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Country-wise Collaborations in HIV/AIDS Research in Kenya and South Africa, 1980–2005

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This study uses co-word and factor analyses to identify and measure country collaborations between Kenya and South Africa and their respective country collaborators. Using the widely accepted indicator of research collaboration, co-authorship of papers, the study used three measurement indicators, namely, the Eigenvectors/scores, the collaboration coefficients (CC) and the strengths (***S)*** of term association to identify key collaborators and evaluate their degree and strengths of collaboration over time. The influence of research collaboration on research impact in Kenya and South Africa was also explored. Results indicate that the two countries largely collaborate with foreign countries, with the USA emerging as the strongest collaborator. Kenya exhibited stronger links with foreign countries while South Africa had much of its papers published through internal collaborations. There have been shifts in research partnerships in the two countries. From the standpoint of impact, Kenya's papers produced a higher average impact than South Africa's papers. Co-authored papers yielded a higher average impact than the single-authored papers, thereby providing a strong argument for encouraging research collaboration not only within the countries but internationally.

Introduction

Collaboration between individuals, institutions and countries has been increasing steadily for decades, covering different disciplines, development categories, institutions, geographical regions, and countries (Kostoff 2001), all propelled by the notion that "collaboration in research is 'a good thing' that should be encouraged" (Katz & Martin 1997, 1). Rao and Raghavan (2003, 230) observe that collaboration in research has become "inevitable and essential research component of every field" given its numerous benefits that include: enabling researchers to share knowledge, skills and techniques; making it possible to transfer tacit knowledge; providing intellectual companionship; plugging a researcher into a wider network of contacts in the scientific community; and, enhancing the potential visibility of a work (Katz & Martin 1997). In addition, it is believed that conducting research through collaboration sometimes reduces the costs of research (Katz & Martin 1997). Many countries have taken note of these benefits and as a result, some of them have launched initiatives aimed at encouraging and strengthening collaboration among individual researchers. Current trends indicate that securing research grants is to a large extent pegged on whether the intended research would be conducted through collaboration. The growing inter-

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est in research collaboration has also been associated with the widening scope of problems resulting from an increase in research complexity and cost, which suggest or even dictate broad collaborations that increasingly involve both local and international partners (Duque *et al.* undated). Recently, these partners have found a common cause in HIV/AIDS research, largely due to the pandemic nature of the disease.

A study conducted by Macias-Chapula and Mijangos-Nolasco (2002) revealed a high pattern of co-authorship of HIV/AIDS papers in central Africa. The authors noted that 91.54% of the papers were published through collaboration. The study, however, did not identify the collaborating countries, institutions and individuals. Consequently, the authors recommended further research to identify the type of collaboration that was noted in their study. On his part, Cohen (2000) has published a list of the country and institutional HIV/AIDS collaborators in Africa. The extent, degree and strength of HIV/AIDS research collaboration in Africa have however remained unexplored.

Purpose

This work presents preliminary findings of an ongoing study on the trends and patterns of collaboration in HIV/AIDS research in eastern and southern African countries. At this stage, the study focuses on two of the most productive countries in the region, namely Kenya and South Africa and seeks to:

a) identify countries that collaborate with Kenya and South Africa in HIV/AIDS research;

b) measure each collaborating country's contribution in terms of the number of co-authored papers throughout the period of study;

c) compare regional and international collaboration in HIV/AIDS research in Kenya and South Africa;

d) consider each country's degree and strength of collaboration throughout the period;

e) examine the trend of each country's collaboration so as to find out whether or not there has been shifts in HIV/AIDS partnerships between Kenya or South Africa with each of their country collaborators; and

f) examine the influence of research collaboration on research impact using co-authored papers in the two countries.

Method and Materials

Procedure

The study used the widely accepted indicator of research collaboration, i.e. the co-authorship of papers, to measure country-wise HIV/AIDS research collaboration in Kenya and South Africa between 1980 and 2005. Data was extracted from the Thomson Scientific's Science Citation Index (SCI®) and Social Sciences Citation Index (SSCI®) by combining several HIV/AIDS-related keywords and the names of the countries. The search was conducted within the author's address and the keyword fields. In this manner, bibliographic details of the relevant papers produced by and on Kenya or South Africa were extracted for analysis. Using publications count, domestically and internationally co-authored papers and major collaborating countries between 1980 and 2005 were identified.

The counting of country-wise co-authorships considered the co-occurrence of Kenya or South Africa with another country in the address field of each record. A country was counted only once, irrespective of how many times it appeared with Kenya or South Africa in the address field of the same record. For instance, consider the following information extracted from the address field (addresses of collaborating authors) of one record:

C1: Univ British Columbia, Ctr Dis Control, Vancouver, BC V5Z 1M9, Canada

Univ Washington, Dept Obstet & Gynecol, Seattle, WA 98195 USA

Univ Nairobi, Dept Med Microbiol, Nairobi, Kenya

Kenya Med Res Inst, Ctr Microbiol Res, Nairobi, Kenya

Univ Manitoba, Dept Med Microbiol, Winnipeg, MB, Canada

Using the principle of calculating permutations (without repeating any set) and allocating a whole number to each, there are a total of 3 country-wise collaborations, which can be presented as follows:

	Collaborating countries	No. of records
1.	Canada and USA	1
2.	Kenya and Canada	1
3.	Kenya and USA	1

For purposes of conducting this study, only the latter two were selected for analysis, since we were concerned solely with Kenya's or South Africa's collaborators. In order to determine whether or not there has been a shift in both regional and international research partnerships with each of the two countries as well as identifying the principal collaborators, four analytical approaches were adopted:

1. First, co-authored HIV/AIDS papers between Kenya or South Africa and other countries were examined throughout the study period, which was split into 8 three-year periods (except for 2004–2005). We classified co-authored papers into two categories, namely domestic and international co-authorships, for purposes of monitoring partnership shifts both at local and international levels.
2. Secondly, each country's strength of association with Kenya or South Africa was measured using the co-word algorithm in order to determine the strength of their collaborative links with the two countries from 1980 to 2005. Here, the co-occurrence of country names at the authors' address field was used to prepare 2 co-occurrence matrices (one each for Kenya and South Africa) which were in turn used to calculate the strengths of association. A country's research collaboration with Kenya and/or South Africa was deemed stronger if its Strength Sij value was closer to 1.
3. Thirdly, the collaborative co-efficient was calculated in order to measure each country's degree of collaboration with Kenya and/or South Africa. As in 2 above, a country's degree of collaboration in HIV/AIDS research with Kenya and/or South Africa was considered high if its collaboration coefficient (CCij) was closer to 1.
4. Fourthly, as a way of triangulation, data were subjected to factor analysis so as to identify the principal country collaborators with Kenya and South Africa. A country's research collaboration was deemed relatively stronger if its Eigenvector/score was higher than the other countries.

The following is a brief description of the co-word analysis metrics that were used and how data were analyzed through factor analysis.

Co-Word analysis metrics

Two metric measures that have been widely used to measure associations between documents using words, phrases and/or descriptors as units of measurement were used to conduct the study. These measures are the *Inclusion Index* (I_{ij}) and the *Strength* (S_{ij}) *of association*. Whereas the *Inclusion Index* principle was used to measure the degree of collaboration between Kenya and/or South Africa and the respective collaborating countries, the *Strength of Association* was used to measure strengths of the ties between these countries from 1980 to 2005. According to Callon *et al.* (as cited in Coulter, Monarch & Konda 1998, 1209), the inclusion index is limited in that it is not "symmetrical (or bidirectional) and tends to highlight mainly the central poles in a domain and depict their relations with descriptors that occur less frequently". Nevertheless, as noted by Jacobs (2002, 551), the metric "offers a reasonable overview both of the absolute frequency with which particular events [or descriptors] occur, and a directional measure of their co-occurrence". The *Inclusion Index* is defined by Coulter, Monarch and Konda (1998, 1209) and Jacobs (2002) thus:

$$I_{ij} = \frac{c_{ij}}{(\min c_i, c_j)}$$

This function is similar to the formula that is used to calculate collaboration coefficients as a means of measuring the degree of research collaboration. The Collaborative Coefficient (CC), originally introduced by Ajiferuke in 1988 (Rao & Raghavan 2003) is defined as the ratio of the number of collaborative papers (e.g. number of documents in which the country pair [D_i and D_j] appears in the authors' address field) to the total number of papers published in a domain during a fixed period of time. It is expressed thus:

$$\mathrm{CC} = \frac{\textit{Total number of co-authored documents}}{\textit{Total number of documents in a domain}}$$

