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Research Partnerships that Count in Sub Saharan Africa's Research Output and Impact: A Bibliometrics Study of Selected Countries, 2000-2019

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Abstract

The purpose of this paper is to examine the extent to which selected countries in sub-Saharan Africa benefit from their research collaboration with other countries, with special focus on countries outside Africa. Data was obtained from the Web of Science's (WoS) citation databases using the country name in a search query CU=Country Name and limiting the search to research articles published between 2000 and 2019. The VOSviewer was used to map the country collaborations in the five sub-Saharan African countries, which were selected for the study, namely Ethiopia, Ghana, Kenya, Nigeria and Tanzania. The findings reveal that the number of collaborating countries has not only increased since 2000 but also that the intensity of collaboration among countries has tremendously grown over time. The USA and England contribute the most to the five countries' research performances and therefore constitute the core country contributors. The collaborators' contribution to the five countries is close to being proportional but greatly differs in terms of percentage share across the five countries. The greatest beneficiary of regional (hereinafter used to refer to 'Africa' or 'African') and international collaboration is Kenya, followed by Nigeria, Ghana, Tanzania and Ethiopia. The collaboration among researchers from different countries is likely to intensify as many governments and funders place more emphasis on research collaboration. Given the current increased interest in university rankings, institutions in sub-Saharan Africa are likely to encourage their researchers to engage in collaborative research that benefits the institutions the greatest.

Keywords: *Research Collaboration, sub-Saharan Africa, Bibliometrics, Citation Impact*

Introduction

The notion that research collaboration bears benefits is globally acknowledged. The published literature is replete with evidence of the drivers and value of research collaboration between and among individual researchers, organisations and countries. An examination of the factors that necessitate research collaboration partially offers glimpses into the anticipated benefits of collaboration. For instance, Cozzens *et al* (2011) and Duque *et al* (2005) have delineated the drivers of research partnerships to include increased specialisation across disciplines and fields, access to expensive instruments or rising costs of technological apparatus, complexity of research problems, growth of interdisciplinary, development of new information and communication technologies, and career advancements. Individual-based characteristics that inform decisions on research partnerships include educational background, academic affiliation and prior innovation output as well as work experience (Okamuro, Honjo and Kato 2013). In their study on the determinants of research collaboration modes, Jeong, Choi and Kim (2011) found that "informal communication, cultural proximity, academic excellence, external fund

inspiration, and technology development levels play significant roles in the determination of specific collaboration modes, such as sole research, internal collaboration, domestic collaboration, and international collaboration". The underlying rationale for research collaboration is therefore anchored in the need to overcome some of the hurdles that are associated with sole research undertakings, such as those outlined above.

On the other hand, the overarching persuasion to engage in research collaboration is based on perceived benefits of research partnerships (Bradley 2008). The benefits can be in the form of outcomes, deliverables, and products (Bourke 2013). Specifically, the benefits include improved research performance (Sooryamoorthy 2017), strengthening of research capacity in countries (Volmink and Dare 2005; Spence *et al.* 2016), improving researchers' abilities and performance (Confraria, Blanckenberg and Swart 2019) and increasing research impact (Katz and Hicks 1997). The most commonly cited benefit, however, is alluded to by many scholars who argue that researchers conduct and publish their researches in anticipation of impact (Roberts, Madden and Corrall 2013); Hanard 2001; Beamish 2006; Alzahrani 2010; and Harnad, Carr and Brody 2001). In fact, it has been observed that, depending on the type of collaboration, co-authored papers increase the citation rates way above single-authored papers (see Smart and Bayer 1986; Gazni and Didegah 2011; Katz and Hicks 1997; Sooryamoorthy 2017). It therefore follows that research collaboration increases research productivity (outputs) and citation impact. This overarching benefit is very important, particularly in view of the prevailing focus on ranking systems for universities and, by extension, countries. One of the fundamental indicators that are considered in the global university ranking systems is research output and citation impact (Hossain and Ahmed 2020), and as such any contributions of one country to another in terms of the number of publications and citation impact as a result of research collaboration boost the ranking of the research partners. Hence, this paper quantitatively investigates the extent to which selected countries in sub-Saharan Africa benefit from their research collaborations, with special reference to international collaboration.

