Research emphasis and collaboration in Africa

Anastassios Pouris[1] and Yuh-Shan Ho[2,*]

[1.] Institute for Technological Innovation, University of Pretoria, Pretoria, South Africa

[2.]Trend Research Centre, Asia University, Taichung 41354, Taiwan

*Corresponding author: e-mail: ysho@asia.edu.tw

Abstract

Scientific co-authorship of African researchers has become a fashionable topic in the recent scientometric literature. Researchers are investigating the effects, modes, dynamics and motives of collaboration in a continental research system which is in an embryonic stage and in different stages of development from country to country. In this article we attempt to provide some additional evidence by examining both patterns of collaboration at country and continental levels and the scientific disciplines emphasised. Our findings indicate that the continent's research emphasises medical and natural resources disciplines to the detriment of disciplines supporting knowledge based economies and societies. Furthermore, we identify that the collaborative patterns in Africa are substantial higher than in the rest of the world. A number of questions related to research collaboration and its effects are raised.

Keywords

Africa; Collaboration; Research; Co-authorship; Scientometrics

Introduction

Research collaboration is a sociological phenomenon that is receiving the attention of researchers and governments internationally (Yeung et al. 2005). Researchers are investigating the effects, modes, dynamics and motives of collaboration, while governments utilise research collaboration as a policy instrument for technology transfer from universities and research councils to industry, for knowledge transfer from abroad, as a means to improve diplomatic relations with other countries by creating goodwill, and to gain political capital (Wagner et al. 2002a). Researchers collaborate with each other for various reasons. This can be to improve their visibility and recognition (Narin et al. 1991), to utilise expensive equipment that is not under their control (Meadows and O'Connor 1971; Schubert and Sooryamoorthy 2010), or to acquire expertise and new ideas (Beaver and Rosen 1978) needed for research.

In the policy domain, scientific collaboration has become an important component of science, technology and innovation policy internationally, with substantial resources being allocated by governments for this objective. Wagner et al. (2002b) estimated that the USA was spending US$3.3 billion in the mid-1990s on international research collaboration.

Similarly, other developed countries were spending substantial amounts as a percentage of their gross domestic product (Wagner et al. 2001). Russell (1995) and Wagner et al. (2001) have suggested that international collaboration is replacing other models as the preferred method of building scientific capacity in developing countries.

While investigations identify the benefits to be derived from collaboration (at least in the currency of science i.e. citations), this collaboration is not without debate related to the risks and benefits of such activities. Arguments expressed include the concern that the spending on international collaboration is not always to the benefit of the paying country and that critical technologies and key knowledge for competitiveness are given away to competitors. Additional concerns have been voiced that collaborative agreements are subordinate to the interests of science and technology to strategic or political ends. Similarly, in the academic domain, researchers have argued that collaboration may be an endogenous self-perpetuating outcome of science, with substantial costs and no commensurate benefits (Jones et al. 2008).

An issue that has received attention and is of importance in the context of Africa is the dependency of the size of collaboration on the size of the scientific community. Narin et al. (1991) found that international co-authorship is higher for scientifically small countries. They argued that scientists in scientifically small countries have far more scientists outside their country with whom to cooperate and far fewer inside their country than scientists in much larger scientific countries do. The argument appeared to be that the collaborative effort is initiated by researchers in small countries who cannot find collaborators.

However, Melin (1999) concluded that "the results indicate that the situation is much more complex than that large country researchers collaborate less internationally than small countries as their scientists more easily can find their partners within the national borders than in smaller countries." Similarly, Boshoff (2009) identified that north–south collaboration takes place in a particular format with the south collaborator basically assisting in fieldwork and data collection. In other words the developed countries' researchers seek collaboration in order to access data and conditions available in the developing countries.

Historically studies on research collaboration were focused on or used data from industrialised countries. More recently, a number of such studies include developing countries in general (Arunachalam and Viswanathan 2008) and African countries (Boshoff 2009; Sooryamoorthy 2009) in particular. Sooryamoorthy (2009) investigated the collaboration patterns of South African researchers and Boshoff (2010) identified the collaborative patterns in the Southern African development community (SADC) countries. Onyancha and Maluleka (2011) found out that knowledge production through collaborative research among sub-Saharan African countries is minimal. Schubert and Sooryamoorthy (2010) showed that "a theory of scientific collaboration building on the notion of marginality and centre-periphery can explain many facets of South African-German collaboration, where South Africa is a semi-peripheral region, a centre for the periphery, and a periphery for the centre".

In the context of African collaboration it should be emphasised that scientometric studies in general and collaboration studies in particular are in an embryonic stage on the African continent. Even South Africa, which is the major producer of research publications on the continent, produces few publications in the field of scientometrics (Pouris 2012).

In this article, the authors use co-authorship analysis to identify the state of research collaboration on the African continent. The questions they attempt to answer are as follows:

- Which scientific disciplines are emphasised in Africa?
- How did research collaboration evolve in Africa during the period 2007–2011?
- Who are the main research partners of African countries?
- Are the patterns of collaboration (extended and disciplinary) in Africa similar to those in the rest of the world?
- How do the various African countries perform in terms of collaboration?
- Which are the main African institutions that are actively engaged in collaboration?

This article goes on to outline the approach the researchers followed and the data sources used. It follows a results and a discussion section and the article ends with conclusions.

Data sources and methodology

Since Price and Beaver (1966) used co-authorship as an indicator of research collaboration, it has become an established method, and a multitude of articles have investigated this phenomenon. The approach has gained popularity, even though it is not without criticism (Katz and Martin 1997; Laudel 2002). In this article we use co-authorship analysis in order to identify the collaborative patterns of African researchers.

