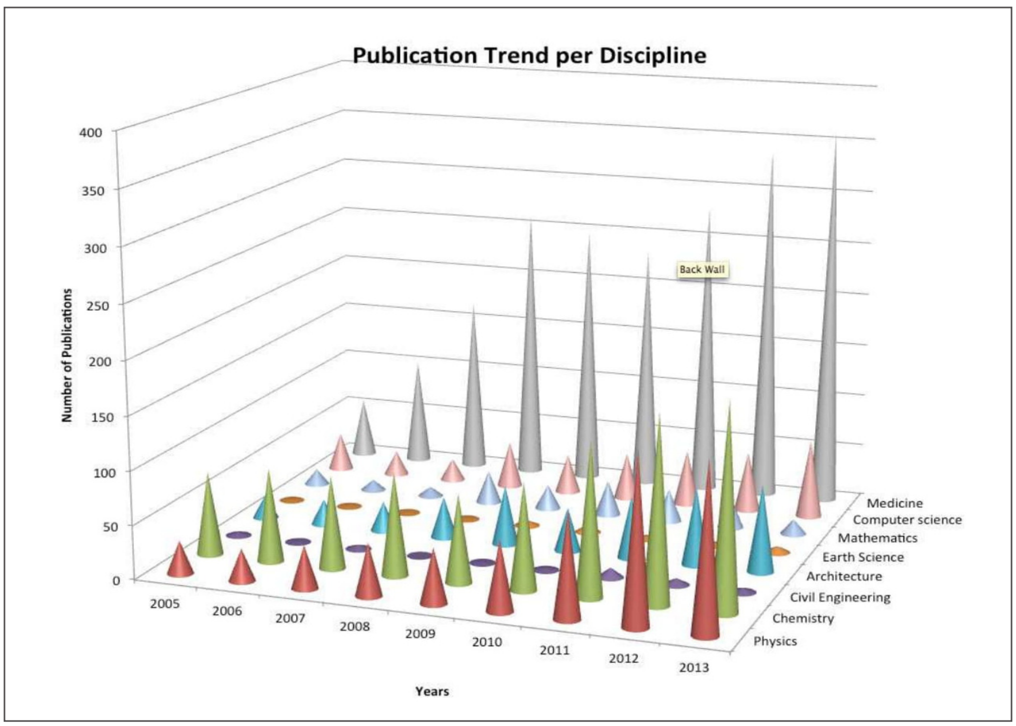

Figure 5. Publication Trend for Disciplines

The percentage increases or decreases are calculated taking 2005 as base year. The over all trends since 2005-2013 for all disciplinary fields except Earth science, civil engineering and mathematics showed a marked increase in publication. Although there was a slow start in all the fields, there was a sudden increase in output of publications from 2010 with the exception of medicine which showed marked increase from 2007 and the trend in publication continued to rise. Looking at the trend in each institution, however reveals important differences. Article production of Universities of Cape Town, Wits and University of Pretoria showed high percentage of increase in Physics, chemistry, Architecture, computer Science and Medicine. There are many reasons behind the rise and fall in research publications over time. Among the influencing factors are funding, policy changes (eg research development and reward), sustainability, mobility of faculty/researcher.

4.5. Scientific Collaboration

Research collaboration is another important indicator of dispersion of publication within or outside an institution. Research collaboration a major focus area in bibliometrics research. Modern research is regarded as increasingly complex and specialized, making it impossible for an individual researcher to master all the knowledge and technical skills needed. In collaboration, different skills complement each other and so doing contribute to the stimulation of knowledge sharing and the generation of innovation and new ideas. As a result, collaborative research activities besides enabling the pooling and sharing of resources for enhanced efficiency also contribute to the quality of the research outcome (Mattson et.al, 2008). Funding agencies and institutions therefore increasingly encourage collaborative research. Grants awarded by many different funding institutions and for many different disciplines often seek to encourage and at times require as a condition, collaborations between different countries, research fields or institutions. Research done by the National Science Foundation of South Africa found that research done by multiple institutions has increased from 40% to 61% between 1988 and 2008. (NSF S&E indicators)

5. Authorship and Collaboration

Author collaboration, institutional collaboration and country collaboration are generally considered as the three primary forms of collaboration. Co-authorship is considered fundamentally in both country collaboration and institutional collaboration. Katz and Martin (1997) reckoned that co-authorship could not be equated with collaboration and it was only one of the important ways to measure collaboration. According to (Pu Han et.al, 2014), there is a general consenses that co-authorship serves as a proxy for scientific collaboration and it is a quantifiable assessment of collaboration indicators.