Related Studies

Do all research collaborations count? It has been observed that collaboration and its benefits vary across countries (Glanzel 2001; Must 2012; Puuska, Muhonen and Leino 2014) as a result of geographical, linguistic, cultural, political and geopolitical factors (Glanzel 2001), disciplines or fields of study (see Bote, Olmeda-Gómez and Moya-Anegón 2013) and language differences, complex management structures, and inequitable access to financial resources, libraries, conferences, training, and publishing opportunities (see Bradley 2008). Bradley (2008) further notes that "mismatched expectations, lack of face-to-face interaction, and different levels of methodological sophistication" may compromise the maximisation of benefits accruing from research collaboration. Despite the fact that many scholars have noted that international collaboration counts more in terms of publications output and impact than domestic and regional collaboration, there are variations in the extent of the international community's contributions to productivity and impact in domestic research (Katz and Hicks 1997; Pouris and Ho 2014; Sooryamoorthy 2017; Puuska, Muhonen and Leino 2014; Chen, Zhang and Fu 2019). For example, Goldfinch, Dale and DeRouen (2003), in their study on science from the periphery, observed that countries that occupy the periphery benefited the most from international collaborations. The authors further noted that domestic collaboration yielded negative relationships as far as their citation count and impact was concerned. It has also been noted that low-impact countries significantly benefit more than the high-impact countries from international collaboration (Bote, Olmeda-Gómez and Moya-Anegón 2013). The key findings in the study, conducted by (Bote, Olmeda-Gómez and Moya-Anegón 2013), which partially mirrors the trajectory of the current study, are:

- the more countries there are involved in the collaboration, the greater the gain in impact;
- the scientific impact of a country does not significantly influence the benefit it derives from collaboration but does seem to positively influence the benefit obtained by the other countries collaborating with it.
- the countries with the highest impact were clear

outliers, tending to provide proportionally more benefit to their collaborating countries than they themselves obtained.

In Africa, Onyancha and Maluleka (2011), in their study on *knowledge production through collaborative research in sub-Saharan Africa: how much do countries contribute to each other's knowledge output and citation impact?* noted that, although the contributions of sub-Saharan African countries to each other's total research papers was low, countries belonging to the same geographic region tended to benefit each other more than they did with countries outside their regions. The aforementioned authors concluded that geographical proximity of sub-Saharan African countries played a big role in knowledge beneficiation among the countries. South Africa contributed the greatest number of publications to Zimbabwe and Botswana while in the East Africa region, Kenya was the biggest contributor to Uganda and Tanzania. South Africa's collaboration with the majority of the countries in the region was attributed to its high-ranking educational institutions which have attracted post-graduate students from other African countries. In terms of citation count and impact, Onyancha and Maluleka's (2011) study reported that most countries contributed very little (that is, less than 1% of total citations) to each other's citation performance, with South Africa contributing the most to Zimbabwe and Botswana; in a similar manner as it did in terms of the number of publications. In other words, the countries' co-authorship of publications with each other did not result in substantive benefits in terms of improving citation counts and impact.

In a more recent study, Onyancha (2020) used a social network analysis to assess, among other aspects, the contributions of the global north and global south to the research output and impact of five countries in sub-Saharan Africa and noted that the global north contributed more publications and citations than the global south. Onyancha (2020), without naming the collaborating countries, observed that the global north contributed the most in terms of publications and citation impact to the selected countries in sub-Saharan Africa. However, the study fell short of addressing the contributions of individual countries to the regional countries. Finally, the participation and contribution of the international scientific community to research in sub-Saharan Africa has received widespread attention, as reflected in the published literature (see Adams, Gurney, Hook and Leydesdorff 2014; Pouris and Ho 2014; Sooryamoorthy 2017; Onyancha 2020). The number of countries that collaborate with sub-Saharan African countries in both the regional and international arena has increased in the recent past, resulting in the formation of several clusters and increased international network linkages for sub-Saharan African countries (Onyancha 2020). Most of these studies, which are largely limited to specific countries and/or disciplines (e.g. Asubiaro and Badmus 2020; Onyancha 2018; Boshoff 2009; Ettarh 2016; Fari and Ocholla 2015; Maluleka and Onyancha 2016; Mouton 2000; Owusu-Nimo and Boshoff 2017; Sooryamoorthy 2011) have identified the collaborating countries but not the extent of their collaboration.

Problem Statement and Purpose of Study

The demand for efficient 'value-for-money' research has resulted, to some extent, in researchers and their affiliate institutions (largely universities) to search for strategic and external partnership support in what Robertson (2010), as cited in Bourke (2013: 501) has termed as the 'new public managerialism' (RPM). The phrase 'value-for-money' research is often associated with impactful research – i.e. research that makes great contribution to academia, society and economy. The search for strategic research partnerships to achieve greater research impact can be said to be anchored in the United Nation's (UN) Sustainable Development Goals (SDGs) and more specifically *Goal 17: Strengthen the means of implementation and revitalize the global partnership for sustainable development*. Of particular interest and relevance to the current study are the following scientific collaboration-linked targets:

(a) Enhance North-South, South-South and triangular regional and international cooperation on and access to science, technology and innovation and enhance knowledge sharing on mutually agreed terms.