Data used in this study was retrieved from the Thomson Reuters Web of Science. Again it should be mentioned that bibliometrics in general and the use of particular databases in particular may have their own shortcomings (Roland 2007; Leydesdorff 2008). For this investigation it may be relevant that African countries may publish their research in local journals and languages which are not covered by the Web of Science. However, we should emphasize that in South Africa the government and the university authorities take actions and provide incentives so the researchers publish in the web of Science indexed journals.

The online version of the Science Citation Index Expanded (SCI-Expanded) was accessed on 18 March 2013. In this study, all journal articles in the SCI-Expanded version that were published by authors on the African continent were selected and analysed in order to identify publishing institutions and countries, and to classify articles as collaborative and single-authored publications. The database was searched using the keywords “Algeria”, “Angola”, “Benin”, “Botswana”, “Burkina Faso”, “Burundi”, “Cameroon”, “Cape Verde”, “Cent Afr Republ”, “Chad”, “Comoros”, “Congo”, “Cote Ivoire”, “Dem Rep Congo”, “Djibouti”, “Egypt”, “Equat Guinea”, “Eritrea”, “Ethiopia”, “Gabon”, “Gambia”, “Ghana”, “Guinea”, “Guinea Bissau”, “Kenya”, “Lesotho”, “Liberia”, “Libya”, “Madagascar”, “Malawi”, “Mali”, “Mauritania”, “Mauritius”, “Morocco”, “Mozambique”, “Namibia”, “Niger”, “Nigeria”, “Rwanda”, “Sao Tome and Prin”, “Senegal”, “Seychelles”, “Sierra Leone”, “Somalia”, “South Africa”, “South Sudan”, “Sudan”, “Swaziland”, “Tanzania”, “Togo”,

"Tunisia", "Uganda", "Western Sahara", "Zambia", "Zimbabwe" and "Zaire" in the address field.

The researchers limited the publication year to between 2007 and 2011, and articles were the only document type considered. Document information such as names of authors, title, year of publication, source journal publishing the articles, contact address, research areas in the Web of Science subject category were downloaded using Microsoft excel. Additional coding was performed manually in order to identify the institutional address of the collaborators.

Affiliations originating from England, Scotland, Northern Ireland and Wales were reclassified as being from the UK (United Kingdom). "Dem Rep Congo" and "Zaire" were reclassified as being from the Democratic Republic of the Congo. Collaboration type was determined by the affiliation of the authors, where the term "internationally collaborative publication" (ICP) was assigned to those articles that were co-authored by researchers from at least two countries. The term "inter-institutionally collaborative publication" was assigned to those articles that were co-authored by researchers from at least two institutions (Li and Ho 2008). The term "institutional independent article" was assigned to articles where the researchers' affiliation was from the same institution. Similarly, the term "African collaborative publication" (ACP) was assigned to articles if authors' affiliations were from different countries on the African continent. The term "outside African continent collaborative publication" (OCP) was assigned if articles were co-authored by authors from Africa and authors from countries outside the African continent. The identified articles were further allocated to the Web of Science subject categories. The journal citation reports (JCR) of 2011 indexes 8,336 journals, classified across 176 web of science categories.

Results and discussion

Language of publication

A total of 112,576 articles were identified. In order to confirm that these articles were published by authors on the African continent, the researchers further examined the affiliations of authors, and excluded articles that were not published by authors in countries on the African continent, which had been accidentally included in the original set. A total of 111,877 articles published by authors in African countries between 2007 and 2011 were therefore analysed. These articles were published in 17 languages, with the majority of them (97 %) being published in English. The non-English language articles were published in French (3,396 articles), German (51), Spanish (39), Portuguese (16), Italian (6), Korean (5), Chinese (4), Russian (3), Arabic (2), Croatian (2), Dutch (2), Japanese (2), Turkish (2), Hungarian (1), Polish (1), and Welsh (1). The importance of the French language was not surprising, since a number of countries on the African continent were French colonies (Chuang et al. 2011).

Output in research areas

Figure 1 shows the distribution of research articles in the various countries. The African publications were allocated to various research areas as categorized in the web of science

categories. Table 1 shows the research areas emphasised in the continent, while Table 2 shows the areas that are underemphasised. These tables also show the number of world publications in the particular fields, the number of African publications, the African share and the activity indices. The activity index characterises the relative research effort a country/region devotes to a given field. It is defined as the country's share in the world's publication output in the given field, divided by the share of the country/region in the world's publication output in all science fields. An index above one means that the region overemphasises the particular field above the world average. An index below one indicates an effort below the world average. An index of one indicates that the region's effort in the particular field corresponds precisely to the world average.

