Afr. J. Lib & Inf. Sc. Vol.21, No. 2 (2011) 101-115

Research Collaborations between South Africa and Other Countries, 1986-2005: An Informetric Analysis

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Abstract

The paper reports the findings of an informetric study of the countries with which South Africa collaborates in research. The study period spans 20 years (10 years each during and after the apartheid era). Data were extracted from the Thomson Reuters citation indexes, namely: Science Citation Index (SCI), Social Sciences Citation Index (SSCI) and Arts and Humanities Citation Index (AHCI). Among the findings, it was observed that multiple-country-author papers, as well as the number of collaborating countries are on the rise since 1986. The USA topped the list of the countries outside Africa collaborating with South Africa while Zimbabwe topped the list of African countries. However, the strength of research collaboration was low for both categories of countries. Regarding impact, international collaboration yielded higher average citations per paper than continental collaboration. The study concludes that there are many unique research areas in which African countries can collaborate, and recommends that these areas should form themes along which scholars in Africa could conduct collaborative research.

Keywords

Research collaboration, research impact, South Africa

Introduction

South Africa's regional, continental and international relations were severely strained during the apartheid era. Prior to 1994, when the Government of National Unity was formed, the country was alienated from the world's mainstream economic, social and political engagements (Levy, 1999). India is said to be the first country to impose sanctions on South Africa in July 1946 – sanctions that were largely trade related (Wehr, Burgess and Burgess, 1994). Saunders and Southey (2001) note that South Africa's apartheid system came under regular attack from the international community from 1952, culminating in its withdrawal from various international organisations. For instance, South Africa was forced to withdraw from the United Nations Educational Scientific and Cultural Organization (UNESCO) in 1956, the International Labour Organization (ILO) in 1961 and the World Health Organization (WHO) in 1965. Schoeman's (1988) *South African Sanctions Directory* reveals that the majority of the sanctions against the country were imposed in the 1980s. These sanctions touched on almost every sector of the country, for example trade/commerce, sports, health, and education, to mention just a few. The sanctions also affected research collaboration between South African scholars/researchers and institutions and their counterparts in the rest of the world. One particular sanction that might have had a profound impact on research was the academic boycott of South Africa between the 1960s and 1990 by the international academia. Coovadia (1999), for instance, argues that the academic boycott against South African

researchers resulted in many scientists from overseas refusing to visit South Africa, or to invite white or black South Africans, unless "the conditions of selective support were met". In summarising the impact of the academic boycott, the Physicians for Human Rights (United Kingdom) and the Johannes Weir Foundation, as cited in Coovadia (1999), concluded in their report on health care under apartheid thus: "the academic boycott had a negative impact on academic work, research, scholarship, and postgraduate teaching."

The scenario has since changed. For instance, a 2009 spot check on the National Research Foundation's website (NRF, 2009) yielded the following subsisting post-2004 research collaboration initiatives: South Africa – Oman Joint Science and Technology Research; South Africa – Poland Joint Science and Technology Research; NRF/CNRS International Scientific and Technological Cooperation (Joint research venture is between South Africa's National Research Foundation and the French National Centre for Scientific Research); South Africa – Hungary Joint Science and Technology Research; South Africa – Kenya Joint Science and Technology Research Programme; Swedish Research Links Programme; South Africa – Argentina Joint Science and Technology Research; NRF – DFG Joint Science and Technology Research (between South African and German researchers). Also, among the research projects that are conducted by South Africa's Medical Research Centre [MRC] is collaboration with the Centre for Health Informatics Research and Development (CHIRAD) in the UK which began in 2004 (MRC, 2007). For its part, the Human Sciences Research Council [HSRC] (2005) collaborates with institutions in virtually all sub-Saharan African countries in all its 10 programme areas.

The few subject-specific studies that have been conducted on research collaboration in South Africa have indicated that the country's research output in terms of publications is largely co-authored by researchers within the country (Onyancha and Ocholla, 2007; Onyancha, 2009). This implies that, although the sanctions imposed on South Africa retarded the country's potential growth and performance on various fronts, the sanctions were a 'blessing in disguise', so to speak, as far as the strengthening of internal collaborations are concerned. It should be noted however that the above studies (i.e. Onyancha and Ocholla, 2007; Onyancha, 2009) were conducted in order to identify the collaboration patterns, trends in and extent of HIV/AIDS research in Eastern and Southern African countries. In contrast, Jacobs (2008) found out in her analysis of the South African publications in the Science Citation Index from 1995 to 2003 in selected scientific fields that national co-authorship of publications contributed only 26% of the country's total publications output while international collaborations contributed 74%. One of the factors that might explain these contrasting findings are differences in the time periods covered in the three studies. Whereas Onyancha and Ocholla (2007) and Onyancha (2009) analysed HIV/AIDS papers published between 1980 and 2005 (apartheid and post-apartheid eras), Jacobs' study covered the years 1995 and 2003 (post apartheid era only). Seemingly, research in South Africa was to a large extent dominated by internal collaboration during the apartheid regime, and the pattern is probably changing in favour of international collaboration.

On a bigger scale, Tijssen (2007) set out to highlight Africa's contribution to the worldwide research literature and one of the variables he considered was Africa's domestic and international collaboration. He noted that 'single institute' papers from African countries contributed an average of 15% of the total African output each four-year period beginning with the period from 1990 to 1993. Domestic co-publication, according to Tijssen, has declined steadily from 48% to 34% while the worldwide-domestic co-publication has continued to increase. He attributes this pattern of co-publication to African researchers' reliance on foreign partners for publishing their research findings in foreign journals.