(b) Promote the development, transfer, dissemination and diffusion of environmentally

sound technologies to developing countries on favorable terms, including on concessional and preferential terms, as mutually agreed.

As highlighted above in the section on literature review, sub-Saharan Africa already enjoys wide research networks, as reflected in the geographic dispersion and the number of countries with which the countries in the region collaborate in research. What is, however, unclear and therefore constitutes the research problem and the focus of this study is: how much is the scientific community's collaboration worth for sub-Saharan African countries in terms of scientific outputs and impact? This research problem revolves around the following specific and interrelated sub-questions:

- Which countries benefit the regional countries the most, in terms of research publications and citation impact as well as collaboration networks?
- By how much does each of the foreign countries improve research output and impact in sub-Saharan African countries?
- Which of the local countries benefit the most from its research partners?
- Do the collaborating partners contribute proportionately across the regional countries?

Research Methodology

The search for relevant data was conducted on 3 February 2020 from the Web of Science's (WoS) three citation indexes – that is, the Science Citation Index (SCI), Social Science Citation Index (SSCI) and Arts and Humanities Citation Index (AHCI). The search, which was limited to research articles published between 2000 and 2019, was conducted using the name of the country in the search query, in the format *CU="country name"*, where country name stands for the name of a country. The countries that were selected for the study were Ethiopia, Ghana, Kenya, Nigeria and Tanzania. These countries are among the top-ranked countries in sub-Saharan Africa in the Scimago country ranking system. South Africa, which is ranked first in the region, was excluded from the study because the country's nature, pattern and extent of research collaboration has been extensively investigated (e.g. Mouton 2000; Sooryamoorthy 2009; Sooryamoorthy 2015. Sooryamoorthy 2017). Furthermore, South Africa produces more than one quarter of all publications in Africa and more than one third of publications in sub-Saharan Africa (Sooryamoorthy 2015), a situation that could have resulted in skewed results.

Data was downloaded and saved in text format (that is, .txt) to conform to the VOSviewer software, which was used to analyze the data. The full bibliographic record was considered the most appropriate format to extract the data. Each record contained the following information: author, title, keywords, author address, abstract, source [journal], language of publication, and cited references. The VOSviewer software that was used to analyse the data provides three options to analyse co-authorships, namely individual authors, institutions or countries. This study focuses on country collaborations, and as a result, the unit of co-authorship analysis was 'country'. All countries and geographical regions were included in the mapping of the collaboration networks for each country under investigation. The VOSviewer visualisation of the data yielded the following data, which was deemed necessary for the study:

- Country name – Collaborating country
- Cluster – A cluster of countries is formed where two or more countries are closely associated in their collaboration
- Links (L) – the number of co-authorship links of a given country with other countries
- Total link strength (TS) – the total strength of the co-authorship links of a given country with other countries
- Number of papers (P) – Number of papers published by researchers in a given country
- Number of citations (C) – Number of citations received by the papers published by researchers in a given country
- Normalized citations (NC) – The total normalised number of citations received by all documents published by researchers in a country

Whereas the links and link strength reflected the contributions of the collaborating countries in terms of the size of their individual networks, the number of papers and citations (including normalised citations) reflected the countries' contributions in terms of research output and citation impact.

Percentages of Country A's contribution to Country B's output and impact (that is x as a percentage of y, where x is country A's publications or citations and y is County B's publications or citations), ranking the countries according to various indicators (using Microsoft's Excel rank syntax Rank= (Number, Ref, [order])), correlation coefficients (using Pearson correlation analysis in Microsoft Excel's Data Analysis Tool), and mean scores (using Microsoft Excel formula to calculate the Average scores) were computed to assess the extent of a country's contribution to each of the five selected countries. The assessment was based on the number of papers, links, link strength, citations and normalized citations.

For purposes of examining whether or not the countries' contributions are proportional across the selected countries, a Pearson correlation test was conducted while ranking the countries according to their percentage contributions was conducted using the Excel Rank function. Unless otherwise explicitly explained, the presentation of data according to countries is not based on the countries' ranking in global ranking systems but according to the alphabetical order.

Results and Discussion

Tables 1 and 2 offer the top 30 benefactors for the selected countries under investigation. As the two maps show, research collaboration in the five countries has become denser in 2015-2019 than it was in 2000-2004. Figure 1 consisted of seven clusters, 2156 links and 14229 total link strength, while Figure 2 comprised 11 clusters, 7947 links, and 184481 total link strength.

The collaboration activity in the five countries has therefore more than doubled between the two time periods, especially when we consider the number of links and total link strength. This pattern is clearly illustrated in Table 1 and Table 2, which provide the clusters of individual country collaborators and their number of links, total link strength, papers and citations.