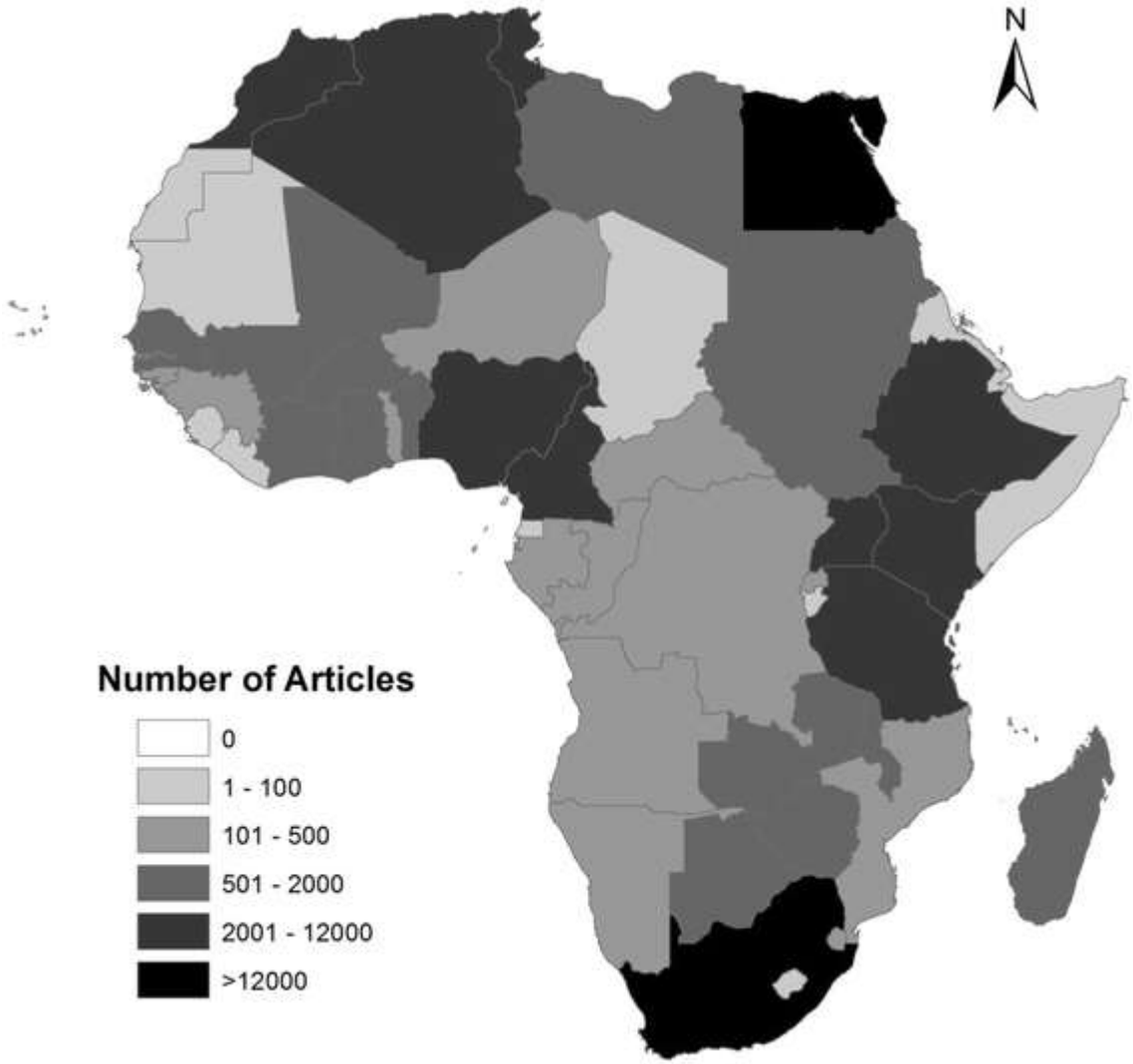

Fig. 1. Distribution of articles published

Table 1. Emphasised African research areas

Research areas	The world	Africa	%	Activity index
Tropical medicine	12,378	3,083	25	13
Parasitology	19,632	2,457	13	6.5
Infectious diseases	48,237	4,380	9.1	4.6
Literature	804	62	7.7	3.9
Integrative and complementary medicine	8,458	634	7.5	3.8
Anthropology	3,930	251	6.4	3.2
Public, environmental and occupational health	73,289	4,181	5.7	2.9
Biodiversity and conservation	16,695	953	5.7	2.9
Water resources	45,377	2,531	5.6	2.8
Entomology	27,051	1,503	5.6	2.8
Virology	28,696	1,587	5.5	2.8
Mineralogy	10,054	531	5.3	2.7
Agriculture	133,673	6,105	4.6	2.3
Plant Sciences	83,768	3,848	4.6	2.3
Mining and mineral processing	10,927	504	4.6	2.3
Mycology	7,778	341	4.4	2.2
Archaeology	2,377	102	4.3	2.2
Food science and technology	81,540	3,390	4.2	2.1
Zoology	56,458	2,279	4.0	2.0
Immunology	89,896	3,394	3.8	1.9
Medical laboratory technology	13,189	503	3.8	1.9
Microbiology	81,321	2,981	3.7	1.9
Veterinary sciences	67,767	2,495	3.7	1.9
Evolutionary biology	24,591	899	3.7	1.9
Biotechnology and applied microbiology	108,945	3,924	3.6	1.8
Forestry	19,401	698	3.6	1.8
Paleontology	11,064	389	3.5	1.8
Environmental sciences and ecology	196,654	6,768	3.4	1.7
Thermodynamics	30,091	1,012	3.4	1.7
Anatomy and morphology	8,338	280	3.4	1.7
Geology	86,994	2,801	3.2	1.6
Life sciences and biomedicine—other topics	39,673	1,259	3.2	1.6
Demography	62	2	3.2	1.6
Women's studies	936	29	3.1	1.6
Marine and freshwater biology	52,464	1,575	3.0	1.5
Crystallography	51,400	1,546	3.0	1.5
Obstetrics and gynecology	46,896	1,400	3.0	1.5
Pharmacology and pharmacy	165,444	4,853	2.9	1.5
Sociology	593	17	2.9	1.5
Nutrition and dietetics	38,840	1,105	2.8	1.4