One other important issue raised in Tijssen's study, which is worth mentioning, is the effect of research collaboration on research impact. A critical review of Tijssen's study reveals that research collaboration, particularly at an international level, increases research visibility which in turn increases the research impact. This view is also held by Adams, Gurney and Marshall (2007) who observed that "collaborative research is also identified as contributing to some of the highest impact activity." Similarly, Katz and Hicks (1997) noted that "collaborating with an author from the home institution or another domestic institution increases the average impact by approximately 0.75 citations while collaborating

with an author from a foreign institution increases the impact by about 1.6 citations." This and other factors or gains associated with research collaboration (see Onyancha and Ocholla, 2007) have resulted in various governments' and institutions' increased focus on collaboration among international and domestic researchers.

This study investigated the patterns and trends in South Africa's research collaboration, with other countries between 1986 and 2005 (one decade each in apartheid and post-apartheid South Africa). Specifically, the study:

(1) Examined the trend of single-country-author and multiple-country-author papers.
(2) Compared the number of countries collaborating with South Africa.
(3) Identified the countries with which South Africa collaborates.
(4) Determined the subject focus areas of research collaboration.
(5) Measured the strength of association between South Africa and each of the collaborating countries.
(6) Compared South Africa's continental and international research collaboration's citation impact.

Methods and Materials

The Thomson Reuters' (previously known as the Institute of Scientific Information and thereafter Thomson Scientific) citation indexes, namely: Science Citation Index (SCI), Social Sciences Citation Index (SSCI) and Arts and Humanities Citation Index (A&HCI) were the sources of the data. Relevant data were extracted from these databases through the online Web of Science, Thomson Reuters' portal to the citation indexes. As the three databases share a search platform, a single search query, '*AD=South Africa*', was used to extract all documents that contained the words 'South Africa' within the author's address field. The search was then refined by date of publication and document type so as to obtain only *articles* published between 1986 and 2005, that is, one decade each during and after the apartheid era. The author's address field was identified as the most appropriate field within which the search was to be conducted in order to retrieve only the records that contained at least one South African institutional address on the assumption that such a record was authored by individuals affiliated to a South African institution. Limiting the search to only *articles* was done on the basis of the widely acknowledged fact that scientific research is disseminated largely through journal articles as opposed to other document types such as books, book chapters, book reviews, technical reports, working papers, letters to the editors, biographies, bibliographies, news items and reprints.

Data analysis was conducted using several analytic technologies (e.g. Sitkis, UCINET for Windows, and Microsoft Excel and Access software) in line with the stated objectives:

(1) *Examine the trend of single-country-author and multiple-country-author papers*: Normally, the term 'co-authorship' is used to refer to "an instance in which two or more individuals jointly author" (Diodato, 1994:6). Since the term 'author' may refer to individual as well as to corporate authorship, this study introduces two terms – 'single-country-author/authorship' and 'multiple-country-author/authorship' paper(s) – to refer to papers authored by South Africa only (i.e. papers that contained multiple names of South African institutions only) and those authored by South Africa in partnership with at least one other country (i.e. papers that contained two or more authors with at least one author from a foreign country and at least one from a South African institution), respectively. It therefore follows that *co-authorship or multiple authorship* is used in this paper to refer to a paper jointly authored among two or more countries, that is, papers originating from partnership between two or more countries.
(2) *Compare the number of countries collaborating with South Africa*: The number of countries was computed in each five-year period from 1986 to 2005. The growth of and percentage increase in

the number of countries was also computed in order to investigate the trend of research collaboration between South Africa and the rest of the world.

(3) *Identify the countries collaborating with South Africa*: *Continental* (African) and *international* (foreign) countries were identified from the authors' addresses. The research output resulting from collaboration with respective countries was calculated, based on the number of records in which the name of a particular country appeared in the authors' address field. In all cases, the name of the country was counted only once irrespective of the number of times it appeared in a given record.

(4) *Determine the subject focus areas of research collaboration*: The purpose of identifying the subject areas was two-fold, namely to:
   i. explore the shifts of research focus by examining the top 10 subject categories originating from papers co-authored outside South Africa in each five-year period; and
   ii. identify subject areas of collaboration between South Africa and continental (African) countries, on the one hand and foreign countries, on the other. Continental and foreign co-authored papers were isolated and analysed separately to identify the subject categories that yielded high frequencies of occurrence.

(5) *Measure the strength of association between South Africa and each collaborating country*: Each country's raw frequency counts were subjected to further analysis using the UCINET software's normalised function to generate normalised frequency counts which in turn were used as indicators of strengths of association between South Africa and each collaborating country. The normalised frequency count ranged between 0 and 1. The closer the figure was to 1, the stronger the collaboration ties between the respective country and South Africa. The reverse of this meant weaker relationships.

(6) *Compare South Africa's continental and international research collaboration's citation impact*: Two approaches were used to measure the impact of South Africa's research collaboration, namely:
   i. Continental and international citation counts and citations per paper were separately analysed in order to find out whether or not there are differences in research impact between international and continental collaborations.
   ii. Citation and citations-per-paper frequencies of papers that contained at least one South African institution's name and no name of an institution outside South Africa were compared with the citations/citations per paper of all papers containing a South African institution's name in the authors' addresses field to find out whether or not collaboration with an outside country changes South Africa's research impact and if so, by how much?