The top of both tables are the countries that were the subject of this paper's investigation (i.e. Nigeria, Kenya, Ethiopia, Tanzania and Ghana). When these countries are excluded, the USA becomes the most active participant in the five countries' research activities. The USA yielded posted the most number of links (170), link strength (14430), papers (5805), citations (196428) and normalised citations (10839.20) in 2000-2004 while its performance between 2015 and 2019 was as follows: links (191), link strength (30194), papers (10225), citations (91481), and normalised citations (15585.06). Other countries that contributed in a big way to the five countries' research performance and collaboration networks include England, Germany, Netherlands, Switzerland, Belgium and Sweden.

Table 1: Top 30 collaborating countries in research in selected countries in sub-Saharan Africa, 2000-2004

No	Country	Cluster	L	TL	P	C	NC
1	Nigeria	4	149	7818	10719	124726	6868,39
2	Kenya	3	168	12465	6478	178546	9798,27
3	USA	3	170	14430	5805	196428	10839,20
4	Ethiopia	3	137	4858	3850	69350	3872,22
5	England	3	159	10048	3494	127635	7037,69
6	Tanzania	3	148	6856	3442	84893	4697,31
7	Ghana	3	143	4989	2944	62953	3488,59
8	South Africa	4	139	5826	2031	60819	3365,96
9	Germany	3	141	4284	1503	46469	2613,61
10	Netherlands	3	135	4175	1219	43665	2411,71
11	Switzerland	3	141	3612	833	37191	2038,18
12	Belgium	1	124	3132	824	30278	1659,36
13	Sweden	3	119	2296	766	21726	1217,35
14	India	1	127	2987	765	37120	2051,34
15	Canada	3	123	2314	742	27836	1561,59
16	France	1	145	3590	733	30288	1660,90
17	China	1	121	2657	698	26910	1503,76
18	Australia	1	136	3100	664	32481	1794,80
19	Uganda	3	119	2508	628	22167	1207,21
20	Italy	1	132	2751	581	23183	1298,54
21	Japan	1	120	2035	548	17908	985,89
22	Norway	3	99	1158	500	12618	718,57
23	Scotland	3	106	1560	469	18855	1040,80
24	Denmark	3	115	1511	453	13512	751,70
25	Spain	1	123	2296	391	22866	1246,04
26	Brazil	1	125	2218	332	21441	1190,32
27	Malaysia	4	104	754	326	6940	394,04
28	Cameroon	2	97	1150	257	7255	400,77
29	Austria	1	115	1195	253	10378	573,32
30	Thailand	2	109	1223	214	18388	1013,18

Another observation that can be made is in regard to the clusters, which reveals that there have been some shifts since the early 2000s. Countries that belonged to the same cluster/s in the 2000-2004 period have shifted to other clusters implying evolving partnerships among researchers in the said countries. Tables 1 and 2 further reveal that only three African countries (i.e. South Africa, Uganda, and Cameroon) featured among the top 30 countries with which Ethiopia, Ghana, Kenya, Nigeria and Tanzania collaborated, implying most of the top contributors to the five countries' research performance were foreign countries.

The tail end of the two lists of countries and/or regions that collaborate with the five sub-Saharan African countries, in terms of their publication outputs, for the periods 2000-2014 and 2015-2019 consists of small countries/regions that co-produced

one or two articles each with at least one of the countries in the region. Tables 3 provides the countries or regions that yielded one paper each in the two time periods. However, some of them posted impressive performance in terms of their number of links, total link strength and citation impact (i.e. number of citations and normalized citations). For example, Armenia and Kosovo (international) and Comoros (regional) had over 20 links each while Surinam, Greenland, and Kyrgyzstan yielded over 120 total link strength, meaning that a country may have contributed little towards another country's publication output, but much more in terms of collaboration networks and citation impact. Table 3 further shows that the number of countries or regions co-publishing one paper each with the five countries has declined from 18 in 2000-2004 to 11 in 2015-2019.

Table 2: Top 30 collaborating countries in research in selected countries in sub-Saharan Africa, 2015-2019