Research areas	The world	Africa	%	Activity index
Medical ethics	3,404	97	2.8	1.4
General and internal medicine	100,127	2,602	2.6	1.3
Mechanics	70,984	1,841	2.6	1.3
Toxicology	41,595	1,061	2.6	1.3
Energy and fuels	64,345	1,640	2.5	1.3
Pediatrics	61,885	1,521	2.5	1.3
Fisheries	21,795	543	2.5	1.3
Physical geography	17,587	433	2.5	1.3
Mathematics	234,623	5,611	2.4	1.2
Respiratory system	33,092	789	2.4	1.2
Ethnic studies	166	4	2.4	1.2
Polymer science	73,242	1,602	2.2	1.1
Nuclear science and technology	44,050	987	2.2	1.1
Meteorology and atmospheric sciences	45,643	951	2.1	1.1
Reproductive biology	19,454	411	2.1	1.1
Electrochemistry	48,073	977	2.0	1.0
Geochemistry and geophysics	39,154	794	2.0	1.0
Pathology	33,635	671	2.0	1.0
Remote sensing	11,176	225	2.0	1.0
Social sciences—other topics	7,195	144	2.0	1.0
Science and technology—other topics	180,934	3,354	1.9	1.0
Metallurgy and metallurgical engineering	74,295	1,424	1.9	1.0
Spectroscopy	37,743	717	1.9	1.0
Oceanography	26,790	502	1.9	1.0
Construction and building technology	19,630	372	1.9	1.0
Imaging science and photographic technology	8,304	155	1.9	1.0
Legal medicine	6,576	122	1.9	1.0

Table 2. Under-emphasised African research areas

Research areas	The world	Africa	%	Activity index
Chemistry	623,271	11,528	1.8	0.9
Urology and nephrology	45,024	827	1.8	0.9
Health care sciences and services	30,713	546	1.8	0.9
Dermatology	27,952	516	1.8	0.9
Biomedical social sciences	4,024	74	1.8	0.9
Engineering	558,483	9,459	1.7	0.9
Dentistry, oral surgery and medicine	36,438	622	1.7	0.9
Automation and control systems	31,445	530	1.7	0.9
Government and law	874	15	1.7	0.9
Materials science	361,943	5,863	1.6	0.8
Genetics and heredity	79,815	1,315	1.6	0.8

Research areas	The world	Africa	%	Activity index
Astronomy and astrophysics	77,633	1,232	1.6	0.8
Art	546	9	1.6	0.8
Family studies	187	3	1.6	0.8
Otorhinolaryngology	23,397	360	1.5	0.8
Business and economics	22,197	333	1.5	0.8
Rheumatology	18,640	285	1.5	0.8
Allergy	9,165	141	1.5	0.8
Geography	1,811	28	1.5	0.8
Physics	593,653	8,326	1.4	0.7
Education and educational research	15,159	214	1.4	0.7
Urban studies	976	14	1.4	0.7
Surgery	139,516	1,832	1.3	0.7
Research and experimental medicine	59,840	778	1.3	0.7
Instruments and instrumentation	55,371	706	1.3	0.7
Ophthalmology	38,176	515	1.3	0.7
Operations research and management science	33,648	423	1.3	0.7
Behavioral sciences	24,654	312	1.3	0.7
Biochemistry and molecular biology	279,571	3,313	1.2	0.6
Computer science	170,265	2,091	1.2	0.6
Endocrinology and metabolism	67,517	786	1.2	0.6
Hematology	44,092	547	1.2	0.6
Sport sciences	32,560	394	1.2	0.6
Information science and library science	6,058	71	1.2	0.6
Microscopy	4,343	53	1.2	0.6
Communication	674	8	1.2	0.6
Architecture	489	6	1.2	0.6
Optics	103,674	1,126	1.1	0.6
Psychiatry	55,756	640	1.1	0.6
Telecommunications	48,460	511	1.1	0.6
Orthopedics	41,713	463	1.1	0.6
Mathematical and computational biology	23,777	261	1.1	0.6
Social Issues	1,905	21	1.1	0.6
Arts and humanities—other topics	87	1	1.1	0.6
Radiology, nuclear medicine and medical imaging	75,168	760	1.0	0.5
Anesthesiology	17,247	173	1.0	0.5
Emergency medicine	12,628	120	1.0	0.5
Substance abuse	7,750	80	1.0	0.5
Physiology	48,460	453	0.93	0.5
Nursing	26,005	242	0.93	0.5
Acoustics	19,411	180	0.93	0.5
Cardiovascular system and cardiology	106,760	964	0.90	0.5

Research areas	The world	Africa	%	Activity index
Rehabilitation	16,268	141	0.87	0.4
Gastroenterology and hepatology	49,125	420	0.85	0.4
Transportation	13,596	115	0.85	0.4
Transplantation	22,339	179	0.80	0.4
Oncology	123,272	959	0.78	0.4
Neurosciences and neurology	216,089	1,459	0.68	0.3
Robotics	5,615	38	0.68	0.3
Audiology and speech-language pathology	7,006	45	0.64	0.3
Biophysics	55,541	340	0.61	0.3
History and philosophy of science	6,749	41	0.61	0.3
Cell biology	101,734	561	0.55	0.3
Psychology	40,044	221	0.55	0.3
Medical informatics	8,938	48	0.54	0.3
Mathematical methods in social sciences	6,290	32	0.51	0.3
Linguistics	1,454	7	0.48	0.2
Developmental biology	18,645	88	0.47	0.2
Philosophy	1,384	6	0.43	0.2
Geriatrics and gerontology	16,030	63	0.39	0.2
Music	375	1	0.27	0.1

Table 1 shows that the most emphasised research fields are those of tropical medicine (12.5 times bigger than that expected from the scientific size of Africa), parasitology (6.5 times bigger) and infectious diseases (4.6 times bigger). The list of emphasised research areas are dominated by medical and natural resources fields (biodiversity, water resources, entomology, mining, etc.).

Table 2 shows the research areas that are underemphasised in Africa. The list includes areas underpinning modern technologies and economies (i.e. engineering, physics, chemistry, materials science, instrumentation and similar research areas). In contrast it should be mentioned that China, which probably has the most directed scientific system, emphasises engineering, physics and chemistry (National Science Board 2010). The obvious question is why Africa does not follow international examples? It is interesting and debatable to consider whether Africa's needs are served best by the current emphasis. The argument is that the small research community and activity on the continent will not be able to resolve current scientific challenges, such as the HIV/AIDS pandemic. If the regional capacity is not able to provide a scientific or technological solution to a challenge, overemphasis to particular disciplines will not be fruitful. Similarly, while internationally the effort is to develop high technology industries based on brain power, African countries ignore these trends. Hence, the argument can be developed that it may be preferable to move away from expensive fields like medicine and focus on wealth-creating disciplines that may require less investment and may be easier to be diffused in the economy and society.