The number of citations per paper was used as an indicator of impact in both approaches.

Results and Discussion

The results are presented and discussed according to the objectives outlined in the methods and materials section and labelled as (1) to (6) above.

Trends of Single-Country-Author and Multiple-Country-Author Papers

As mentioned in the methodology, single-country-author papers refer to papers about South Africa authored by South African researchers only, represented in Fig. 1 as 'SA only'. This category of papers shows a slight increase from 2605 in 1986 to 2867 papers in 1987, a percentage increase of 10.1%. Apart from occasional increments, the number of single-country-author papers has declined steadily since 1988. For instance, the papers decreased from 2770 in 1988 to 2522 in 1989, and there was a further decline to 2477 in 1990. Generally speaking, the number of single-country-author papers decreased from 2605 in

1986 to 1815 in 2005. It is projected that this trend may continue as long as collaborations continue between South African researchers and their counterparts in other countries.

Multiple-country-author papers, on the other hand, have continued to increase since 1986, the year in which South Africa's papers co-authored with other countries totalled 332. The following year (i.e. 1987) yielded 424, a percentage increase of 27.7. There was a slight decline by 46 papers in 1988, which was followed by a growth rate of 4.2% in 1989, which registered a total of 394 papers. Thereafter, the growth of multiple-country-author papers accelerated, almost at an exponential rate and peaked at 1754 in 2004. In fact, the trend line indicates that the growth rate of multiple-country-author papers has steadily increased at a higher rate than the total number of South African papers, especially after 1994 when South Africa's apartheid regime was replaced by the Government of National Unity. This may imply an opening up of South Africa's collaboration space, both continentally and internationally. The SA-Agg line graph depicts the trend of growth of South Africa's total number of papers between 1986 and 2005.

Number of Collaborating Countries

Fig. 2 provides the number of countries that collaborated with South Africa in the production of research articles between 1986 and 2005. It was noted that the number of countries collaborating with South Africa, just as the number of multiple-country-author papers, has steadily increased from just 43 in 1986 to 115 in 2005. It was however noted that the growth rate has slowed down from 31.15% in 1995 to 3.60% in 2005. This trend is not entirely unique as the number of participating countries would initially grow at a fast rate and stabilise at some stage at which the distinction between core and periphery participants becomes clear. In their study on collaboration in HIV/AIDS research, Onyancha and Ocholla (2007) observed that South Africa collaborated with a total of 75 countries, comprising 51 foreign and 24 continental countries between 1980 and 2005. It would seem that the higher the number of fields included in the investigation, the higher the number of collaborating countries as revealed in this study, which has broadened the scope to include all fields of research.

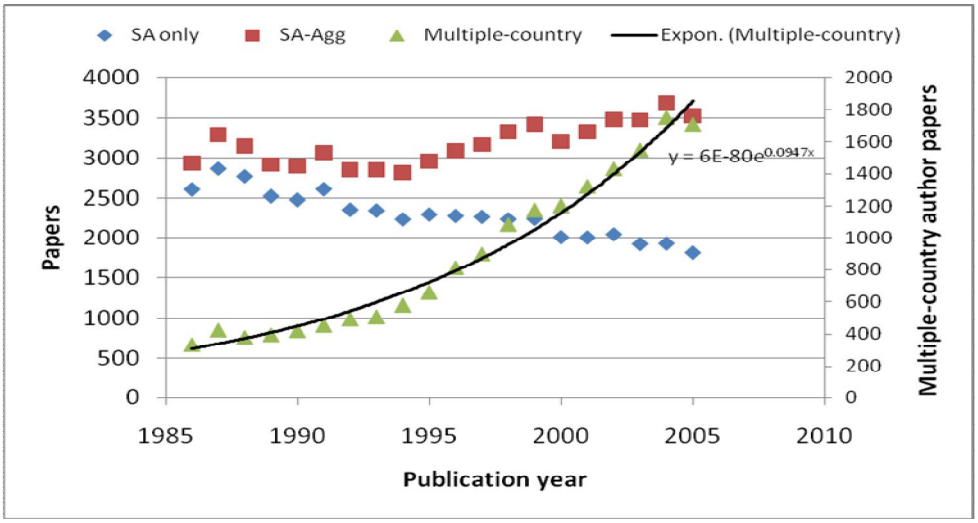

Fig. 1: Trends of single-country (South Africa) and multiple-country authored papers.