Hence, we adopted and used the following formula to calculate the collaboration coefficients:

$$CC_{ij} = \frac{c_{ij}}{(c_i, c_j)}, \; 0 \le cc_{ij} \le 1$$

In their critical analysis of the *Strength* (S_{ij}) *of Association*, Coulter, Monarch & Konda (1998, 1209) observe that it (a) does not impose the conceptual inclusion property of the *Inclusion Index* (b) provides an intuitive measure of the strength of association between terms, indicating only that there is some semantic relationship or other (c) is easier to use and understand and (d) it allows associations of both major and minor descriptors and is symmetrical in their relationships. The authors conclude that the metric can be used as the "basis for several complementary measures of interactions of descriptors and descriptor networks in a unified manner" (1998, 1209). It is ex-

Table 1: Publications output in Kenya and South Africa

	1983-1985	1986-1988	1989-1991	1992-1994	1995-1997	1998-2000	2001-2003	2004-2005	TOTAL
Kenya									
Articles by (c_j)	0	13	53	102	110	145	171	120	714
Articles by/on (c_i,c_j)	1	17	65	114	166	213	231	169	976
Percentage (%)	0.00	76.47	81.54	89.47	66.27	68.08	74.03	71.01	73.16
South Africa									
Articles by (c_j)	10	22	68	117	193	415	628	476	1929
Articles by/on (c_i,c_j)	10	24	70	128	210	506	779	586	2313
Percentage (%)	100.00	91.67	97.14	91.41	91.90	82.02	80.62	81.23	83.40

Key: *ci – Refers to articles written by authors whose address bore Kenya or S. Africa as country of affiliation; cj – Refers to articles written concerning HIV/AIDS in Kenya and South Africa by authors (which excludes articles written by Kenyan or S. African authors on HIV/AIDS about other countries other than the two); ci,cj – combines the two and provides the total number of articles written by/in and about Kenya and S. Africa as long as the articles address HIV/AIDS.*

pressed by Krsul (2002) and Coulter *et al.* (1998) as follows:

$$S_{ij} = \frac{c^2_{ij}}{(c_i \cdot c_j)}, 0 \leq s \leq 1$$

Notes: The S_{ij} is the strength of association between the country pair (D_i and D_j) and in which case country D_i is either Kenya or South Africa and country D_j is the collaborating country; CC_{ij} is the collaboration coefficient between the country pair (D_i and D_j); C_{ij} is the number of records in which the country pair (D_i and D_j) appears; C_i is the number of records in which country D_i appears; and C_j is the number of records in which country D_j appears. The appearance of country names was limited to only the authors' addresses field.

Factor Analysis

UCINET version 6 was used to conduct a factor analysis so as to establish the principal collaborating countries with Kenya and South Africa. Factor analysis is a technique that decomposes a matrix into factors using either principal components or minimum residuals methods. In the case of the principal components method, the technique is used to conduct an analysis in which the matrix is factored into a product of the most dominant eigenvectors (Borgatti, Everett & Freeman 2002). In this case, the input data file contained a 2-mode matrix while the analysis yielded the following output files:

1. The number of factors – number of factors into which to decompose the matrix;
2. The factor scores – file containing the factor scores for each actor (i.e. collaborating country) on each factor (i.e. Kenya or South Africa);
3. The factor loadings – file containing the factor loadings for each actor on each factor;
4. The eigenvectors – file containing eigenvalues corresponding to each eigenvector (factor); and
5. The factor score coefficients – file containing the factor coefficients for each actor on each factor.

The Eigenvectors file was used to plot scatter graphs for each factor (i.e. countries – Kenya and South Africa) as well as a cluster diagram as presented in Figures 8, 9, and 10.

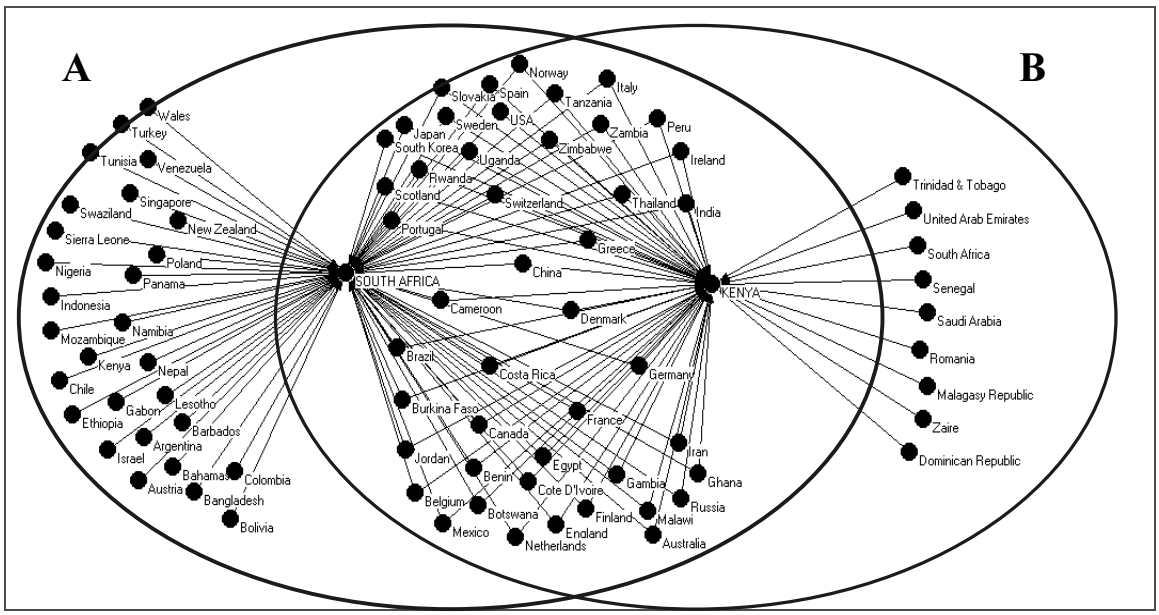
Results and discussion

Results are presented and discussed under seven sub-headings: 1) HIV/AIDS research output in Kenya and South Africa; 2) countries collaborating with Kenya and South Africa; 3) trends of HIV/AIDS research collaboration in Kenya and South Africa; 4) the countries' collaboration coefficients; 5) countries' strengths of collaboration; 6) country collaborators' Eigenvectors/scores; and 7) the influence of research collaboration on research impact.

HIV/AIDS publications output in Kenya and South Africa

Table 1 provides the total number of publications produced on Kenya and South Africa, as well as

Figure 1. Kenya's and South Africa's country collaborators



these countries' publications output between 1980 and 2005. For both countries, the number of records has shown an upward trend since 1983–1985 when Kenya recorded a total of 1 record while South Africa had 10 records. Whereas Kenya's only record, published in 1983–1985, did not involve Kenyan authors, all of South Africa's papers (10 or 100%) involved the participation of authors based in the country. Kenya participated in the publication of 714 (73.16%) out of the total 976 papers produced in and about Kenya, while South Africa's productivity was at 1929 (83.40%) of the total 2313 papers.