Characteristics of collaborative publication outputs

Figure 2 shows the growth in single-country articles and internationally collaborative articles from the African continent. During the five-year period, the number of articles increased by 50 %. The single-country articles increased by 35 %, while the internationally collaborative articles grew by 66 %—almost twice the growth of the single-country articles. It is interesting to compare the share of internationally collaborative articles from Africa (54 % of 111,877 articles) with those in other countries during the period 2007–2011. A comparison of publications and collaborations in the top 20 prolific countries in the world is shown in Table 3. A total of 5,114,346 articles were published in SCI-Expanded version over the same period. The BRIC members, which include Brazil (26 %), Russia (33 %), India (20 %), and China (23 %), had relatively similar percentages of internationally collaborative articles. Higher percentages could be found in the G7 countries, including the USA (33 %), Germany (51 %), Japan (26 %), the UK (54 %), France (52 %), Italy (44 %), and Canada (49 %).

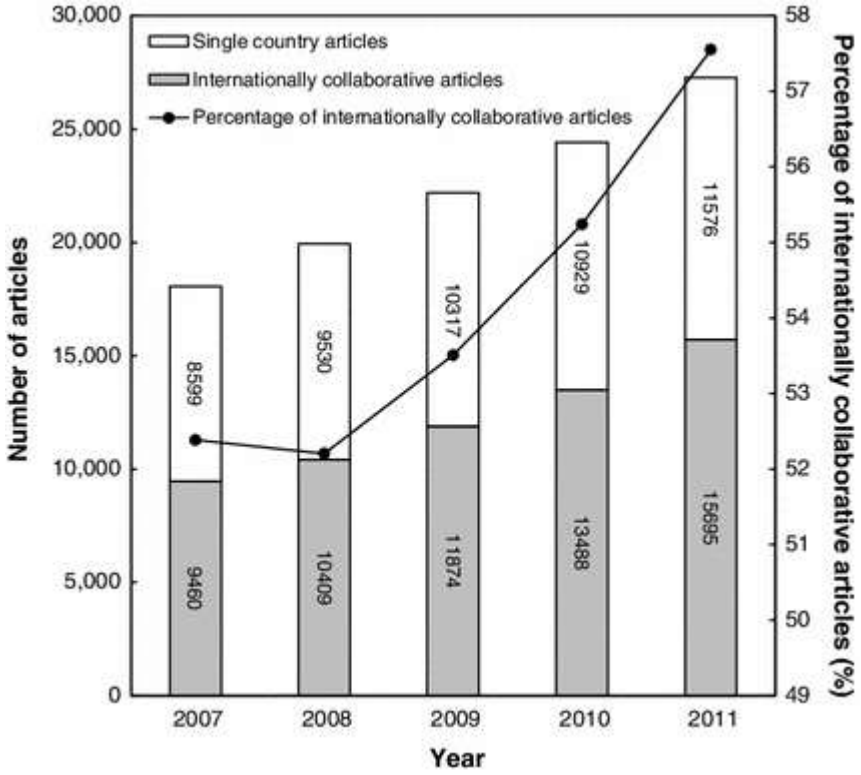

Fig. 2. Growth in African collaboration: 2007–2011

Table 3. Collaborative Patterns of the top 20 productive countries (2007–2011 in SCI-Expanded)

Country	Total articles (% of the world)	IP (% of a country)	ICP (% of a country)
USA	1,377,409 (27)	921,697 (67)	455,712 (33)
China	609,146 (12)	469,411 (77)	139,735 (23)
Germany	386,163 (7.6)	188,830 (49)	197,333 (51)
Japan	363,394 (7.1)	269,136 (74)	94,258 (26)
UK	362,217 (7.1)	168,412 (46)	193,805 (54)
France	283,128 (5.5)	134,793 (48)	148,335 (52)
Italy	226,000 (4.4)	126,788 (56)	99,212 (44)
Canada	224,989 (4.4)	115,556 (51)	109,433 (49)
India	190,070 (3.7)	151,389 (80)	38,681 (20)
Spain	188,464 (3.7)	103,978 (55)	84,486 (45)
South Korea	180,047 (3.5)	131,826 (73)	48,221 (27)
Australia	153,574 (3.0)	78,101 (51)	75,473 (49)
Brazil	140,722 (2.8)	103,731 (74)	36,991 (26)
Russia	131,586 (2.6)	88,485 (67)	43,101 (33)
Netherlands	121,934 (2.4)	53,964 (44)	67,970 (56)
Taiwan	109,105 (2.1)	85,455 (78)	23,650 (22)
Turkey	97,418 (1.9)	81,078 (83)	16,340 (17)
Switzerland	94,797 (1.9)	31,210 (33)	63,587 (67)
Poland	88,638 (1.7)	58,232 (66)	30,406 (34)
Sweden	85,693 (1.7)	35,250 (41)	50,443 (59)

IP single-country articles; *ICP* internationally collaborative articles

However, as shown in Table 4, the individual African countries exhibit substantially higher collaboration patterns. Nigeria was the only country with a collaboration rate lower than 50 %. Twenty-nine countries published more than 90 % of their articles in collaboration with other countries. It is possible that the division of the continent into 54 countries may be a contributor to the substantial number of collaborative articles but other factors may also affect the apparent pattern.