No.	Country	Cluster	L	TL	P	C	NC
1	Nigeria	5	179	20021	16011	74432	14836,48
2	USA	8	191	30194	10225	91481	15585,06
3	Kenya	7	185	23464	9874	75935	12535,89
4	Ethiopia	8	165	12398	8581	42455	8014,21
5	Ghana	2	169	12084	6851	36630	6724,32
6	England	3	186	21382	6147	59323	10351,65
7	Tanzania	2	167	11751	5082	35082	5893,02
8	South Africa	4	173	14647	4628	37454	6799,34
9	Germany	9	165	10450	2854	28256	5021,01
10	China	1	153	8252	2599	23875	4783,26
11	Netherlands	8	162	8205	2068	23984	3965,94
12	Australia	2	171	9318	1909	25638	4396,74
13	Canada	3	166	7777	1746	22728	3831,67
14	India	1	166	7505	1741	21729	3935,71
15	Switzerland	11	173	8189	1592	20744	3621,16
16	Belgium	4	146	5837	1385	14972	2483,70
17	Sweden	3	143	5327	1346	15647	2479,20
18	Malaysia	5	134	3219	1335	8335	1766,65
19	France	7	161	7876	1330	17123	3114,82
20	Uganda	2	148	5368	1185	10322	1778,48
21	Italy	1	153	6033	1106	13732	2386,97
22	Scotland	3	141	4341	981	11312	1981,65
23	Japan	9	139	4032	938	10936	1749,59
24	Norway	7	131	3171	899	8944	1589,92
25	Denmark	4	130	3618	846	12713	1955,71
26	Spain	3	149	5277	838	13166	2073,94
27	Brazil	1	160	5367	765	14179	2464,65
28	Pakistan	1	125	2469	507	6258	1385,75
29	Saudi Arabia	1	111	1991	498	5195	987,22
30	Cameroon	2	130	2475	490	4246	869,60

Table 3: Least country contributors to the research performance of selected countries in sub-Saharan Africa, 2000-2004 and 2015-2019

No.	Country	Cluster	L	TL	P	C	NC
	2000-2004						
1	Armenia	1	23	23	1	13	0,90
2	Bhutan	1	2	2	1	6	0,29
3	Cape Verde	2	10	10	1	21	1,10
4	French Guiana	2	10	10	1	24	1,35
5	Greenland	3	14	14	1	138	6,63
6	Kosovo	1	22	22	1	36	2,48
7	Kyrgyzstan	2	7	7	1	120	6,77
8	Maldives	1	17	17	1	11	0,58
9	Micronesia	1	6	6	1	3	0,14
10	Montenegro	1	9	9	1	41	1,97
11	Neth Antilles	3	4	4	1	38	1,99
12	North Korea	1	18	18	1	25	1,29
13	Sao Tome and Prin	1	3	3	1	21	1,10
14	St Vincent	4	2	2	1	25	1,31
15	Surinam	2	8	8	1	143	7,35
16	Tonga	1	5	5	1	40	2,09
17	Tuvalu	2	10	10	1	69	3,61
18	Vanuatu	2	12	12	1	46	2,60
	2015-2019						
1	Antigua and Barbu	1	12	12	1	5	1,64
2	British Virgin Isl	4	15	15	1	1	1,19
3	Cayman Islands	2	8	8	1	18	2,03
4	Comoros	1	24	24	1	2	2,37
5	Cook Islands	6	5	5	1	1	0,11
6	Liechtenstein	11	2	2	1	3	0,98
7	Neth Antilles	8	3	3	1	11	0,92
8	Niue	6	5	5	1	1	0,11
9	North Korea	2	11	11	1	9	1,54
10	Reunion	7	2	2	1	10	1,13
11	Tonga	6	4	4	1	62	5,16

When we excluded the focal countries (i.e. Ethiopia, Ghana, Kenya, Nigeria and Tanzania) from the analysis of collaborating countries, so as to gauge each collaborating country's unique contribution, it was noted that the number of links, link strength, papers, citations and normalized citations reduced drastically. However, when we ranked the collaborating countries according to their unique percentage share of the regional countries' performance using the five indicators, we observed that the USA was the topmost country in all but two countries, namely Nigeria and Tanzania, where the USA was ranked in the second position after England, in terms of links in each case. Similarly, England was

largely ranked the second most contributing country outside of Africa (Table 5) with exceptions being in Ethiopia (links), Nigeria (links and papers) and Tanzania (links). The other top-ranked countries were the Netherlands, and Germany. These countries could be said to be the core contributors to the five countries' research performance. Evidently, the positions taken by each of the countries below England were more fluid than it was the case with the USA and England. In the ranking of the regional countries, South Africa topped the list of the main contributors to the five countries' research performance, followed by Uganda, Cameroon, Malawi, and Burkina Faso (Table 6).

Table 4: Correlation of collaboration performance of all countries across five regional countries

		ET					*GH*					*KE*					*NG*				
		L	TL	P	C	NC	L	TL	P	C	NC	L	TL	P	C	NC	L	TL	P	C	NC
ET	L	1.00																			
	LS		1.00																		
	P			1.00																	
	C				1.00																
	NC					1.00															
GH	L	0.87					1.00														
	LS		0.92					1.00													
	P			0.93					1.00												
	C				0.94					1.00											
	NC					0.95					1.00										
KE	L	0.89					0.91					1.00									
	LS		0.95					0.94					1.00								
	P			0.93					0.97					1.00							
	C				0.95					0.97					1.00						
	NC					0.96					0.97					1.00					
NG	L	0.90					0.91					0.91					1.00				
	LS		0.86					0.86					0.87					1.00			
	P			0.86					0.92					0.90					1.00		
	C				0.92					0.92					0.93					1.00	
	NC					0.94					0.93					0.93					1.00
TZ	L	0.82					0.85					0.87					0.81				
	LS		0.92					0.91					0.94					0.78			
	P			0.90					0.92					0.95					0.83		
	C				0.93					0.94					0.96					0.87	
	NC					0.92					0.94					0.96					0.86