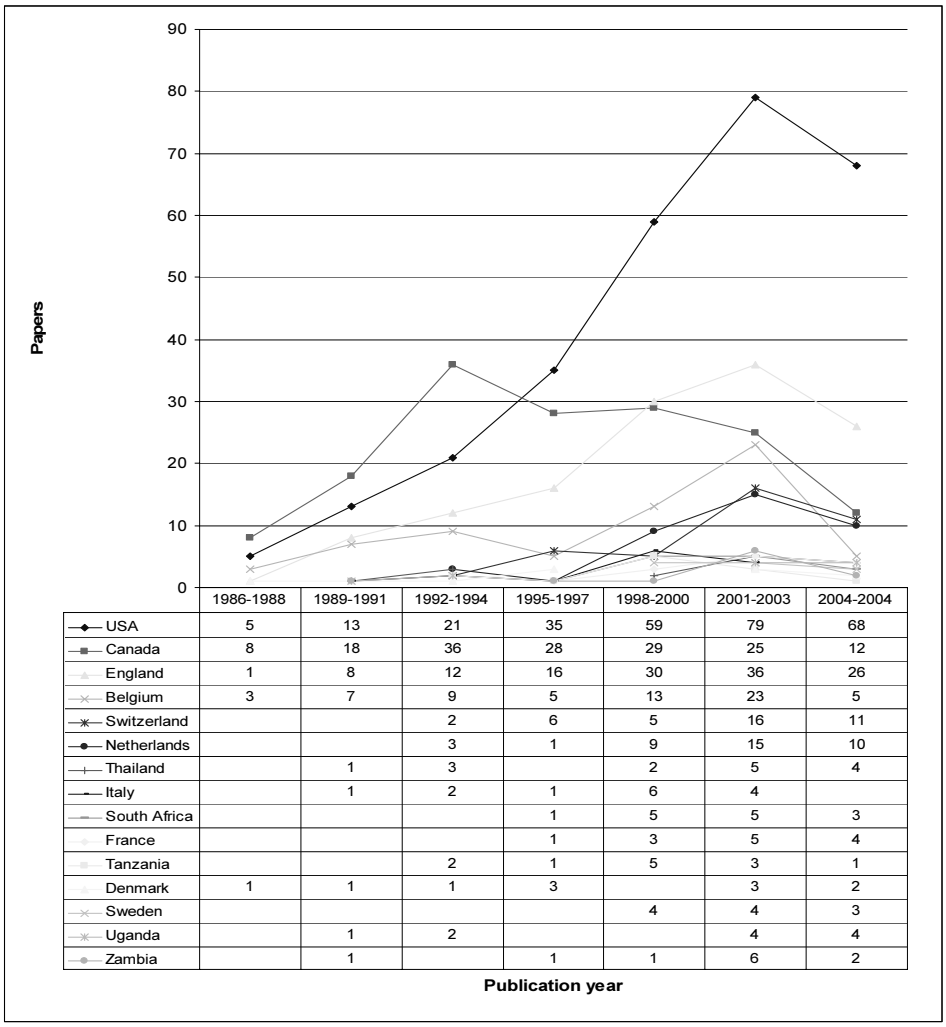
Countries collaborating with Kenya and South Africa

A total of 75 countries co-authored papers with South Africa. This comprised 51 (68%) foreign and 24 (32%) regional (i.e. African) countries. In the case of Kenya, there were a total of 56 countries consisting of 38 (67.9%) foreign and 18 (32.1%) regional countries. Figure 1 shows countries that collaborate with Kenya and/or South Africa. Circle A consists of countries that collaborated with South Africa while Kenya's collaborators are represented in circle B. The intersection of circle A and B consists of countries that collaborated with both South Africa and Kenya.

Trends of HIV/AIDS research collaboration in Kenya and South Africa

When ranked according to the total number of co-authored papers, Kenya's top 10 leading foreign collaborators were the USA (280), Canada (156), England (129), Belgium (65), Switzerland (40), Netherlands (38), Thailand (15), Italy (14), France (12), and Denmark (11). Out of the total 18 regional countries, only South Africa (14), Tanzania (12), Uganda (11), Zambia (11), Cameroon (9), and Zaire (8) featured among the top 20 leading collaborators. Figure 2 shows that Canada maintained the lead amongst international countries from 1986 to 1994, from which point on the USA emerged as the top ranking collaborator. Gabon (1) was the first African country to co-author papers with Kenya. However, this country completely disappeared from Kenya's partners list. Apart from Canada, whose co-authored papers with Kenya have continued to dwindle since 1992–1994's peak, other major collaborators such as the USA and England have continued an upward trend. Seemingly Canada, which dominated the scene and was ranked number one between 1986 and 1994, is gradually disappearing from Kenya's list of key HIV/AIDS research partners. Belgium, Switzerland and the Netherlands have each contributed remarkably towards the country since 1986.

Figure 2: Trends and patterns of co-authored papers between Kenya and the top 15 ranking countries, 1980-2005

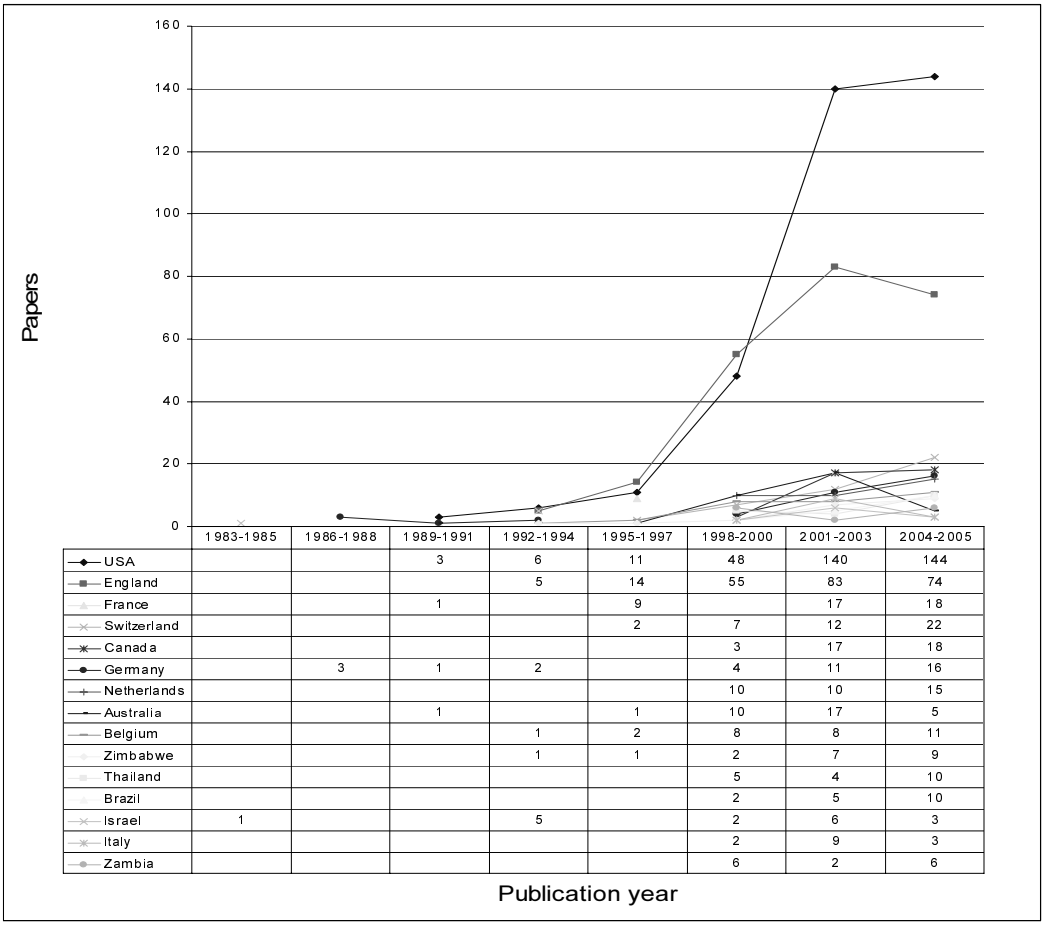


	1986-1988	1989-1991	1992-1994	1995-1997	1998-2000	2001-2003	2004-2004
USA	5	13	21	35	59	79	68
Canada	8	18	36	28	29	25	12
England	1	8	12	16	30	36	26
Belgium	3	7	9	5	13	23	5
Switzerland			2	6	5	16	11
Netherlands			3	1	9	15	10
Thailand		1	3		2	5	4
Italy		1	2	1	6	4	
South Africa				1	5	5	3
France				1	3	5	4
Tanzania			2	1	5	3	1
Denmark	1	1	1	3		3	2
Sweden					4	4	3
Uganda		1	2			4	4
Zambia		1		1	1	6	2

Internationally, South Africa's main partners in the publication of HIV/AIDS research include the USA (352), England (231), France (45), Switzerland (43) Canada (38), Germany (37), Netherlands (35), Australia (30), Belgium (20) and Thailand (19) as shown in Figure 3. A trend analysis indicates that Israel was the first country to enter collaboration with South Africa in 1983–1985. The two countries co-authored one paper. Israel did not collaborate with South Africa again until 1992–1994. Germany (3) was the second foreign country to co-author papers with South Africa. It was actually the only country in 1986-1988. It has maintained a constant appearance since then, except for the year 1995–1997 when it did not participate in any paper co-authorship activities with South Africa. Five foreign countries emerged in 1989–1991, with the USA co-contributing 3 papers, while France, Germany, Australia, Portugal and Mexico each co-published one article each with South Africa. Each succeeding year has seen more countries enter partnerships with South Africa, with the USA leading, except for the periods between 1995–1997 and 1998–2000, when it was ranked second with 11 and 48 records respectively. During these periods, England was the leading collaborator with 14 and 55 co-authored papers. It was observed that Canada, despite its late entry in 1998–2000, was ranked fifth with 3 co-authored papers in 1998–2000, 17 in 2001–2003 and 18 in 2004–2004.