Table 4. Structure of research collaboration in African countries

Country	Total articles	IP (%)	ICP (%)	OCP (%)	ACP (%)	SP (%)
South Africa	29,473	13,743 (47)	15,730 (53)	14,585 (49)	1,145 (3.9)	2,493 (8.5)
Egypt	24,126	13,726 (57)	10,400 (43)	10,247 (42)	153 (0.63)	3,853 (16)
Tunisia	11,507	5,806 (50)	5,701 (50)	5,552 (48)	149 (1.3)	391 (3.4)
Nigeria	9,664	6,887 (71)	2,777 (29)	2,228 (23)	549 (5.7)	900 (9.3)
Algeria	7,391	3,025 (41)	4,366 (59)	4,269 (58)	97 (1.3)	404 (5.5)
Morocco	6,153	2,447 (40)	3,706 (60)	3,595 (58)	111 (1.8)	226 (3.7)
Kenya	4,480	731 (16)	3,749 (84)	3,483 (78)	266 (5.9)	97 (2.2)
Cameroon	2,483	518 (21)	1,965 (79)	1,734 (70)	231 (9.3)	85 (3.4)

Country	Total articles	IP (%)	ICP (%)	OCP (%)	ACP (%)	SP (%)
Uganda	2,411	373 (15)	2,038 (85)	1,901 (79)	137 (5.7)	73 (3.0)
Tanzania	2,354	330 (14)	2,024 (86)	1,904 (81)	120 (5.1)	86 (3.7)
Ethiopia	2,350	688 (29)	1,662 (71)	1,545 (66)	117 (5.0)	156 (6.6)
Ghana	1,700	437 (26)	1,263 (74)	1,182 (70)	81 (4.8)	63 (3.7)
Senegal	1,293	204 (16)	1,089 (84)	985 (76)	104 (8.0)	22 (1.7)
Sudan	1,063	333 (31)	730 (69)	688 (65)	42 (4.0)	49 (4.6)
Malawi	1,059	144 (14)	915 (86)	808 (76)	107 (10)	27 (2.5)
Burkina Faso	1,008	86 (8.5)	922 (91)	836 (83)	86 (8.5)	15 (1.5)
Zimbabwe	1,007	165 (16)	842 (84)	663 (66)	179 (18)	40 (4.0)
Cote d Ivoire	936	269 (29)	667 (71)	632 (68)	35 (3.7)	15 (1.6)
Benin	852	109 (13)	743 (87)	661 (78)	82 (10)	14 (1.6)
Madagascar	782	68 (8.7)	714 (91)	703 (90)	11 (1.4)	11 (1.4)
Zambia	739	41 (5.5)	698 (94)	658 (89)	40 (5.4)	18 (2.4)
Botswana	721	191 (26)	530 (74)	392 (54)	138 (19)	75 (10)
Libya	613	179 (29)	434 (71)	371 (61)	63 (10)	53 (8.6)
Mali	538	32 (5.9)	506 (94)	479 (89)	27 (5.0)	8 (1.5)
Mozambique	492	21 (4.3)	471 (96)	437 (89)	34 (6.9)	8 (1.6)
Gabon	433	16 (3.7)	417 (96)	399 (92)	18 (4.2)	9 (2.1)
Congo	384	29 (7.6)	355 (92)	322 (84)	33 (8.6)	11 (2.9)
Gambia	384	21 (5.5)	363 (95)	357 (93)	6 (1.6)	5 (1.3)
Niger	371	28 (7.5)	343 (92)	283 (76)	60 (16)	5 (1.3)
Namibia	349	39 (11)	310 (89)	261 (75)	49 (14)	19 (5.4)
Democratic Republic of the Congo	310	20 (6.5)	290 (94)	276 (89)	14 (4.5)	5 (1.6)
Rwanda	275	15 (5.5)	260 (95)	235 (85)	25 (9.1)	7 (2.5)
Mauritius	249	90 (36)	159 (64)	149 (60)	10 (4.0)	17 (6.8)
Togo	231	54 (23)	177 (77)	154 (67)	23 (10)	5 (2.2)
Swaziland	152	29 (19)	123 (81)	79 (52)	44 (29)	14 (9.2)
Angola	116	4 (3.4)	112 (97)	106 (91)	6 (5.2)	1 (0.86)
Seychelles	112	4 (3.6)	108 (96)	106 (95)	2 (1.8)	3 (2.7)
Guinea Bissau	111	2 (1.8)	109 (98)	109 (98)	0 (0)	1 (0.90)
Guinea	109	4 (3.7)	105 (96)	99 (91)	6 (5.5)	1 (0.92)
Central African Republic	105	7 (6.7)	98 (93)	87 (83)	11 (10)	0 (0)
Mauritania	86	4 (4.7)	82 (95)	57 (66)	25 (29)	5 (5.8)
Eritrea	86	8 (9.3)	78 (91)	77 (90)	1 (1.2)	2 (2.3)
Lesotho	83	7 (8.4)	76 (92)	45 (54)	31 (37)	2 (2.4)
Sierra Leone	79	8 (10)	71 (90)	63 (80)	8 (10)	2 (2.5)
Chad	73	5 (6.8)	68 (93)	60 (82)	8 (11)	4 (5.5)
Burundi	67	1 (1.5)	66 (99)	64 (96)	2 (3.0)	1 (1.5)
Cape Verde	30	0 (0)	30 (100)	30 (100)	0 (0)	0 (0)
Djibouti	26	3 (12)	23 (88)	22 (85)	1 (3.8)	3 (12)
Liberia	23	0 (0)	23 (100)	22 (96)	1 (4.3)	1 (4.3)

Country	Total articles	IP (%)	ICP (%)	OCP (%)	ACP (%)	SP (%)
Comoros	20	0 (0)	20 (100)	16 (80)	4 (20)	1 (5.0)
Equatorial Guinea	18	0 (0)	18 (100)	18 (100)	0 (0)	0 (0)
Somalia	8	0 (0)	8 (100)	6 (75)	2 (25)	0 (0)
Sao Tomé and Principe	7	0 (0)	7 (100)	7 (100)	0 (0)	0 (0)
Western Sahara	1	0 (0)	1 (100)	1 (100)	0 (0)	0 (0)

IP single-country articles; *ICP* articles published by multiple countries; *OCP* articles published in collaboration with countries outside the African continent; *ACP* articles published in collaboration with countries on the African continent only; *SP* single-author articles; *%* percentage of articles in a country

To summarise, on the African continent, internationally collaborative articles grew from 52 to 58 % over the 2007–2011 period. Internationally, articles that list institutions from more than one country, i.e. internationally co-authored articles, also grew dramatically, but only from 10 to 24 % over the 1990–2010 period (National Science Board 2012).