Key: ET- Ethiopia, GH-Ghana, KE-Kenya, NG-Nigeria

Table 5: Ranking the international country contributors to the selected countries' research performance

		Ethiopia				**Ghana**				**Kenya**				**Nigeria**				**Tanzania**				**Ranking**	
No.	Coll Country	L	TL	P	C	L	TL	P	C	L	TL	P	C	L	TL	P	C	L	T L	P	C	World	Interna-tional
1	USA	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	2	1	1	1	1	1
2	England	1	2	2	2	2	2	2	2	2	2	2	2	1	2	3	2	1	2	2	2	2	2
3	Netherlands	4	3	4	3	13	11	5	5	12	4	5	4	8	4	15	6	8	8	8	6	4	3
4	Germany	3	6	3	4	8	5	4	3	8	6	4	5	9	12	5	5	11	14	20	18	5	4
5	Switzerland	9	8	15	10	6	6	9	7	4	10	10	8	11	9	16	15	4	3	6	4	6	5
6	Australia	14	16	12	13	3	8	8	9	8	9	12	7	10	10	9	13	18	12	14	15	7	6
7	France	11	9	11	12	8	10	14	10	10	11	9	11	5	6	14	8	19	17	16	14	8	7
8	Belgium	6	4	6	7	19	21	20	21	5	13	11	9	15	11	21	14	13	11	12	12	9	8
9	Canada	23	23	16	17	11	15	10	8	7	7	6	6	13	28	10	11	10	19	13	10	10	9
10	India	13	12	5	9	11	13	19	18	11	12	16	10	5	18	7	9	30	24	24	17	11	10
11	Sweden	11	11	8	5	36	14	13	17	13	15	14	17	11	36	25	27	9	9	7	8	13	11
12	Italy	8	13	13	14	17	27	22	24	16	16	19	14	17	7	8	10	26	22	18	21	14	12
13	China	15	26	14	20	18	20	6	13	17	19	13	15	5	5	6	4	37	48	22	37	15	13
14	Scotland	24	19	23	22	19	23	18	15	14	17	15	16	17	33	18	26	13	13	15	13	16	14
15	Spain	17	25	18	15	23	24	27	27	19	21	23	20	22	8	22	12	26	15	19	19	17	15
16	Japan	24	20	19	16	19	34	15	20	18	32	17	23	26	14	11	7	24	39	17	28	18	16
17	Denmark	27	24	24	24	24	22	12	12	27	25	22	22	28	40	42	35	12	7	9	11	19	17
18	Brazil	21	34	30	25	15	29	33	33	23	20	25	19	19	15	13	16	35	25	30	25	20	18
19	Norway	10	10	9	11	49	52	31	44	36	50	36	38	41	56	42	38	20	16	11	16	23	19
20	Thailand	39	63	53	56	22	32	38	31	20	24	29	18	32	44	37	21	22	20	28	22	25	20

Do the collaborating countries contribute proportionately across the regional countries? The results presented in Tables 1 and 2 suggest that, save for a few cases, each country's share in Ethiopia's, Ghana's, Kenya's, Nigeria's and Tanzania's links, link strength, papers, and citation impact, varies. As a result, we conducted a Pearson correlation test to assess the performance of the countries or regions across the five sub-Saharan countries. The test yielded high and statistically significant coefficients ranging from r = 0.78, p = 0.001 to r = 0.97, p = 0.001 (see Table 4). In terms of the links, the highest coefficient (i.e. r = 0.91) was registered between Kenya and Nigeria, Kenya and Ghana and Ghana and Nigeria, while a coefficient value of r = 0.95 was obtained in the analysis of total link strength between Kenya and Ethiopia

The other relationships that produced high correlation coefficients above r = 0.90 as shown in Table 4 are (a) total link strength (Ethiopia vs. Ghana, r = 0.92; Ethiopia vs. Tanzania, r = 0.92; Ghana vs. Kenya, r = 0.94; Ghana vs. Nigeria, r = 0.92; Ghana vs. Tanzania, r = 0.92), (b) papers (Ethiopia vs. Kenya, r = 0.93; Ethiopia vs. Ghana, r = 0.93), (c) citations (all relationships, except Nigeria vs. Tanzania, yielded coefficients above r = 0.09), and (d) normalised citations (all relationships, except Nigeria vs. Tanzania, yielded coefficients above r = 0.09).

