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Trends in African Scientific Output and Impact 1996–2015

Mike Thelwall
University of Wolverhampton, UK

Abstract

It is important to analyse the scientific performance of nations to help evaluate the effectiveness of current policies and to aid future planning. In response, this article reports a trend analysis of the number of Scopus-indexed publications and their average impact for 48 African countries 1996-2015, using fractional authorship counting and field normalised log citation rates, relative to the world average. The results show an encouraging and almost universal trend for African countries to increase their share of the world's output during this period, but most also experienced a decrease in their citation impact relative to the world average. The decline in relative citation impact is not an immediate cause for concern since it may be a by-product of increasing research capacity reducing the reliance upon international collaboration. Thus, African policymakers should be broadly satisfied with their efforts so far, but should be aware of the long-term need to reverse the declining trend in average research impact.

Introduction

National governments spend substantial amounts of money on academic research, either directly in the form of research-only organisations or research-funding schemes, or indirectly in the form of higher education finance that is expected to include an element of research. Scholarly achievements are expected to have many societal benefits from helping the education system to improving national competitiveness and quality of life. Because of the public money spent on research, it is important to monitor the progress of a country's researchers to inform future policy-making and planning. Research spending in Africa lags the rest of the world (Confraria and Godinho, 2015) and seems to be predominantly channelled through higher education in most countries. Research in Africa tends to specialise in health issues (e.g., tropical medicine) and in topics related to the exploitation of natural resources rather than covering all academic topics (Pouris and Ho, 2014). Because of this, Africa makes few published academic contributions to some areas, such as music and philosophy within the arts and humanities, at least in terms of journal articles.

Collaboration is important for African research published in international scientific indexes, and particularly with the United States of America (USA), the United Kingdom (UK) and France (Confraria and Godinho, 2015). For example, within Central Africa, the legacy of colonialism still affects research, with academics tending to collaborate with researchers in the former colonising countries (35% of all output in Central Africa). In Central Africa, almost all published research in the Web of Science is produced through international collaboration (85%) (Boshoff, 2009; see also: Ettarh, 2016; Mêgnigbêto, 2013b), and the proportion of international collaboration may be increasing in some African countries (Sooryamoorthy, 2010). African nations may even adapt their research practices to improve their chances of attracting international collaborations and funding (Moyi Okwaro and Geissler, 2015). A later study of West Africa confirmed the numerical dominance of collaborations with non-African countries – mainly UK, USA and France (Mêgnigbêto, 2013a). Internal collaboration patterns in African research fall into three groups – Northern, South-Eastern and South-Western that tend to collaborate with each other more than with other African countries (Toivanen and Ponomariov, 2011).

An analysis of African articles in the Web of Science 1981-2011 reveals that Africa started to increase steadily its share of the world's publications from about the year 2000. A few countries (Mozambique, Zambia, Mali, Tanzania, Uganda, Malawi, Kenya) published research that had impact above the world average (Confraria and Godinho, 2015). The citation indicator used has since been replaced in the bibliometric community for being inadequate (Waltman, van Eck, van Leeuwen, Visser, and van Raan, 2011), and so these findings are not robust.

There have been several bibliometric studies of aspects of African research. These include an investigation of South African universities (Jacobs, 2006), sections of a book on the same topic (Sooryamoorthy, 2015) as well as many studies of individual research topics or broad fields (Molatudi, Molotja, and Pouris, 2009; Uthman and Uthman, 2007), and individual universities (Ocholla, Mostert, and Rotich, 2016). One study analysed scientific output in Africa 2000–2004 (academic publications and patents) but no changes over time (Pouris and Pouris, 2008). An investigation of African scientific productivity 1996–2009 reported the proportion of the world's articles in Scopus for 26 countries and years as well as their relative impact although relative impact is not defined (Arencibia-Jorge, 2012). The current paper extends this report by adding the years 2010-2015, using a new relative citation indicator that is not unduly affected by the skewed nature of citations (see the methods section below), and considering 22 additional countries. This allows previous findings to be checked and updated. as well as allowing countries with a lower level of scientific productivity to be checked.

Research Questions

The research questions are mainly descriptive, with the first two assessing changes in the two main measurable dimensions of research output: quantity and average impact.

- **RQ1**: How have African countries' shares of the world's publications changed since 1996?
- **RQ2**: How have African countries' citation impacts changed relative to the world average since 1996?
- **RQ3**: Is there evidence that African nations with low academic output tend to produce low quality research?

Methods

The research design was to use a large sample of the world's articles 1996 –2015 with publication counts and field normalised citation indicators to identify changes in publication share (i.e., the number of publications relative to the world) and average citation impact relative to the world over time.

Out of the two major citation databases, Scopus was selected as the data source for its broader international coverage than the Web of Science (Li, Burnham, Lemley, and Britton, 2010; López-Illescas, de Moya-Anegón and Moed, 2008; Moed and Visser, 2008). The coverage of Scopus is much smaller before 1996, so, this year was chosen as the starting point. The end point of 2015 was chosen to allow at least a year for (almost) all articles to attract citations.