Scientific research collaboration is a priority in South Africa and all efforts are made to improve research in all areas of science. For research to succeed in science, collaboration is encouraged both within and between institutions, nationally and internationally. The globalized science research has resulted, among other things, in a generalized increase in international scientific collaboration making necessary updated information on scientific co-operation, co-authorship, and influence. This is important to both developing and developed countries and the result obtained demonstrates that the percentage of national collaboration rose from 79% in 2005 which is considered as the base year for this study to 91% in 2013. Share of co-authored papers grew from 67% to 89%. Co-authored papers appreciated to 133%. And the percentage of South African authors have declined from 50% in 2005 to 36% by the end of 2013 and 64% of all publications involved multi country collaboration.

Authorship and Collaboration- top 15 Journals

Name of a Journal	Number of articles	Co-authored articles
South African Medical Journal	713	684
South African journal of Science	564	523
Acta crystalographica section structure	556	540
South African Journal of Physics	548	536
Water South Africa	533	490
Mineral Engineering	278	244
Astrophysical Journal	275	250
AIDS	254	222
African journal of veterinary research	197	160
International Journal of Electrochemical research	165	151
South African Journal of surgery	159	137
South African Journal of Chemistry	139	126
Journal of Ethno pharmacology	136	117
Journal of virology	99	73
Journal of Archaeological Science	89	80
Total	**4705**	**4333**

Table 5. Collaboration patter in the top journals

6. International Collaboration

Countries that collaborated with South Africa were USA, England, Germany, France, Australia, Canada, Italy and Netherlands. 80% of the research was conducted with nine countries, mainly Europe and North American countries, and Japan. The largest contribution of 29% belonged to USA followed by England and Germany 11% and 13% respectively. South Africa consulted with Asian countries such as Japan, China, India, Taiwan and South Korea which constituted about 7%. Lately with BRIC countries – Btrazil, Russia, India and China in the areas of physics, Chemistry, Astronomy, Geochemistry, Nanotechnology and computer technology.

On analyzing the data on the web of science for African research, South Africa ranks the top position in medicine, computer science and Mathematics and second rank in Chemistry, Engineering and third position in Material Science.

A t-test was used to determine if there was a statistical significant difference between the means of national and international collaborations. The p-value of 0.01671 ($p\text{-value} < 0.027$) indicates that South Africa authors collaborate more frequently with international scientists than with national. A non-parametric chi-square statistical analysis has been conducted to determine if there are significant differences in the proportion of co-authorship among the eight institutions. The resulting ($p\text{-value} < 0.005$), shows that there are significant differences in the rate of collaborations among the institutions.

7. Conclusions

The result of our study showed that out of the 8 fields of study among 8 institutions during 2005-2013 of which University of Cape Town accounts for the largest share of South African publications which is 33.24% followed by WITS, 19.75% and University of Pretoria 18.77%. The University of Kwazulu- Natal with 10.11% share and Stellenbosch stands at 6.09%. University of Johannesburg has done well in the fields of physics and chemistry, the outputs in other fields need to be improved and universities of western Cape and Rhodes universities share accounts of 2.37% and 5.25% respectively. While growth of publications in each institution reveals important differences, gradual increase in total article production is apparent.

We observe that the South African education system presents levels of concentration of performance within universities that are high and at times greater than that between them. This situation to a certain extent allows the search for a competitive advantage with the resulting production of outstanding research institutions, which are capable of attracting and retaining the top scientists both nationally and internationally. This in a way brings about dispersion of performance and indicates the intensity of competitiveness in research institutions and universities. We also notice that in the competitive system, the variability of performance within is much less compared to between universities. The results of the research shows that two universities with the same average research performance could have altogether different impacts on national economic development. As far as competitive systems are concerned, dispersion of performance within universities is so high that it is very difficult to perceive strong differences in performances between universities. The results obtained can be used as indicators for policy making and examine the effectiveness of selective funding of universities based on national research assessment exercises.

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