Table 6: Ranking regional country contributors to the selected countries' research performance

		Ethiopia				**Ghana**				**Kenya**				**Nigeria**				**Tanzania**				**Overall Ranking**	
No.	Coll Country	L	TL	P	C	L	TL	P	C	L	TL	P	C	L	TL	P	C	L	TL	P	C	World	Regi-onal
1	South Africa	7	5	7	6	5	3	3	4	3	3	3	3	3	3	2	3	5	5	4	5	3	1
2	Uganda	20	14	17	18	14	16	21	25	14	8	7	13	13	19	20	25	6	10	10	9	12	2
3	Cameroon	26	36	38	31	16	17	23	26	29	34	27	41	20	25	19	30	13	30	33	29	21	3
4	Malawi	43	35	36	34	37	26	28	22	32	18	24	21	24	45	47	58	24	18	21	20	22	4
5	Burkina Faso	31	29	39	43	26	12	16	16	44	29	35	42	32	35	36	54	36	23	32	30	24	5
6	Senegal	36	27	46	42	32	18	25	29	49	40	39	47	24	39	46	62	41	44	41	46	28	6
7	Mozambique	36	37	48	44	65	41	49	38	32	31	37	33	57	42	56	51	16	21	29	26	29	7
8	Zimbabwe	45	46	34	38	37	43	48	54	37	30	28	25	64	65	53	64	23	29	27	24	31	8
9	Zambia	43	56	55	52	40	45	44	56	23	23	26	36	43	52	51	61	34	31	25	27	32	9
10	Sudan	22	21	32	27	42	44	54	51	37	47	40	45	51	53	59	65	32	42	47	38	34	10
11	Mali	66	51	59	57	43	25	29	28	42	27	33	34	54	50	53	70	39	37	45	42	37	11
12	Egypt	29	43	35	36	33	40	37	45	53	69	47	57	27	46	31	43	48	75	62	63	39	12
13	Cote Ivoire	48	41	60	46	37	28	30	42	51	55	55	63	29	51	48	63	44	51	50	60	41	13
14	Benin	61	76	70	81	46	31	24	37	45	53	48	60	43	43	32	52	31	35	38	53	42	14
15	Dem Rep Congo	48	62	61	80	33	42	55	40	39	49	43	49	43	55	65	48	26	46	46	49	46	15
16	Rwanda	41	55	48	59	78	61	60	72	52	39	33	55	63	62	74	82	47	43	35	54	52	16
17	Botswana	57	54	31	62	61	65	67	106	54	45	50	32	62	74	53	74	68	55	44	43	57	17
18	Niger	85	59	62	75	65	39	41	60	73	78	64	83	48	47	33	67	62	53	64	66	58	18
19	Gabon	93	106	96	78	49	35	43	23	76	52	69	61	81	88	98	91	39	34	43	36	64	19
20	Gambia	55	42	67	49	55	30	35	30	54	26	45	39	43	63	65	68	125	137	150	162	66	20

Table 7: Countries' average contribution to and share of selected sub-Saharan African countries' research performance (Mean Score and Mean Percentage Share)

		Mean (x□)			Mean % share		
	Measurement Indicator	**Int.**	**Reg.**	**Tot.**	**Int.**	**Reg.**	**Tot.**
Ethiopia	L	35.75	50.02	39.56	23.12	32.21	25.36
	LS	876.18	894.92	885.20	0.89	0.89	0.88
	P	106.25	77.07	99.63	0.70	0.51	0.64
	C	1957.18	1451.89	1843.40	1.04	0.77	0.96
	NC	186.63	153.41	179.71	1.23	1.01	1.17
Ghana	L	45.46	65.43	50.81	27.22	38.74	30.06
	LS	316.78	559.06	380.93	0.41	0.72	0.49
	P	94.43	104.91	98.09	0.79	0.88	0.81
	C	2269.22	2450.70	2338.56	1.39	1.50	1.41
	NC	170.57	206.15	181.54	1.44	1.74	1.51
Kenya	L	59.31	81.25	65.06	31.62	43.20	34.42
	LS	3106.15	3568.94	3240.22	1.21	1.37	1.24
	P	221.63	203.39	218.87	0.99	0.91	0.97
	C	7510.43	5935.09	7168.76	1.58	1.25	1.49
	NC	407.98	331.80	391.90	1.82	1.48	1.72
Nigeria	L	47.63	69.75	53.49	26.10	38.00	29.07
	LS	1408.95	1261.68	1377.65	1.48	1.31	1.43
	P	156.05	154.94	157.27	0.43	0.43	0.43
	C	4506.72	2794.07	4101.15	1.23	0.76	1.10
	NC	471.27	333.99	439.82	1.32	0.94	1.21
Tanzania	L	37.58	63.66	44.48	22.12	37.19	25.86
	LS	1464.66	1613.00	1510.13	1.18	1.28	1.20
	P	115.07	108.13	114.35	1.00	0.94	0.98
	C	3459.01	3248.30	3437.31	1.49	1.39	1.45
	NC	192.44	208.46	198.51	1.60	1.74	1.63