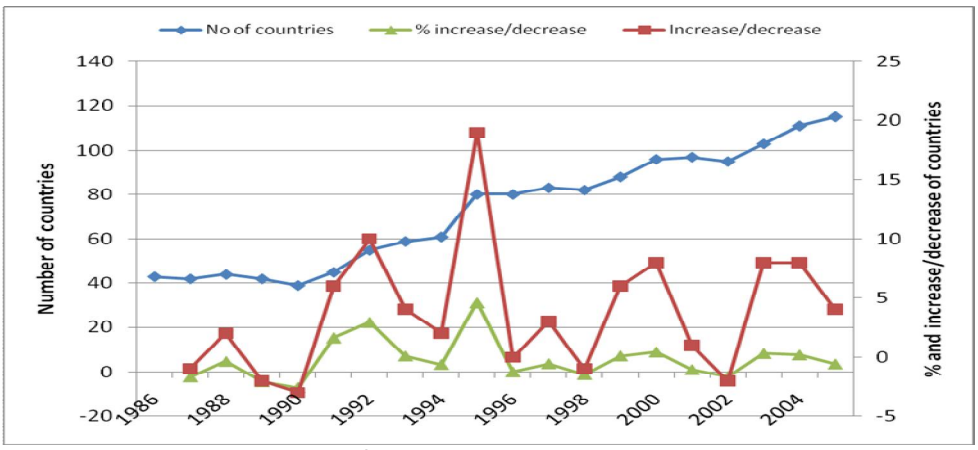

Fig. 2: Growth in the number of collaborating countries

Collaboration with Researchers in African and Non-African Countries

Overall, out of the 53 independent African countries, 46 (86.8%) participated in research collaboration with South Africa between 1986 and 2005. Table 1 shows that Zimbabwe was the leader with 224 articles, followed by Namibia (180), Kenya (168), Nigeria (123), Botswana (102), Ethiopia (77), Zambia (51), Tanzania (45), Mozambique (44) and Uganda (42). An examination of each country's contribution as a percentage of continental country-author papers reveals that the core continental collaborators were Zimbabwe, Namibia, Kenya, Nigeria and Botswana. It is worth noting that besides Kenya and Nigeria, the other three countries are located in the Southern Africa Development Community (SADC) region of which South Africa is also part. Other SADC countries which recorded a reasonably high number of multiple-country-author papers with South Africa are Zambia (51), Tanzania (45), Mozambique (44), Malawi (37), Swaziland (30), Madagascar (17) and Lesotho (15). Explaining this phenomenon, Onyancha and Ocholla (2007:252) observe that countries tend to collaborate more with their neighbouring countries. In their study on HIV/AIDS research collaboration in Kenya and South Africa, Onyancha and Ocholla (2007) found that Kenya collaborated more with countries in the eastern African region while South Africa's continental collaboration largely involved Southern African countries. Similar observations were made by Katz (1994), Liang and Zhu (2002, Moed, Glanzel and Schmoch (2004), and Lariviere, Gingras and Archambault (2006).

Table 1: South Africa's African Country Collaborators

	Papers	%[a]	%[b]	%[c]		Papers	%[a]	%[b]	%[c]
Zimbabwe	224	0.35	17.95	1.23	Cote d'Ivoire	13	0.02	1.04	0.07
Namibia	180	0.28	14.42	0.99	Mali	12	0.02	0.96	0.07
Kenya	168	0.26	13.46	0.93	Algeria	11	0.02	0.88	0.06
Nigeria	123	0.19	9.86	0.68	Zaire	11	0.02	0.88	0.06
Botswana	102	0.16	8.17	0.56	Sudan	8	0.01	0.64	0.04
Ethiopia	77	0.12	6.17	0.42	Gabon	8	0.01	0.64	0.04
Zambia	51	0.08	4.09	0.28	Congo	7	0.01	0.56	0.04
Tanzania	45	0.07	3.61	0.25	Angola	5	0.01	0.40	0.03
Mozambique	44	0.07	3.53	0.24	Eritrea	5	0.01	0.40	0.03
Uganda	42	0.07	3.37	0.23	Mauritius	4	0.01	0.32	0.02
Egypt	37	0.06	2.96	0.20	Rwanda	4	0.01	0.32	0.02

Malawi	37	0.06	2.96	0.20	Cen. Africa Rep.	4	0.01	0.32	0.02
Cameroon	31	0.05	2.48	0.17	Guinea	2	0.00	0.16	0.01
Swaziland	30	0.05	2.40	0.17	Guinea Bissau	2	0.00	0.16	0.01
Ghana	22	0.03	1.76	0.12	Seychelles	2	0.00	0.16	0.01
Senegal	19	0.03	1.52	0.10	Burundi	1	0.00	0.08	0.01
Madagascar	17	0.03	1.36	0.09	Chad	1	0.00	0.08	0.01
Benin	15	0.02	1.20	0.08	Comoros	1	0.00	0.08	0.01
Lesotho	15	0.02	1.20	0.08	Libya	1	0.00	0.08	0.01
Tunisia	15	0.02	1.20	0.08	Mauritania	1	0.00	0.08	0.01
Burkina Faso	14	0.02	1.12	0.08	Niger	1	0.00	0.08	0.01
Morocco	14	0.02	1.12	0.08	Sierra Leone	1	0.00	0.08	0.01
Gambia	13	0.02	1.04	0.07	Togo	1	0.00	0.08	0.01

Key:
%[a]: Country's % contribution to South Africa's total publication output (N=63426)
%[b]: Country's % contribution to continental multiple-country-author papers (N=1248)
%[c]: Country's % contribution to all multiple-country-author papers (N=18147)

Internationally, South Africa's country collaborators numbered 126. The USA was the leader with 5811 papers, followed by England (3274), Germany (2126), Australia (1627), Canada (1214), France (1152), Netherlands (810), Belgium (626) and Italy (625). The bibliometric principles of a few entities (i.e. authors and journals) accounting for the majority of publications also seem to hold in regard to countries which were the focus in this study since the USA, England and Germany accounted for 66.34% of the international multiple-country-author papers. This pattern was also witnessed in the continental research collaboration. A total of 123 countries produced the remaining 33.66% of the publications. Notably, researchers based in institutions in the USA are the majority collaborators with South African researchers (see also Onyancha and Ocholla, 2007; Jacobs, 2008; Sooryamoorthy, 2009a).