Regionally, South Africa collaborated with 24 countries, Zimbabwe leading with 20 papers, followed by Zambia (14), Kenya (13) and Malawi (12). Zimbabwe was the first regional country to co-author papers with South Africa, and although it appears South Africa's regional partnerships had shifted to Zambia and Kenya by 1998–2000, this movement was temporary, as Zimbabwe gained the lead in the years that followed. Malawi started slowly, and its co-author papers with South Africa

Figure 3: Trends and patterns of co-authored papers between South Africa and the top 15 ranking countries, 1980-2005



	1983-1985	1986-1988	1989-1991	1992-1994	1995-1997	1998-2000	2001-2003	2004-2005
USA			3	6	11	48	140	144
England				5	14	55	83	74
France			1		9		17	18
Switzerland					2	7	12	22
Canada						3	17	18
Germany		3	1	2		4	11	16
Netherlands						10	10	15
Australia			1		1	10	17	5
Belgium				1	2	8	8	11
Zimbabwe				1	1	2	7	9
Thailand						5	4	10
Brazil						2	5	10
Israel	1			5		2	6	3
Italy						2	9	3
Zambia						6	2	6

have continued to increase exponentially. If this trend persists, it is likely that it may become the top collaborator with South Africa.

Country collaborators' collaboration coefficients

Table 2 provides the ratio of each country's co-authored papers with Kenya to the total number of papers produced on and about Kenya. The findings indicate that the top ranked country is the USA, which produced a collaborative coefficient of 0.2869 or 28.69% of Kenya's total publications (i.e. 976), followed by Canada (0.1598 or 15.98%), England (0.1322 or 13.22%), Belgium (0.0666 or 6.66%) and Switzerland (0.0410 or 4.10%). Among top ranked regional country collaborators are South Africa (0.0143 or 1.43%), Tanzania (0.0123 or 1.23%), Uganda (0.0113 or 1.33%), Zambia (0.0113 or 1.113%) and Cameroon (0.0092 or 0.92%). The trend of co-authorship using the collaboration coefficient is similar to the analysis shown above. For instance, results in Table 2 show that the CC for the USA's contributions dropped by 0.0941 in the period 1986–1988, and further by 0.0158 (1.58%) between 1989 and 1991. Thereafter, the USA's collaboration with Kenya grew by 0.0266 (2.66%) and continued to grow up until 2004–2005 when it recorded a remarkable CC of 0.4024 (40.24%). This indicates that over 40% of HIV/AIDS publications produced in and about Kenya were produced in partnership with the USA.

In the case of South Africa (Table 3), the highest CC was recorded by the USA (0.1522 or 15.22%) followed by England (0.0999 or 9.99%), France (0.0195 or 1.95%), Switzerland (0.0186 or 1.86%) and Canada (0.0164 or 1.64%). Zimbabwe topped the list of regional South African country collaborators with a CC of 0.0086 (0.86%) followed by Zambia (0.0061 or 0.61%), Kenya (0.0056 or 0.56%), Malawi (0.0052 or 0.52%), Nigeria (0.0048

Table 2: Kenya's 25 top country collaborators: collaboration coefficients

	1983-1985	1986-1988	1989-1991	1992-1994	1995-1997	1998-2000	2001-2003	2004-2005	TOTAL
USA	0.0000	0.2941	0.2000	0.1842	0.2108	0.3709	0.3420	0.4024	0.2869
Canada	0.0000	0.4706	0.2769	0.3158	0.1687	0.1174	0.1082	0.0710	0.1598
England	0.0000	0.0588	0.1231	0.1053	0.0964	0.1690	0.1558	0.1538	0.1322
Belgium	0.0000	0.1765	0.1077	0.0789	0.0301	0.1080	0.0996	0.0296	0.0666
Switzerland	0.0000	0.0000	0.0000	0.0175	0.0361	0.0751	0.0693	0.0651	0.0410
Netherlands	0.0000	0.0000	0.0000	0.0263	0.0060	0.0704	0.0649	0.0592	0.0389
Thailand	0.0000	0.0000	0.0154	0.0263	0.0000	0.0235	0.0216	0.0237	0.0154
Italy	0.0000	0.0000	0.0154	0.0175	0.0060	0.0188	0.0173	0.0000	0.0143
South Africa	0.0000	0.0000	0.0000	0.0000	0.0060	0.0235	0.0216	0.0178	0.0143
France	0.0000	0.0000	0.0000	0.0000	0.0060	0.0235	0.0216	0.0237	0.0133
Tanzania	0.0000	0.0000	0.0000	0.0175	0.0060	0.0141	0.0130	0.0059	0.0123
Denmark	0.0000	0.0588	0.0154	0.0088	0.0181	0.0141	0.0130	0.0118	0.0113
Sweden	0.0000	0.0000	0.0000	0.0000	0.0000	0.0188	0.0173	0.0178	0.0113
Uganda	0.0000	0.0000	0.0154	0.0175	0.0000	0.0188	0.0173	0.0237	0.0113
Zambia	0.0000	0.0000	0.0154	0.0000	0.0060	0.0282	0.0260	0.0118	0.0113
Cameroon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0329	0.0303	0.0059	0.0092
Japan	0.0000	0.0000	0.0000	0.0088	0.0000	0.0188	0.0173	0.0178	0.0092
Germany	0.0000	0.0000	0.0308	0.0175	0.0000	0.0000	0.0000	0.0178	0.0082
Zaire	0.0000	0.0000	0.0615	0.0351	0.0000	0.0000	0.0000	0.0000	0.0082
Brazil	0.0000	0.0000	0.0154	0.0175	0.0000	0.0094	0.0087	0.0000	0.0061
Ireland	0.0000	0.0000	0.0000	0.0000	0.0000	0.0094	0.0087	0.0059	0.0061
Australia	0.0000	0.0000	0.0000	0.0000	0.0060	0.0047	0.0043	0.0118	0.0051
Benin	0.0000	0.0000	0.0000	0.0000	0.0000	0.0094	0.0087	0.0059	0.0041
Burkina Faso	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0118	0.0041
Finland	0.0000	0.0000	0.0000	0.0000	0.0120	0.0000	0.0000	0.0000	0.0041

or 0.48%), Uganda (0.0039 or 0.39%) and Tanzania (0.0030 or 0.30%). Unlike Kenya whose country collaborators such as the USA, England and Canada had high CCs during the period of study, the collaborators' CCs in South Africa were low. Nevertheless, the countries' CCs demonstrate an upward trend. For example, the USA's CC has increased from 0.0429 in 1989–1991 to 0.2457 in 2004–2005, while England's CC grew by 0.0872 (87.2%) from 0.0391 in 1992–1994 to 0.1263 in 2004–2005. Similar patterns were observed in other countries, an indication of research productivity through collaborations.

Country collaborators' strengths of collaboration

Figures 4 and 5 show the distribution pattern of the strengths S_{ij} of association between Kenya and each of her country collaborators. Figure 4 provides information on international collaboration, while regional collaboration is presented in Figure 5. Both figures indicate a mixture of growth patterns. Internationally, it can be seen that the USA emerged as the strongest collaborator in Kenya after 1995–1996. Prior to this, Canada exhibited strong collaborative links with Kenya having recorded an S_{ij} value of 0.6154 in 1986–1988, 0.2779 in 1989–1991, 0.3434 in 1992–1994 and 0.2160 in 1995–1997, against USA S_{ij} values of 0.3205 in 1986–1988, 0.1993 in 1989–1991, 0.1395 in 1992–1994 and 0.1954 in 1995–1997. By 1998–2000, the two countries had swapped positions and while the USA's strength of association continued to grow, Canada's S_{ij} values were in continued decline. England is slowly emerging as a strong collaborator in Kenya, as illustrated in the growth