In order to answer the question on which country, among the five selected for the study, benefits the most from its regional and international collaborators, Table 7 provides the collaborating countries' mean scores and mean percentage share of the five countries' research performance. The mean scores in columns 3-5 simply refer to the average score per country that collaborated with the five countries while the percentage share refers to collaborating countries' share (in percentage) of each of the five countries' (in column) links, link strength, papers, citations and normalized citations. For example, the average number of links of the countries that collaborated with Ethiopia from 2000 to 2019 (see row three from the top) is 35.75 (international [foreign] countries), 50.02 (other regional or African countries), and 39.56 (both categories of countries), while the same countries' percentage share of Ethiopia's total number of links is 23.12% (international), 32.21% (regional) and 25.36% (both categories of countries). In view of the aforementioned explanation of how to read Table 7, Kenya benefits the most from both the other African and international countries. For instance, the average contribution of all the countries in the case of Kenya is 65.06 links, 3240.22 total link strength, 218.8 papers, 7168.76 citations, 391.90 normalised citations. This pattern is replicated in the countries' percentage share across the five countries investigated in the study. Nigeria was the second-most beneficiary in all indicators except in the case of normalised citations where it overtook Kenya.

Conclusions and Recommendations

The academic ranking of universities, individual researchers and even countries, in recent times, is one of the factors that has heightened the interest in research collaboration, particularly because research collaboration increases productivity and improves citation impact. The need to have partnerships that yield maximum productivity and impact of research is therefore greater in the contemporary scientific community and research circles than before, despite the unethical behaviors that have been reported regarding passive collaboration. The current study, which sought to examine the extent of research collaboration in the selected countries, reveals that five sub-Saharan African countries that were the subject of investigation in the study, have witnessed wide collaboration networks [both regionally and internationally], increased co-authorship of papers and, as a result, increased citation impact. The international collaborators are dominated by the USA and England, which co-produce over 90% of each of the regional countries' papers. The international scientific community, however, does not contribute reciprocally on the number of links and link strength while their contribution in the number of citations and citation impact is relatively high when compared to the regional countries' share. The rest of Africa contributes more in terms of the average number of links and link strength than the international community, implying that all the regional countries have strong collaboration links with each other and with the rest of the five countries' collaborators. Regarding the regional country that has benefitted the most from international and regional collaboration, Kenya gained the most followed by Nigeria and Ghana, with the greatest benefit being in the form of papers and citation impact originating from the countries' partnerships with the international community.

Implications of the Study

In view of the current study's findings, one would ask: Should countries in Africa strategically engage in partnerships that benefit them the most? Which partnerships should be revitalized or strengthened in line with the UN's 17th SDG? Africa is already disadvantaged in terms of research resources such as funding, research facilities (e.g. laboratories and other scientific equipment), and capacity (i.e. number of researchers per national population size). In responding to the foregoing question, one is reminded of the old adage, *he who pays the piper calls the tune*. Do African countries have a say on which countries they can collaborate with in research, especially in situations where the proposed research is initiated and funded by foreign countries? Do African researchers care which country funds their research and therefore determines the trajectory of the funded research as long as they receive funding which is often hard to secure in the continent? We do not have answers to these questions, but as institutions and researchers in Africa ponder on the questions, among others, there is need to take note of the benefits that accrue from different partnerships; partnerships which, in our view, should be maintained and strengthened. The study has demonstrated that while collaborating with some countries yields high returns in terms of papers, collaboration links and citation impact, other partnerships lead to low returns. Nevertheless, while it is true that international collaboration increases productivity and impact, the current study has similarly revealed that regional collaboration benefits the African countries the most in terms of collaboration links and link strength, which may in turn increase productivity and impact. As such, there is need to nurture African regional collaborations as the countries pursue international collaboration. Finally, we believe that the realization of the targets in the UN's Goal 17 in sub-Saharan Africa, as they pertain to science and technology, depends on many factors, including strategically seeking for and contractually establishing mutually beneficial research partnerships in and for the region.

Further Research

This study used data from three citation indexes for the sciences, social science, and arts and humanities. It is possible that lumping the data for these research domains together might not have revealed the differences that may exist in the different research domains. There is therefore need for further research to consider the existence of differences in research collaboration as a result of disciplinary differences. Further research is also recommended to explore the collaboration patterns in the African countries that were not covered in this study.

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