Table 2: South Africa's Collaborators outside Africa

	Papers	%[a]	%[b]	%[c]	Country	Papers	%[a]	%[b]	%[c]
USA	5811	9.16	34.39	32.02	Russia	275	0.43	1.63	1.52
England	3274	5.16	19.37	18.04	Denmark	251	0.40	1.49	1.38
Germany	2126	3.35	12.58	11.72	Peoples Rep. China	243	0.38	1.44	1.34
Australia	1627	2.57	9.63	8.97	Norway	182	0.29	1.08	1.00
Canada	1214	1.91	7.18	6.69	Finland	152	0.24	0.90	0.84
France	1152	1.82	6.82	6.35	Argentina	146	0.23	0.86	0.80
Netherlands	810	1.28	4.79	4.46	Hungary	140	0.22	0.83	0.77
Belgium	626	0.99	3.70	3.45	Greece	124	0.20	0.73	0.68
Italy	625	0.99	3.70	3.44	Chile	121	0.19	0.72	0.67
Scotland	550	0.87	3.25	3.03	Ireland	117	0.18	0.69	0.64
Israel	548	0.86	3.24	3.02	Wales	116	0.18	0.69	0.64
Switzerland	544	0.86	3.22	3.00	Mexico	113	0.18	0.67	0.62
Japan	469	0.74	2.78	2.58	Czech Republic	108	0.17	0.64	0.60

Sweden	422	0.67	2.50	2.33	Northern Ireland	100	0.16	0.59	0.55
Spain	401	0.63	2.37	2.21	Portugal	87	0.14	0.51	0.48
New Zealand	336	0.53	1.99	1.85	Taiwan	83	0.13	0.49	0.46
Austria	329	0.52	1.95	1.81	South Korea	81	0.13	0.48	0.45
Poland	320	0.50	1.89	1.76	Saudi Arabia	80	0.13	0.47	0.44
India	269	0.42	1.59	1.48	Turkey	80	0.13	0.47	0.44
Brazil	260	0.41	1.54	1.43	Ukraine	70	0.11	0.41	0.39

Key:
%[a]: Country's % contribution to South Africa's total publication output (N=63426)
%[b]: Country's % contribution to international multiple-country-author papers (N=16899)
%[c]: Country's % contribution to all multiple-country-author papers (N=18147)

A comparison of the research output resulting from the two categories of collaboration (i.e. continental and international) reveals that there is more collaborative activity at the international level than there is on the continental scene. Tijssen (2007:308) explains it thus:

> A fair share of the internationally co-authored publications can be attributed to genuine international cooperation, where researchers share and exchange ideas, resources and facilities. Part of it will result from non-African scientists and scholars with dual appointments, or those researchers on working visits and temporary stays in African countries (e.g. for field work) that list both their home address and temporary address, and vice versa in the case of scientists with a home country in Africa …

This argument is corroborated by Sooryamoorthy (2009a) who observes that international collaboration is preferred to domestic collaboration in the publication of South Africa's scientific papers. Domestic collaboration, in this case, refers to continental collboration, that is collaboration between South Africa and another African country. Similar findings were noted by Onyancha and Ocholla's (2007) study on HIV/AIDS research and Jacobs' (2008) study on natural and applied sciences. While noting that 12 (out of the 15 countries investigated) African countries' research was largely through collaboration, Narvaez-Berthelemot, Russell, Arvanitis, Waast and Gaillard (2002) noted that South Africa's international collboration accounted for less than 30% of the total country's scientific publications. The authors did not, however, compare continental (i.e. African) collaboration and international collboration.

Strengths of Association Between South Africa and its Collaborators

In bibliometrics, the strengths of association between participating entities are computed using different approaches. The use of Krsul's (2002) mathematical function is one such approach. The other approach involves the normalisation of raw frequency counts using UCINET's analytic approaches. The latter was used to examine how strong the partnerships between South Africa and its country collaborators are. According to the compilers of UCINET (Borgatti, Everett and Freeman, 2002), the euclidean technique of normalisation "standardizes the euclidean norm to be one. This is achieved by dividing the rows, columns or matrix by the current Euclidean norm" thereby producing values for each pair of factors in a matrix. The values reflect the strength of association among the participating elements in a matrix. International collaborations produced the following normalised frequency counts for the top country collaborators: USA (0.065), England (0.037), Germany (0.024), Australia (0.018), Canada (0.014), France (0.013), Netherlands (0.009), Belgium (0.007), Italy (0.007), Scotland (0.006), Israel (0.006), Switzerland (0.006), Japan (0.005), Sweden (0.005) and Spain (0.005).