Table 3: South Africa's 25 top country collaborators: collaboration coefficients

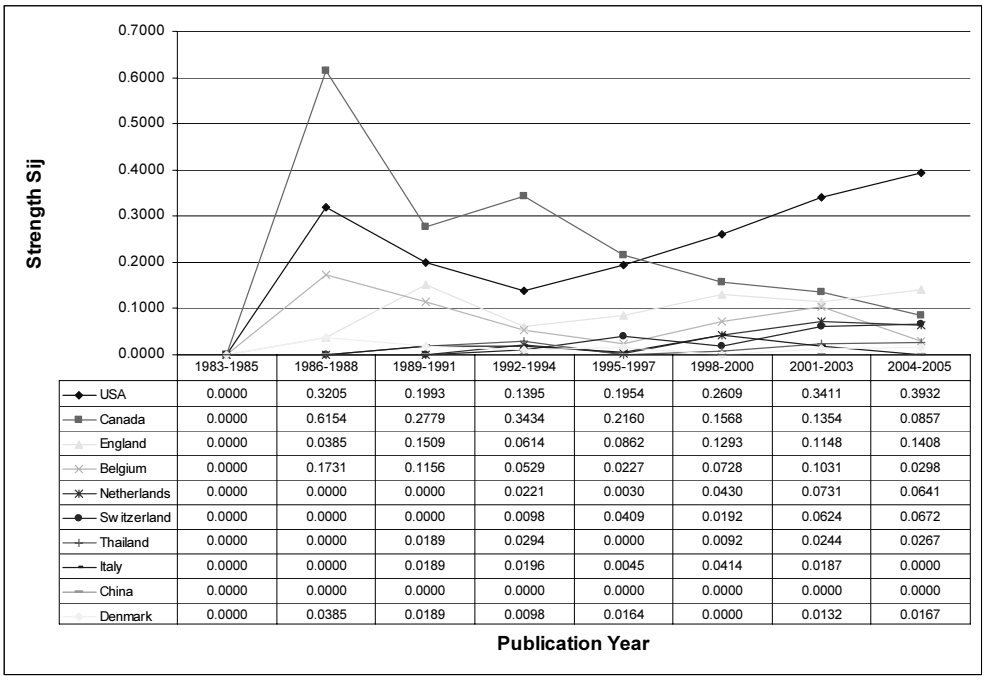
	1983-1995	1986-1988	1989-1991	1992-1994	1995-1997	1998-2000	2001-2003	2004-2005	TOTAL
USA	0.0000	0.0000	0.0429	0.0469	0.0524	0.0949	0.1797	0.2457	0.1522
England	0.0000	0.0000	0.0000	0.0391	0.0667	0.1087	0.1065	0.1263	0.0999
France	0.0000	0.0000	0.0143	0.0000	0.0429	0.0000	0.0218	0.0307	0.0195
Switzerland	0.0000	0.0000	0.0000	0.0000	0.0095	0.0138	0.0154	0.0375	0.0186
Canada	0.0000	0.0000	0.0000	0.0000	0.0000	0.0059	0.0218	0.0307	0.0164
Germany	0.0000	0.1250	0.0143	0.0156	0.0000	0.0079	0.0141	0.0273	0.0160
Netherlands	0.0000	0.0000	0.0000	0.0000	0.0000	0.0198	0.0128	0.0256	0.0151
Australia	0.0000	0.0000	0.0143	0.0000	0.0048	0.0198	0.0218	0.0085	0.0147
Belgium	0.0000	0.0000	0.0000	0.0078	0.0095	0.0158	0.0103	0.0188	0.0130
Zimbabwe	0.0000	0.0000	0.0000	0.0078	0.0048	0.0040	0.0090	0.0154	0.0086
Thailand	0.0000	0.0000	0.0000	0.0000	0.0000	0.0099	0.0051	0.0171	0.0082
Brazil	0.0000	0.0000	0.0000	0.0000	0.0000	0.0040	0.0064	0.0171	0.0073
Israel	0.1000	0.0000	0.0000	0.0391	0.0000	0.0040	0.0077	0.0051	0.0073
Italy	0.0000	0.0000	0.0000	0.0000	0.0000	0.0040	0.0116	0.0051	0.0061
Zambia	0.0000	0.0000	0.0000	0.0000	0.0000	0.0119	0.0026	0.0102	0.0061
Kenya	0.0000	0.0000	0.0000	0.0000	0.0048	0.0079	0.0064	0.0051	0.0056
Malawi	0.0000	0.0000	0.0000	0.0000	0.0000	0.0020	0.0039	0.0137	0.0052
Spain	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0064	0.0119	0.0052
Argentina	0.0000	0.0000	0.0000	0.0000	0.0000	0.0020	0.0039	0.0119	0.0048
Austria	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0103	0.0051	0.0048
Nigeria	0.0000	0.0000	0.0143	0.0000	0.0000	0.0000	0.0051	0.0102	0.0048
Uganda	0.0000	0.0000	0.0000	0.0000	0.0048	0.0000	0.0039	0.0085	0.0039
Scotland	0.0000	0.0000	0.0000	0.0000	0.0000	0.0059	0.0051	0.0017	0.0035
Sweden	0.0000	0.0000	0.0000	0.0078	0.0000	0.0020	0.0026	0.0051	0.0030
Tanzania	0.0000	0.0000	0.0000	0.0078	0.0000	0.0000	0.0039	0.0051	0.0030

of its S_{ij} from 0.0385 in 1986–1988 to 0.1408 in 2004–2005. Her collaborative tie with Kenya is stronger than Canada's which had enjoyed strong ties in the mid 1980s.

Regionally, Cameroon was the top ranked country with an overall S_{ij} value of 0.0113 followed by Tanzania (0.0101), Zaire (0.0090), Zambia (0.0085), South Africa, 0.0076), Uganda (0.0074), Benin (0.0045), Burkina Faso (0.0037), Egypt (0.0032) and Senegal (0.0025). Unlike findings from the analysis on international collaboration, it was observed that no one country in the region (i.e. Africa) had maintained strong collaborative links with Kenya throughout the study period. Nevertheless, it can be seen from Figure 5 that Zaire dominated the scene in 1989–1991 and 1992–1994 with S_{ij} values of 0.0755 and 0.0314 respectively. South Africa's S_{ij} was the highest at 0.0192 in 1998–2001 (it should be noted that this was after its acceptance into the global scientific arena) while Cameroon recorded her highest S_{ij} value of 0.0409 in 2001–2003. Similarly, it was noted that although South Africa led in the total number of co-authored papers with Kenya, it is Cameroon that emerged the leader when considering the strength of association. In fact, South Africa dropped from position one to five.

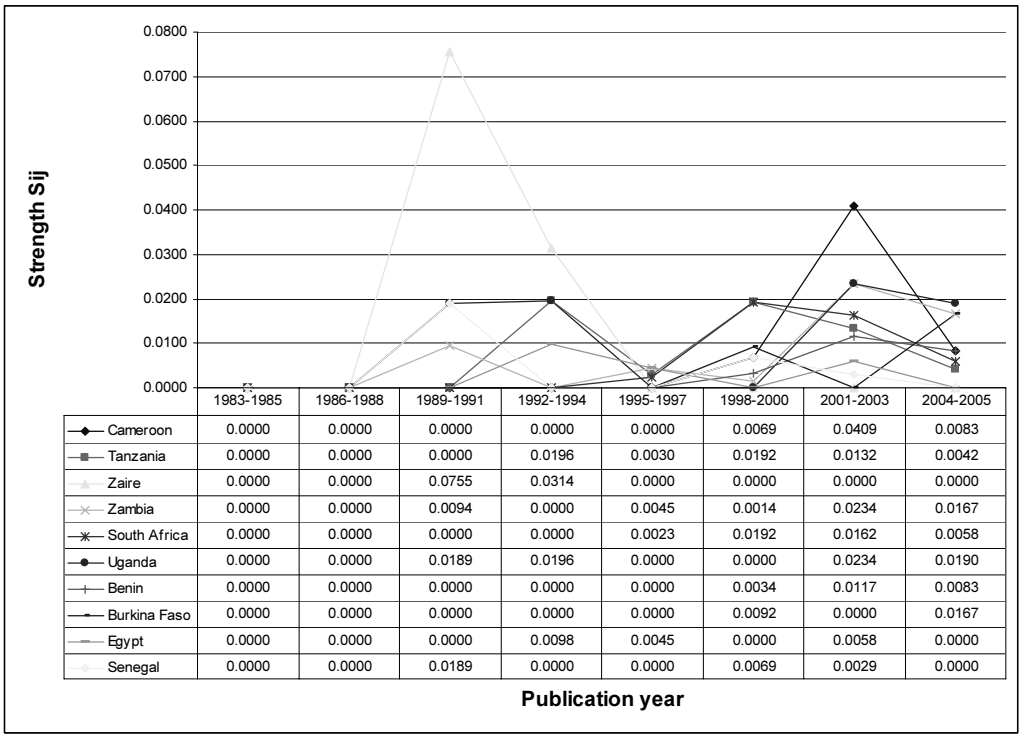
In South Africa, the overall performance of foreign countries according to the strengths of association was as follows: USA (0.1198), England (0.0814), Austria (0.0157), Germany (0.0148), France (0.0144), Switzerland (0.0135), Netherlands (0.0132), Canada (0.0127), Belgium (0.0111), and Australia (0.0097). Whereas Germany (0.1364) was the strongest collaborator with South Africa in 1986–1988, the country's S_{ij} continued to decline