The authors have already referred to the finding that international co-authorship is higher for scientific small countries. However, it is important from a policy perspective to identify the benefits or otherwise of international collaboration on the African continent. Does the African agenda direct the collaborative research agenda or is collaboration directed by international imperatives?

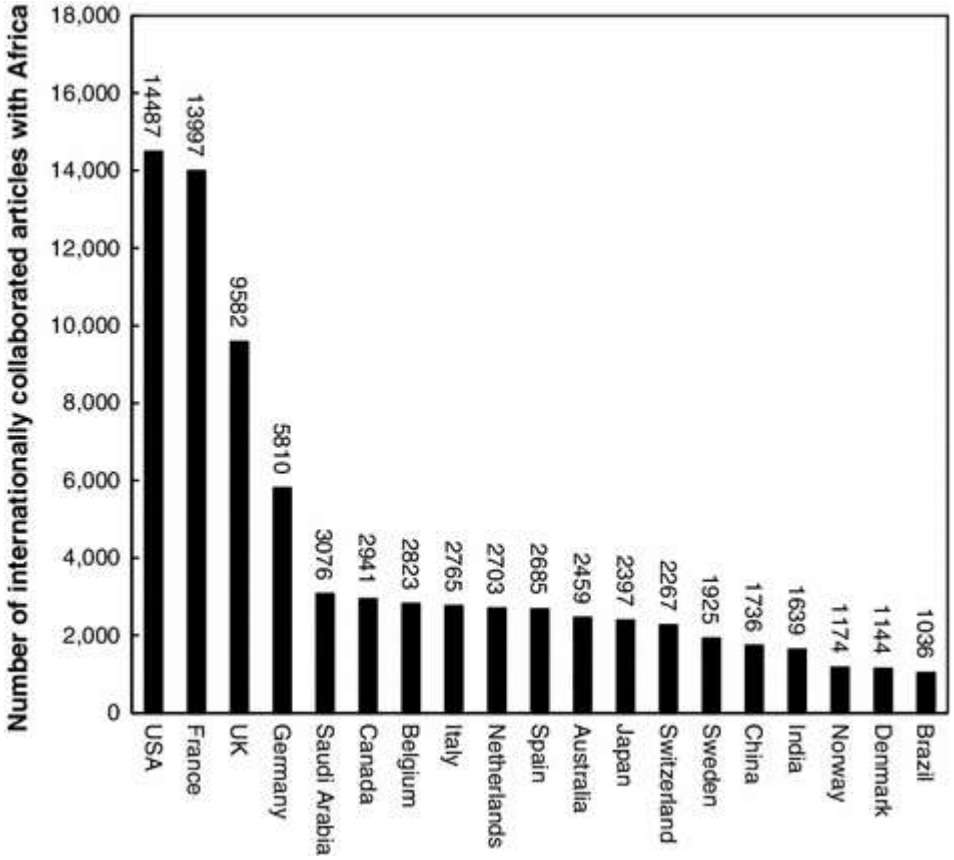

Fig. 3. Main collaborating countries with Africa 2007–2011

Figure 3 shows the main countries collaborating with Africa. The USA, France and the UK are the main collaborating partners, which produce many more publications with authors from Africa than other countries do. It is important to note that these countries are the most collaborative countries in the world (National Science Board 2012). The three countries (USA, France, and UK) are also the largest funders of research in biosciences, with more emphasis on medicines and agricultural sciences, in Africa.

Table 4 shows the collaborative patterns of individual countries in Africa. The table shows the number of articles produced by individual countries over the 2007–2011 period, the share of articles co-authored internationally (ICP), the share of single-authored articles (SP), the share of articles co-authored with at least one author outside the African continent (OCP) and the share of articles co-authored with authors on the African continent (ACP).

The SP column is informative. Egypt and Botswana had the highest share of single-authored articles (16 and 10 % respectively). The share of single-authored articles is very small (a single-digit number for most countries). As these figures cover all scientific disciplines (those that may need collaboration and those that do not), this can raise the question as to whether there is a scarcity of researchers on the continent that are able to undertake research on their own. The ICP column shows that, with the exception of Nigeria (29 %) and Egypt (43 %), all other countries produce more collaborative articles with co-authors from other countries than with local co-authors.

It is important to note that the number of OCP articles is many times bigger than the ACP articles. What drives researchers, say in Botswana and Zimbabwe, to produce more than 74 % of their collaborative publications outside Africa? South African universities are a few hours away by car. Europe and the USA are a number of hours away by plane. Similarly, why does Egypt collaborate almost exclusively with non-African countries? It may be argued that African collaboration is not driven by local researchers searching for collaborators, but by the availability of resources and interests outside the continent.

Table 5 identifies the most prolific institutions on the African continent and the structure of their publications for the period 2007–2011. Egyptian (9) and South African (7) institutions dominate the list. Nigeria, Uganda, Tunisia and Ethiopia also appear in the list. All institutions have a larger number of inter-institutional collaborative articles than single-institution articles.