Continentally, South Africa's strength of association with African countries registered the following scores: Zimbabwe (0.003), Namibia (0.003), Kenya (0.003), Nigeria (0.002) and Botswana (0.002). Others include Ethiopia, Zambia, Tanzania, Mozambique, Uganda, Egypt and Malawi which

scored a strength value of 0.001 each. The rest of the countries yielded zero normalised frequency counts, which implies minimal partnership with South Africa. As a score of 1.00 would indicate absolute collaboration, it follows that the strength of association values generated by South Africa's continental and international collaborators indicates very weak relationships. This pattern is also reflected in the percentage contribution of each country in relation to the total number of publications produced by South Africa between 1986 and 2005 (i.e. 63426) shown in Tables 1 and 2 as %[a]. For instance, the leading international collaborator – the USA – participated in the authorship of a mere 9.16% of South Africa's total publications, followed by England (5.16%), Germany (3.35%), and Australia (2.57%) while South Africa's leading continental collaborator – Zimbabwe – contributed even a smaller portion (i.e. 0.35%) of the country's total research output.

Citation Impact of South Africa's Continental and International Collaboration

The figures in table 3 show the number of articles and citations that were respectively produced and received by continental-only and international-only collaborations. The purpose of this analysis was to compare the citation impact of South Africa's continental and international collaboration. The table reveals that, throughout the entire period of study, international collaboration registered higher scores in terms of the number of citations and the h-index while there was a mixed pattern when comparing the citation impact of the two types of collaboration by the number of citations per paper. International collaboration's average citations were higher than those of continental collaboration in 1986-1990 (22.20) and 1996-2000 (20.80) while continental collaboration emerged on top in 1991-1995 (45.66) and 2001-2005 (15.15). This pattern, generally, reveals that, whereas international collaboration yields more citations, its citations per paper is slightly lower than that of continental collaboration. The higher values of the h-index in terms of international collaboration can partly be attributed to a higher number of papers produced through international than through continental collaboration.

Table 3: Impact of South Africa's Research Collaboration

	1986-1990	**1991-1995**	**1996-2000**	**2001-2005**
Papers				
Continental	73	87	334	754
International	1891	2644	4998	7366
Citations				
Continental	945	3972	6525	11424
International	41988	64960	103979	109619
Citations/paper				
Continental	12.95	45.66	19.54	15.15
International	22.20	24.57	20.80	14.88
H-index				
Continental	18	28	38	47
International	84	96	106	99

Table 4: Comparison of Citation Impact of Internally and Externally Authored Papers

	South Africa only				South Africa with the rest of the World			
	Papers	*Citations*	*Cites/paper*	*h-index*	*Papers*	*Citations*	*Cites/paper*	*h-index*
1986	2605	27640	10.6	59	2937	34137	11.6	65
1987	2867	29308	10.2	58	3291	38427	11.7	69
1988	2770	29502	10.7	58	3148	37692	12.0	67
1989	2522	21889	8.7	49	2916	30697	10.5	61
1990	2477	25875	10.5	56	2897	35797	12.4	69
1991	2609	25873	9.9	56	3063	38426	12.6	69
1992	2356	24890	10.6	53	2849	36711	12.9	69
1993	2346	22210	9.5	50	2853	35045	12.3	67
1994	2237	21990	9.8	53	2815	34010	12.1	68
1995	2297	20872	9.1	49	2955	37096	12.6	65
1996	2279	19866	8.7	49	3091	37508	12.1	69
1997	2268	18866	8.3	46	3167	36848	11.6	67
1998	2238	18400	8.2	46	3323	42423	12.8	68
1999	2244	17013	7.6	41	3418	39338	11.5	66
2000	2011	16108	8.0	44	3212	39664	12.4	70
2001	2007	13801	6.9	37	3327	39281	11.8	65
2002	2047	13848	6.8	36	3478	33803	9.7	59
2003	1925	11284	5.9	34	3475	34759	10.0	62
2004	1931	10471	5.4	31	3685	34280	9.3	60
2005	1815	7746	4.3	28	3526	26829	7.6	49

Table 4 compares the citation impact of papers that were authored within South Africa with those co-authored by South African scholars and any other scholar(s) from outside South Africa. Results reveal that, throughout the entire period of study, the average number of citations per paper (as an indicator of citation impact or research impact) was higher for international collaboration than for that generated by papers authored within South Africa. A similar pattern was witnessed in the analysis of the h-index, which is another way of measuring impact.

Subject Focus in South Africa's Continental and International Research Collaboration

A subject content analysis of the literature on any given subject field or discipline is intended to serve different purposes, among which are the following: (a) to monitor the changing level of interest by researchers on a given subject; (b) to track the introduction of new terms that reflect innovations and discoveries in the knowledge base; (c) to mirror what happens to subject access as the knowledge base and environment of a discipline grow and/or change; (d) to describe a concept or topic using the related terms; and (e) to establish core terms upon which a particular subject's curriculum can be developed (see Macias-Chapula, Sotolongo-Aguilar, Magde and Solorio-Lagunas, 1999:565; Bierbaum and Brooks, 1995; Onyancha and Ocholla, 2009).