Figure 4: Kenya's top 10 foreign collaborators ranked by the strengths of Association



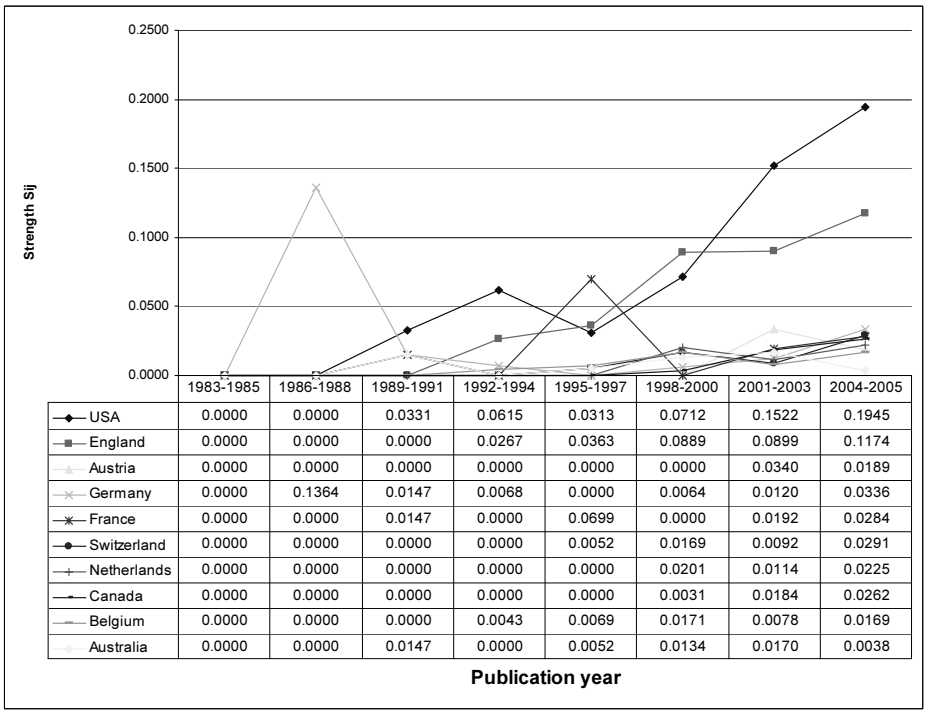
	1983-1985	1986-1988	1989-1991	1992-1994	1995-1997	1998-2000	2001-2003	2004-2005
USA	0.0000	0.3205	0.1993	0.1395	0.1954	0.2609	0.3411	0.3932
Canada	0.0000	0.6154	0.2779	0.3434	0.2160	0.1568	0.1354	0.0857
England	0.0000	0.0385	0.1509	0.0614	0.0862	0.1293	0.1148	0.1408
Belgium	0.0000	0.1731	0.1156	0.0529	0.0227	0.0728	0.1031	0.0298
Netherlands	0.0000	0.0000	0.0000	0.0221	0.0030	0.0430	0.0731	0.0641
Switzerland	0.0000	0.0000	0.0000	0.0098	0.0409	0.0192	0.0624	0.0672
Thailand	0.0000	0.0000	0.0189	0.0294	0.0000	0.0092	0.0244	0.0267
Italy	0.0000	0.0000	0.0189	0.0196	0.0045	0.0414	0.0187	0.0000
China	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Denmark	0.0000	0.0385	0.0189	0.0098	0.0164	0.0000	0.0132	0.0167

Figure 5: Kenya's top 10 regional collaborators ranked by the strengths of Association



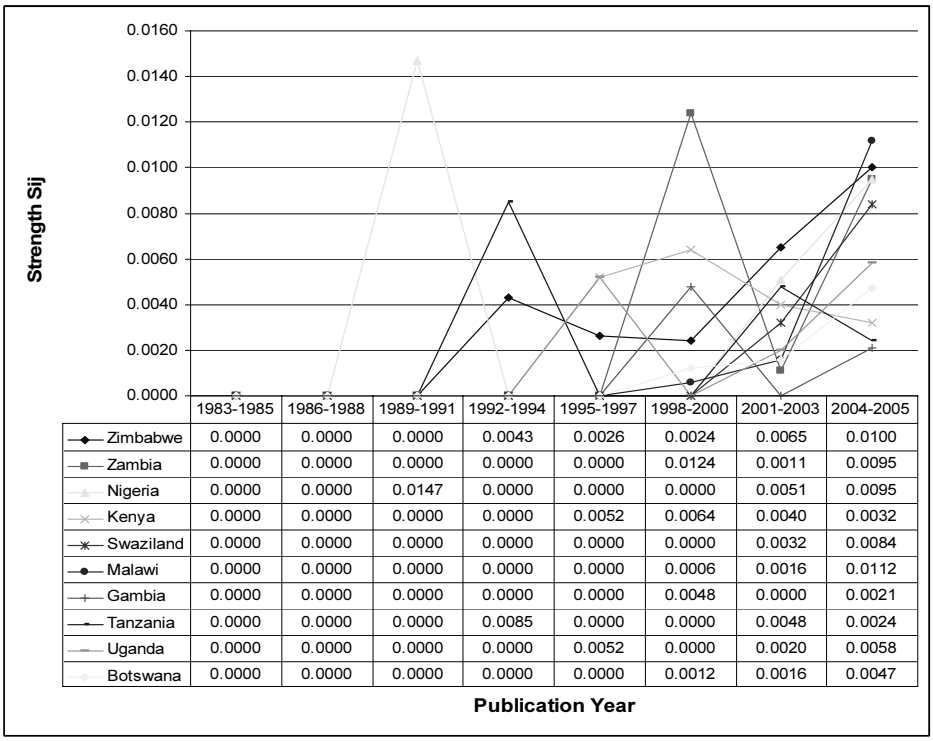
	1983-1985	1986-1988	1989-1991	1992-1994	1995-1997	1998-2000	2001-2003	2004-2005
Cameroon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0069	0.0409	0.0083
Tanzania	0.0000	0.0000	0.0000	0.0196	0.0030	0.0192	0.0132	0.0042
Zaire	0.0000	0.0000	0.0755	0.0314	0.0000	0.0000	0.0000	0.0000
Zambia	0.0000	0.0000	0.0094	0.0000	0.0045	0.0014	0.0234	0.0167
South Africa	0.0000	0.0000	0.0000	0.0000	0.0023	0.0192	0.0162	0.0058
Uganda	0.0000	0.0000	0.0189	0.0196	0.0000	0.0000	0.0234	0.0190
Benin	0.0000	0.0000	0.0000	0.0000	0.0000	0.0034	0.0117	0.0083
Burkina Faso	0.0000	0.0000	0.0000	0.0000	0.0000	0.0092	0.0000	0.0167
Egypt	0.0000	0.0000	0.0000	0.0098	0.0045	0.0000	0.0058	0.0000
Senegal	0.0000	0.0000	0.0189	0.0000	0.0000	0.0069	0.0029	0.0000

Figure 6: South Africa's foreign collaborators: strengths of association



	1983-1985	1986-1988	1989-1991	1992-1994	1995-1997	1998-2000	2001-2003	2004-2005
USA	0.0000	0.0000	0.0331	0.0615	0.0313	0.0712	0.1522	0.1945
England	0.0000	0.0000	0.0000	0.0267	0.0363	0.0889	0.0899	0.1174
Austria	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0340	0.0189
Germany	0.0000	0.1364	0.0147	0.0068	0.0000	0.0064	0.0120	0.0336
France	0.0000	0.0000	0.0147	0.0000	0.0699	0.0000	0.0192	0.0284
Switzerland	0.0000	0.0000	0.0000	0.0000	0.0052	0.0169	0.0092	0.0291
Netherlands	0.0000	0.0000	0.0000	0.0000	0.0000	0.0201	0.0114	0.0225
Canada	0.0000	0.0000	0.0000	0.0000	0.0000	0.0031	0.0184	0.0262
Belgium	0.0000	0.0000	0.0000	0.0043	0.0069	0.0171	0.0078	0.0169
Australia	0.0000	0.0000	0.0147	0.0000	0.0052	0.0134	0.0170	0.0038