SP single-author articles; *IP* single-institution articles; *ICP* articles published by multiple institutions; *OCP* articles published in collaboration with institutions outside the African continent; *ACP* articles published in collaboration with institutions on the African continent only; *%* percentage of articles in an institution

It should be emphasised that in South Africa, the funding system of universities—where universities are subsidised by the government according to the number of publications produced by their members of staff (Pouris 1991)—is a disincentive to inter-institutional collaboration. Collaborating institutions have to share the government subsidy.

Table 5. Most prolific institutions in Africa and their collaborative patterns (2007–2011)

Institution	Total articles	SP (%)	IP (%)	ICP (%)	OCP (%)	ACP (%)
University of Cape Town, South Africa	5,454	302 (5.5)	994 (18)	4,460 (82)	3,283 (60)	107 (2.0)
Cairo university, Egypt	4,151	422 (10)	1,212 (29)	2,939 (71)	1,573 (38)	12 (0.29)
University of the Witwatersrand, South Africa	3,955	364 (9.2)	996 (25)	2,959 (75)	2,080 (53)	98 (2.5)
University of Stellenbosch, South Africa	3,884	193 (50)	1,030 (27)	2,854 (73)	1,819 (47)	82 (2.1)
University of Pretoria, South Africa	3,790	232 (6.1)	1,158 (31)	2,632 (69)	1,557 (41)	184 (4.9)
University of KwaZulu-Natal, South Africa	3,413	290 (8.5)	1,011 (30)	2,402 (70)	1,654 (48)	134 (3.9)
Ain Shams university, Egypt	2,664	369 (14)	869 (33)	1,795 (67)	938 (35)	15 (0.56)
National research centre, Egypt	2,659	141 (5.3)	917 (34)	1,742 (66)	824 (31)	27 (1.0)
Mansoura university, Egypt	1,926	278 (14)	823 (43)	1,103 (57)	723 (38)	5 (0.26)
University of Alexandria, Egypt	1,852	315 (17)	657 (35)	1,195 (65)	844 (46)	23 (1.2)
University Ibadan, Nigeria	1,537	93 (6.1)	447 (29)	1,090 (71)	396 (26)	105 (6.8)
Makerere university, Uganda	1,347	40 (3.0)	151 (11)	1,196 (89)	1,014 (75)	64 (4.8)
Assiut university, Egypt	1,267	173 (14)	410 (32)	857 (68)	591 (47)	1 (0.079)
Rhodes university, South Africa	1,204	71 (5.9)	416 (35)	788 (65)	501 (42)	61 (5.1)
Suez canal university, Egypt	1,165	140 (12)	246 (21)	919 (79)	702 (60)	8 (0.69)
Faculté des Sciences de Tunis, Tunisia	1,135	26 (2.3)	230 (20)	905 (80)	580 (51)	23 (2.0)
Al Azhar university, Egypt	1,062	110 (10)	220 (21)	842 (79)	429 (40)	2 (0.19)
Zagazig university, Egypt	1,061	152 (14)	378 (36)	683 (64)	411 (39)	9 (0.85)
University of Johannesburg, South Africa	1,015	80 (7.9)	331 (33)	684 (67)	448 (44)	21 (2.1)
University of Addis Ababa, Ethiopia	936	56 (6.0)	178 (19)	758 (81)	540 (58)	28 (3.0)

The high share of inter-institutional collaborative articles from South African universities indicates that the forces promoting inter-institutional collaboration are stronger than the adverse impact of the funding mode. It should be mentioned that at other universities—such as the National Taiwan University (21 %) and Peking University in China (31 %) (Wang et al. 2011)—internationally collaborative articles make up a lower percentage of the total number of articles.

Conclusions

This article set as its objective the identification of the co-authorship patterns of research on the African continent (as they are manifested in the Thomson Reuters indexed journals) and the elaboration of the findings. The authors identified, from a policy perspective, the importance of assessing the benefits or otherwise of international collaboration on the African continent. While the majority of the international literature considers scientific collaboration to be beneficial for both partners, there is no scarcity of the opposite arguments.

For example, arguments have been expressed that the USA may lose out due to the Asian strength, which may be fuelled by globalisation trends. Similarly, in the African context, it has been argued that South Africa spends considerable research effort in the field of HIV/AIDS; well above what is expected from its relative scientific size, and it is doubtful that the HIV/AIDS epidemic can be resolved by South African research alone, without the support of the rest of the world. This emphasis may need further assessment (Pouris and Pouris 2011). Scientific small countries, because of their scientific limitations, have to be particularly attentive to their research priorities in order to optimise their developmental goals.

The above argument is further supported by the identified disciplinary emphasis of Africa's research. Africa's research emphasises natural resources and medical fields. While it can be argued that this emphasis is underlined by the resources available on the continent and the diseases present, it may be argued that these priorities may not necessarily be the best options for the continent's developmental objectives. It should be mentioned that Africa countries have limited research prioritisation mechanisms, and any embryonic efforts in this domain are based on the immediate needs of the existing activities, and not on the most achievable and beneficial efforts for the future when the research outputs will materialise.

In this context, the Asian research priorities are informative. Why is the research focus of China and other Asian countries on engineering, physics and chemistry (disciplines supporting knowledge-based societies) while Africa focuses on medical and natural resources?

Identification of the research outputs of the African countries and their related collaborative patterns shows that the continent suffers from subcritical research systems and collaboration dominance. Single-author articles appear to be on the verge of extinction on the continent. It may be argued that this is the effect of the foreign funding sources which favour group of researchers and not individual researchers. The revealed structure raises a number of policy concerns. Should Africa's science and development not be better served by the creation of regional research and innovation systems (that is aiming to create an African Research Union)? How do the high dependencies on non-African collaboration affect the continent's research evolution and priorities? Is African research individualism and inspiration stifled by excessive collaboration?

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