This study examined the subject categories that were the focus of both continental and international collaboration in order to (a) check for shifts of research interest and (b) identify the subject focus of local and international scholars when conducting research through collaborations. In total, 230 subject categories were identified in international collaborations while 159 subject categories constituted focus areas of research collaboration by continental collaborating scholars. The most targeted subject area in the international collaboration category was *astronomy and astrophysics* which yielded 1071 (6.34%)

records followed by *biochemistry and molecular biology* (728), *plant sciences* (666), *ecology* (657), *zoology* (538), *mathematics* (474), *pharmacology & pharmacy* (465), *immunology* (459), *infectious diseases* (459) and *microbiology* (450). On the local/continental scene, South Africa's collaboration with African countries is largely focused on *veterinary sciences* which yielded 101 (8.09%) records followed, by *ecology* (86), *public, environmental and occupational health* (80), *environmental sciences* (71), *plant sciences* (70), *zoology* (66), *infectious diseases* (59), *tropical medicine* (53), *multidisciplinary sciences* (50) and *biochemistry and molecular biology* (49). A comparison of the aforementioned subject areas of international and continental collaboration revealed that the priorities in both cases are different. Although the majority of the focus areas in international collaboration featured in the continental collaboration category, their ranking differed greatly. For instance, whereas *veterinary sciences* was ranked number 20 in international collaboration, it was ranked number one continentally. Perhaps this explains that local researchers' common interest (or research among African scholars) differs from that held among international scholars. Whereas continental research areas are largely dictated by unique problems which are common to most countries in Africa, subject areas of research in international collaboration are usually determined by the international community which, in most cases, funds the research. It is not unique to find that international scholars who would like to collaborate with continental counterparts steer research in such a way that it focuses on research areas (i.e. niche areas) of the latter's institutional or country of affiliation, especially in situations where their countries or institutions are the main or sole funding institutions or countries. On the other hand, continental collaboration focuses on common problem areas, a situation that may explain the high ranking of such subject categories as *ecology*, *public health*, *environmental sciences*, *plant sciences*, and *tropical medicine* besides *veterinary sciences*.

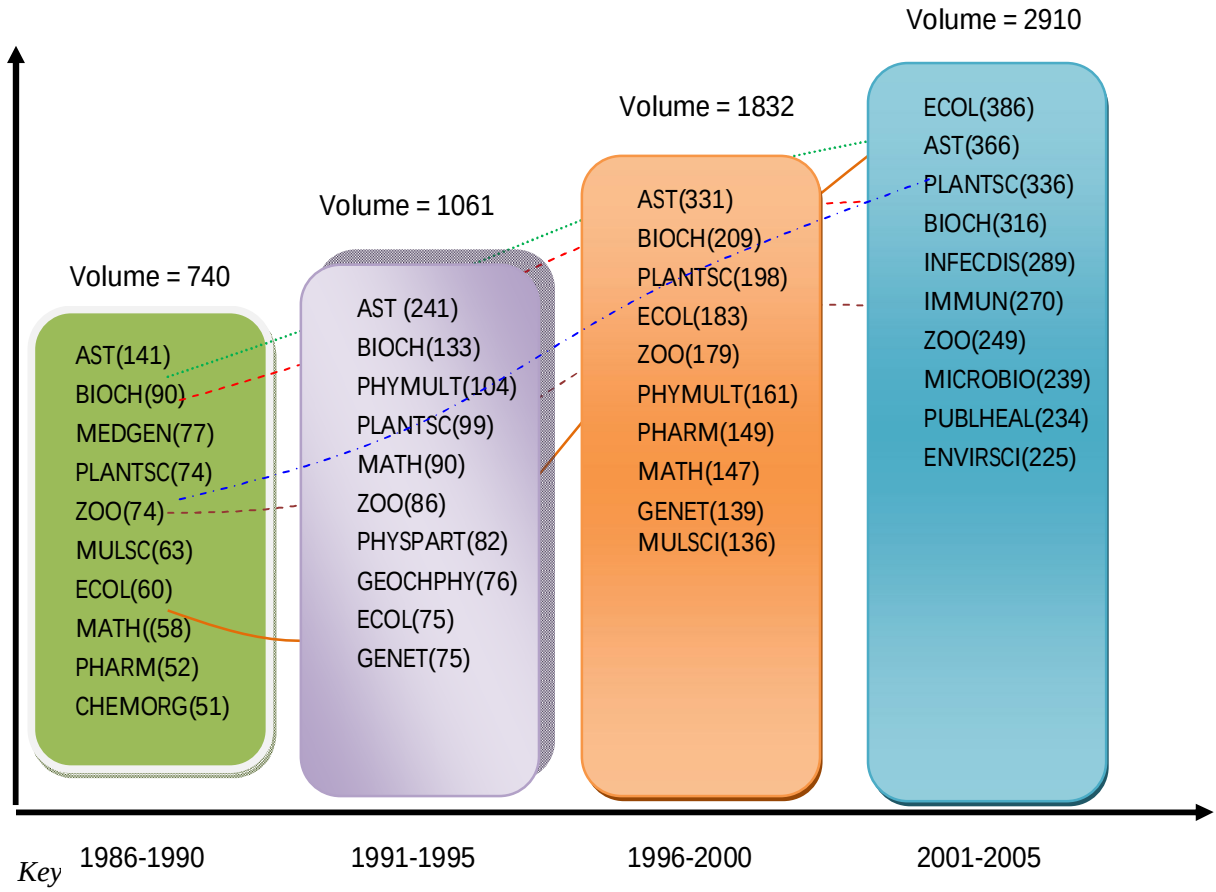

Fig. 3: Shifts in collaboration in selected subject focus areas

Volume: volume of co-published papers in the top 10 subject categories in each year period
Subject categories: *AST* (Astronomy and Astrophysics); *BIOCH* (Biochemistry and Molecular Biology); *MEDGEN* (Medicine, General and Internal); *PLANTSC* (Plant Science); *ZOO* (Zoology); *MULSC* (Multidisciplinary science); *ECOL* (Ecology); *MATH* (Mathematics); *PHARM* (Pharmacology and Pharmacy); *CHEMORG* (Chemistry, Inorganic and Nuclear); *PHYMULT* (Physics, Multidisciplinary); *PHYSPART* (Physics, Particles and Fields); GEOCHPHY (Geochemistry and Geophysics); GENET (Genetics and Heredity); IMMUN (Immunology); MICROBIO (Microbiology); ENVIRSCI (Environmental Science); PUBLHEAL (Public, Environmental and Occupational Health)