Figure 7: South Africa's top 10 regional collaborators ranked by the strengths of association



	1983-1985	1986-1988	1989-1991	1992-1994	1995-1997	1998-2000	2001-2003	2004-2005
Zimbabwe	0.0000	0.0000	0.0000	0.0043	0.0026	0.0024	0.0065	0.0100
Zambia	0.0000	0.0000	0.0000	0.0000	0.0000	0.0124	0.0011	0.0095
Nigeria	0.0000	0.0000	0.0147	0.0000	0.0000	0.0000	0.0051	0.0095
Kenya	0.0000	0.0000	0.0000	0.0000	0.0052	0.0064	0.0040	0.0032
Swaziland	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0032	0.0084
Malawi	0.0000	0.0000	0.0000	0.0000	0.0000	0.0006	0.0016	0.0112
Gambia	0.0000	0.0000	0.0000	0.0000	0.0000	0.0048	0.0000	0.0021
Tanzania	0.0000	0.0000	0.0000	0.0085	0.0000	0.0000	0.0048	0.0024
Uganda	0.0000	0.0000	0.0000	0.0000	0.0052	0.0000	0.0020	0.0058
Botswana	0.0000	0.0000	0.0000	0.0000	0.0000	0.0012	0.0016	0.0047

until it hit zero in 1995–1997, then picked up in 1998–2000 and continued to grow until 2004–2005 when the country recorded a S_{ij} value of 0.0336. Fig. 6 shows that two countries, i.e. USA and England, have emerged as strong collaborators in South Africa. The USA's S_{ij} grew from 0.0331 in 1989–1991 to 0.1945 in 2004–2005 while England's S_{ij} value grew exponentially from 0.000 in 1989–1991 to 0.1174. Other countries recorded similar patterns, although with weaker collaborative links. An analysis of South Africa's regional country collaborators reveal a mixture of patterns of growth: Zimbabwe led with an overall S_{ij} value of 0.0058, followed by Zambia (0.0048), Nigeria (0.0045), Kenya (0.0037), Swaziland (0.0031), Malawi (0.0030), Gambia (0.0028), Tanzania (0.0021), Uganda (0.0020) and Botswana (0.0019). Figure 7 indicates that there are no clear strong collaborator(s) since most countries' S_{ij} values have shown an up/down/up/down pattern of growth. Shifts in terms of partnerships are more clearly visible in Figure 7 than any other illustration in this study. Although there have been cases where some countries have exhibited strong collaborative links, as illustrated by several peak points in Figure 7, the overall performance shows that none of these countries dominated throughout the entire study period. The highest peak indicates that Nigeria was the strongest collaborator in 1989–1991 with a S_{ij} value of 0.0147. The 1992–1994 year period saw the emergence of Tanzania with 0.0085, while Zambia was leading in 1998–2000 with 0.0124. Nigeria, Swaziland and Zimbabwe's S_{ij} have shown remarkable and continued growth since 1998–2000.

Country collaborators' Eigenvectors/scores

Results from the factor analysis revealed similar findings to that of the co-word analysis. In the case of South Africa, the highest Eigenscore was recorded by the USA (6.975), followed by England (4.464), France (0.605), Switzerland (0.563), Canada (0.459), Germany (0.439), Netherlands (0.397) and Australia (0.376). Belgium was number nine with a score of 0.293 followed by Zimbabwe (0.086), Thailand (0.065), Israel (0.024), and Brazil (0.024). Kenya's principal collaborators include the USA (5.811), Canada (3.070), England (2.474), Belgium (1.059), Switzerland (0.507), and Netherlands (0.463).

Figure 8: Scatter graph showing Kenya's country collaborators.

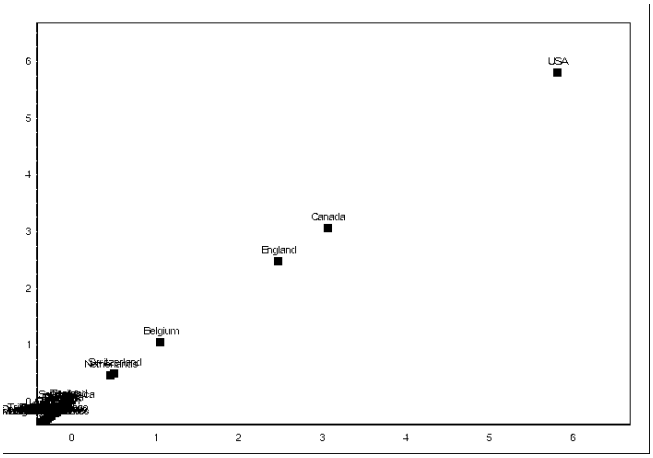


Figure 9: Scatter graph showing S. Africa's country collaborators.

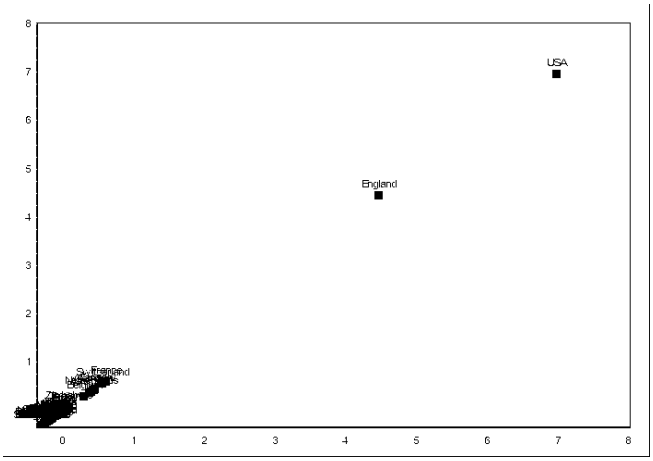
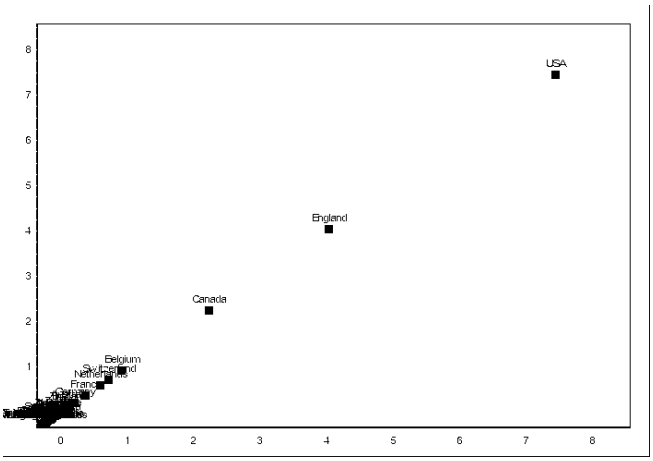


Figure 10: Scatter graph showing Kenya's & S. Africa's combined country collaborators



When the overall collaboration performance of the countries was computed, again, the USA led with an Eigenscore of 7.449 followed by England (4.035), Canada (2.238), Belgium (0.909), Switzer-

Table 4: Influence of research collaboration on research impact in Kenya and S. Africa

Number of Authors	Total Cites		Papers		Cites per paper	
	KEN	SA	KEN	SA	KEN	SA
1	761	1830	104	440	7.32	4.16
2 and more	17593	15053	872	1870	20.18	8.05
TOTAL*	18354	16883	976	2310	18.81	7.31

** Three papers were excluded from the analysis of South Africa's total number of papers because they did not contain names of the authors.*

land (0.714), Netherlands (0.597), France (0.369), Germany (0.211), Australia (0.137), and Thailand (0.105). Figures 8–10 shows each country's collaborative pattern with Kenya (Figure 8), South Africa (Figure 9) and Kenya and South Africa (Figure 10).

Influence of research collaboration on HIV/AIDS research impact

Table 4 compares citations per paper and the nature of authorship (i.e. single- or multiple-authorship) so as to find out whether or not research collaboration leads to high research impact. It was noted that Kenya's 104 single-author papers (one-author papers) received a total of 761 citations, yielding 7.32 citations per paper while South Africa's 440 single-author papers produced 4.16 citations per paper.

Kenya's total multiple-author papers were 872 while South Africa yielded 1870 papers in that category. Their respective total citations totalled 17593 and 15053, thus producing 20.18 (Kenya) and 8.05 (South Africa) citations per paper.

Conclusions and recommendations

The number of countries that collaborate in HIV/AIDS research with Kenya or South has exponentially increased over the last two decades. From just 5 countries in 1986–1988 (in the case of Kenya) and South Africa's one collaborating country each in 1983–1985 and 1986–1988, the number of countries has increased to the current 56 (Kenya) and 75 (South Africa). For South Africa, this figure comprised 51 (68%) and 24 (32%) foreign and regional (i.e. African) countries respectively. In the case of Kenya, the figure consisted of 38 (67.9%) foreign and 18 (32.1%) regional countries. The study's findings concur with what most writers have commonly noted in previous studies, i.e. Less Developed Countries (LDCS) largely collaborate with Developed Countries (DCS). In the case of Africa, it has been shown that countries within the continent publish majority of their publications as a result of international collaboration (Narvaez-Berthelemont *et al.* 2001).

In this study, a relatively high pattern of collaboration was recorded between the two countries and several of the industrialized nations. It was noted that out of Kenya's top 10 ranked collaborators, only one was from the African continent, i.e. South Africa. Kenya's foreign collaborators were, in descending order, the USA, Canada, England, Belgium, Switzerland, Netherlands, and Thailand. Similar findings were found in South Africa, where only one country from Africa (i.e. Zimbabwe) featured in the top 10 ranked countries. All the rest were foreign countries which included the USA, England, France, Switzerland, Canada, Germany, Netherlands, Australia, and Belgium. This pattern has been attributed to the dependence of developing countries on industrialized countries for research publication (Narvaez-Berthelemont *et al*. 2001) [although this applies mostly to the Kenyan situation].

Evidently, the USA has emerged as a strong collaborator in the two countries, particularly since the beginning of the last decade, most probably because of its increased funding of HIV/AIDS research projects in developing countries, in general and in the two countries, in particular. Most countries' research collaboration in Kenya or South Africa has not been consistent, and as regards the strengths of association between Kenya or South Africa and the rest of the world, it was found that Canada, England, Switzerland and the USA have maintained strong relationships with Kenya and South Africa (although the trend has taken an up/down/up/down pattern). In

South Africa, the USA and England have emerged as the only strong collaborators in HIV/AIDS research. But in both cases, it is the USA that has exhibited strong collaborative relationships with the two countries. Her association has grown from strength to strength.

Comparably, regional collaboration is minimal, although with commendable visibility. Seemingly a country's locality and proximity plays an important role in country-wise collaboration. Kenya tends to cooperate more with countries within the eastern Africa region, while South Africa's regional collaborative activities largely involve southern African countries (which were more visible in the country's analysis). With countries in the two regions becoming more attached to regional organizations (SADC, in the case of South Africa and the East African Community for Kenya), this pattern is likely to continue.

Notably, Kenya collaborates with fewer African countries than South Africa. Kenya's regional (i.e. African) collaborators were 18 while South Africa collaborated with 24 African countries. This pattern may be attributed to South Africa's well-developed education, research capacity and institutions which could be attracting researchers from other African countries. For instance, research conducted by students from other African countries but who study in South Africa especially at post-graduate level, is largely published in conjunction with the student's supervisor/study leader. The supervisor/study leader, in this case, is a lecturer/faculty member/academic in one of the universities in South Africa. Another notable observation is that Kenya's collaborative relationship with foreign countries was stronger than South Africa's, a country that appears to be keen on internal co-authorships. This pattern of collaboration on the part of South Africa may have contributed to the country's lower average citation impact (7.31) when compared to Kenya's (18.81). In their study '*How much is a collaboration worth?*' Katz & Hicks (1997) observed that domestic collaboration increases the average impact by approximately 0.75 citations while international collaboration (collaborating with authors from foreign institutions) increases the impact by about 1.6. South Africa's lack of international scientific collaboration and impact and subsequent continued reliance on internal collaboration largely stems from its alienation from social, political and economic activities during the apartheid era. However, the country has achieved remarkable progress in research collaboration since the end of apartheid in 1994.

Overall, the study revealed that there have been shifts in partnerships in HIV/AIDS research on Kenya and South Africa especially with the low ranked countries as illustrated by the countries' shifts in positions or ranks. However, the top-ranked collaborating countries with Kenya and South Africa showed some extent of stability. This whole pattern is likely to continue depending on the collaborating countries' interest in HIV/AIDS research in the two countries. Their interest is likely to be influenced by several factors some of which include satisfactory accountability regarding research grants, strengthening of research institutions which include the institutions of higher learning, the countries' political and economic stability, dependence of these countries on donor funding for HIV/AIDS research, and other factors that influence collaboration between researchers such as personal factors (e.g. trust, expertise, social networks, personal compatibility, common professional traits); resource-related factors (e.g. support from funding agencies, support from scientists' institutions, literature, scientific publishing, students, time); motivational factors (e.g. learning and teaching, new discoveries, fun, external rewards); and "common ground" factors (e.g. physical proximity, research organizations, disciplinary bias, discipline-specific languages, bridges), etc (Maglaughlin & Sonnenwald 2005, 507).

Previous studies have illustrated that country-wise collaboration in HIV/AIDS research in Africa has not been without friction (Cohen 2000). Stresses and strains have characterized most projects undertaken by researchers in Africa, especially in conjunction with foreign colleagues. Cohen (2000) observes that tensions have been especially high with regard to equity (i.e. access to financial resources and facilities, participation, transfer of technology, self-reliance, training opportunities, and credit) and the use of lab facilities by African researchers for personal transactions. Even greater controversy stems from the conflict generated between domestic and international researchers surrounding appropriate ethical research in different countries and geographical regions, especially when conducting HIV trials on hu-

mans. In the words of Silverio (2002: introduction, para 1):

> Questions have arisen regarding how American researchers conduct studies in Africa. This controversy stems from the fact that HIV research on human subjects affects the economic and social welfare of the population under study.

Such situations may cause, or could have caused, some countries to pull out of HIV/AIDS projects in which they had interest in the region, thus the pattern witnessed in this study. Monitoring shifts in HIV/AIDS research partnerships would, in our view, assist in policy formulations especially on the part of regional countries regarding both domestic and foreign collaboration. Regional countries would find it prudent to review their status of research collaboration with countries whose collaborative activities are on the decline. The identification of reasons for such trend patterns would assist in decision-making processes that would lead to well-coordinated research activities. It is also important to monitor shifts in collaboration as such shifts may have an effect on research quality as illustrated by Katz and Hicks (1997).

There is a strong case for promoting not only research collaboration among researchers in Kenya and South Africa but also international collaboration in the region. Table 3 shows that whereas single-author papers produced 7.32 and 4.16 citations per paper, multiple-author papers yielded 20.18 and 8.05 citations per paper for Kenya and South Africa, respectively, implying that Kenya's research impact is almost three times higher when that research is conducted through collaboration while South Africa's research impact of collaboration is double that of single-authorship. Hence, we strongly feel that since research collaboration increases average impact, it should be encouraged. Secondly, international collaboration seems to play a vital role as far as research impact is concerned.

Triangulation offers researchers multiple ways of investigating a problem with a view to comparing results. In that regard, it was observed that results generated from both co-word and factor analyses significantly portrayed similar patterns of collaboration between Kenya or South Africa and each of their country collaborators. Preference of one method over another would, in our view, depend on a researcher's intended study problem and objectives. Indeed, for purposes of conducting this study, the two methods helped to identify the principal collaborating countries with Kenya and South Africa over time. It was nevertheless observed that the results statistically varied. For instance, whereas the USA recorded a strength S_{ij} association of 0.2698 and a CC of 0.2869 in her collaboration with Kenya, her Eigenscore was 5.811. In short, although all the three analytical approaches can be used to determine a country's relationship in research collaboration with other countries, in order to determine how closely associated one country is to another, the strength S of association value is the most valid. However, if the amount of data is large, one is advised to use factor analysis.

Finally, this study has demonstrated the application of informetrics and its several methodologies (including co-word analysis) in research evaluation, an activity that is increasingly becoming a significant role for the library and information science (LIS) profession. Decisions and policies affecting research in a giv-en institution or country can today be made or formulated based on the findings from informetric analyses which have been made easier through the availability of evaluative tools such as online citation indexes and other electronic databases that index published research findings. Almost all academic and research institutions and some countries all over the world have established centres that are charged with the task of planning the monitoring and evaluation of their research output and impact for accountability purposes. This perhaps calls for the popularization of informetrics in our LIS schools in Kenya and South Africa on the one hand and in Africa as a whole, particularly by introducing the course into the LIS curriculum.

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