None of the patterns above (both continental and outside Africa) reflects South Africa's research output in different subject categories as shown in Sooryamoorthy (2009a). According to Sooryamoorthy's study, the most researched areas in South Africa include: *general and internal medicine*, *plant sciences*, *zoology*, *multidisciplinary sciences*, *ecology*, *biochemistry and molecular biology*, *surgery*, *veterinary sciences*, and *marine and freshwater biology*. It therefore follows that the most productive research area undertaken through collaborative initiatives is not always the most researched subject area in a country. Concerning the shifts of collaboration in the top ranking research areas, Fig. 3 reveals that *astronomy and astrophysics*, which dominated the scene from 1986 to 2000 was ranked in the second position behind *ecology* in the 2001-2005 period. *Ecology* has therefore emerged as the most researched area in South Africa's overall collaborative research. It was ranked in position seven in 1986-1990, 9 in 1991-1995, four in 1996-2000. Other subject areas that have maintained their presence among the 10 top ranking subject categories include: *astronomy and astrophysics*, *biochemistry and molecular biology*, *plant science*, *zoology*, and *ecology*.

Conclusions and Recommendations

Research collaboration between South Africa and other countries has increased since 1986, with most of it being recorded after 1994 when the government of national unity was formed. In fact, the growth pattern of the collaborated publications is exponential. This pattern is likely to persist now that South African scholars are increasingly becoming visible, both continentally and internationally. Onyancha and Ocholla (2007) argue that not only does South Africa continue to attract skilled manpower from other African countries, but the country also boasts a well-developed and quality education system which attracts students, especially at postgraduate level, from neighbouring countries. South African institutions of higher learning continue to dominate various rankings of African research institutions and organisations (cf. the Academic Ranking of World Universities (ARWU) drawn by the Institute of Higher Education of Shanghai Jiao Tong University (http://www.arwu.org/); World University Ranking of the Times Higher drawn in collaboration with a private company QS Quacquarelli Symonds (http://www.topuniversities.com/); World Universities' Ranking on the Web, maintained by Interlab (http://www.webometrics.info/); and of late, SCImago Institutions Ranking (http://www.scimagoir.com/). These rankings may possibly be influencing the decisions by scholars and students from other African states to migrate to South Africa thereby boosting the country's publications output through collaborative research.

The USA continues to top the list of the countries that collaborate with South Africa. Previous studies (e.g. Jacobs, 2008; Molatudi, Molotja and Pouris, 2009; Narvaez-Berthelemot et al., 2002; Onyancha and Ocholla, 2007; Sooryamoorthy, 2009a) indicate that the USA is the leading collaborator with South Africa in various fields. Generally, it was observed that the industrialised nations (or developed countries) contribute the majority of the externally collaborating publications. For instance, the collaborated publications of the leading three countries (i.e. the USA, England and Germany) account for over 60% of the total multiple-country-author papers. This pattern may slightly change as scholars from the rest of Africa are likely to improve South Africa's continental collaboration since some universities in the country are promoting visits by scholars from the continent.

As regards impact, it has been shown that South Africa's external research collaboration yields higher citation impacts than internally collaborated research (Onyancha and Ocholla, 2007; Sooryamoorthy, 2009b). Generally speaking, South Africa's domestic/continental and internal collaboration yields lower citation impact values when compared to internationally collaborated publications. This, in our view, presents a strong case for justifying international collaboration on the part of South African researchers, as in so doing both their international visibility and their citation influence will be improved. Skills and knowledge transfer among the collaborating scientists will also be enhanced.

The similarities and differences in subject focus of continental and international research collaboration were noted in this study. Among the top twenty subject areas that featured in continental collaboration but not in international collaboration are: *tropical medicine*, *agriculture, dairy and animal science*, *food science and technology*, *entomology*, *parasitology*, *meteorology and atmospheric sciences*, and *virology*. These areas may constitute unique but common areas of interest of African researchers. Blignaut (2005) outlines several problems that are characteristically unique to most African countries. The majority of Blignaut's problems fall into the subject categories listed above. It is worth saying therefore that Africa's problems should constitute collaborative research areas of interest among African scholars since research is intended to solve the socio-economic and political problems unique to a particular geographical region. Unfortunately for Africa, most decisions about the subject areas of research collaboration, especially at the international level, are made by foreign countries which fund most research in developing countries. This affects South Africa to an extent. However, South Africa has the potential in terms of the available financial and human resources to dictate the choice of research focus areas for collaboration within and outside Africa. These areas would include those highlighted by Blignaut (2005), such as the following: subsistence agriculture, land productivity, population growth, food production, animal rearing and its effect on limited land, extensive use made of biomass and fuelwood for cooking, heating and lighting purposes, the harvesting of wood for energy purposes leading to the loss in biodiversity, vegetation cover and eventually land degradation and desertification, the consequences of the prevalence and impact of HIV/Aids and the pending land reforms

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