Scopus categorises academic journals into broad and narrow subject categories. A sample of narrow categories was chosen for the analysis. To generate a systematic sample, the seventh narrow subject category within each Scopus broad subject category was selected, replacing the seventh category with another in cases when there were less than seven. After excluding one small category that only had results after 2006 (Dental Assisting) and adding an extra category for one large broad field, the selected categories were: Applied Microbiology and Biotechnology; Atomic and Molecular Physics, and Optics; Cell Biology; Computer Vision and Pattern Recognition; Control and Systems Engineering; Dermatology; Discrete Mathematics and Combinatorics; Emergency Nursing; Endocrine and Autonomic Systems; Finance; Fluid Flow and Transfer Processes; Forestry; Fuel Technology; Geology;

Health, Toxicology and Mutagenesis; History and Philosophy of Science; Human Factors and Ergonomics; Medical Laboratory Technology; Organizational Behaviour and Human Resource Management; Pharmaceutical Science; Polymers and Plastics; Small Animals; Social Psychology; Spectroscopy; Statistics, Probability and Uncertainty and Transplantation.

Scopus indexes various types of object, from conference papers to editorials. To ensure homogeneity of the data, only documents registered as journal articles in Scopus were included. Standard journal articles are the primary output type covered by Scopus, and are the most important documentary outputs of most areas of science, excluding the arts, humanities and some social sciences. They are therefore the logical choice for analysis.

The citation counts and author affiliations of all journal articles in the set were downloaded from Scopus during December 2016 and January 2017, using Scopus API queries such as the following for Forestry (subject code 1107) journal articles. A separate query was submitted for each year, including the year as a refinement parameter for the query.

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Articles were assigned to countries using the fractional counting method: if a proportion p of an article's authors were from a given country, then p of the article and p of the articles' citations would be assigned to that country. In some cases, the Scopus records were incomplete because there were more authors than country affiliations or more country affiliations than authors. These incomplete records were excluded. This is a small percentage and mostly applies to highly co-authored articles; and so, because of the fractional counting scheme used, this should not affect the results much.

Raw citation counts are not useful for comparisons between countries or years because the average number of citations per paper varies greatly between fields and years. A field normalised citation indicator is therefore needed. The Mean Normalised Log Citation Score (MNLCS) (Thelwall, 2017ab) was chosen in preference to the more standard Mean Normalised Citation Score (MNCS) (Waltman, van Eck, van Leeuwen, Visser, and van Raan, 2011) to avoid being unduly influenced by individual highly cited articles. This is important because citation data is highly skewed (de Solla Price, 1976; Thelwall, 2016), and this is particularly problematic for the MNCS for the relatively small numbers here for individual years. The MNLCS is therefore a substantial improvement for African countries with low publication outputs. The MNLCS is calculated as follows:

- Replace the citation count c of each article by $\ln(1+c)$. This log transformation reduces the skewing and prevents individual highly cited articles from having a major influence on the results.
- Calculate the average (arithmetic mean) $\overline{\ln(1+c)}$ of the $\ln(1+c)$ values for all the world's articles, performing a separate calculation for each field and year. In the present data, this resulted in 26x20=520 calculations, one for each field and year.
- Divide all the log transformed citation counts by the world average for the field and year $\ln(1+c)/\overline{\ln(1+c)}$ to get the field and year normalised log-transformed citation count.
- Calculate the arithmetic mean of the field and year normalised log-transformed citation counts separately for each year and country (for the main graphs) and for each year, country and field (for field-graphs, shown only in the online supplement).

Results

As has been previously shown, a few African countries produce most of Africa's papers, and many countries have a very low total research output (Table 1). This pattern holds when fractional counting is used, as in Table 1, and is not affected by the data source here, being only 26 out of the 310 Scopus categories.

Table 1: The 48 African countries recorded in Scopus for at least one of the years 1996–2015

Rank	Country	Articles	Africa %	World %
1	Egypt	11098.6	29.5%	0.43%
2	South Africa	9032.2	24.0%	0.35%
3	Nigeria	4160.7	11.0%	0.16%
4	Tunisia	3803.2	10.1%	0.15%
5	Algeria	2286.9	6.1%	0.09%
6	Morocco	2181.1	5.8%	0.08%
7	Kenya	706.9	1.9%	0.03%
8	Cameroon	539.5	1.4%	0.02%
9	Ethiopia	536.6	1.4%	0.02%
10	Ghana	453.3	1.2%	0.02%
11	Tanzania	316.8	0.8%	0.01%
12	Uganda	266.8	0.7%	0.01%
13	Zimbabwe	232.9	0.6%	0.01%
14	Senegal	232.5	0.6%	0.01%
15	Sudan	213.8	0.6%	0.01%
16	Botswana	200.9	0.5%	0.01%
17	Libya	180.7	0.5%	0.01%
18	Burkina Faso	163.8	0.4%	0.01%
19	Cote d'Ivoire	161.8	0.4%	0.01%
20	Benin	108.1	0.3%	0.00%
21	Malawi	100.1	0.3%	0.00%
22	Zambia	85.6	0.2%	0.00%
23	Madagascar	73.0	0.2%	0.00%
24	Namibia	62.7	0.2%	0.00%
25	Togo	60.5	0.2%	0.00%
26	Mozambique	56.1	0.1%	0.00%
27	Congo	54.2	0.1%	0.00%
28	Mali	48.3	0.1%	0.00%
29	Rwanda	42.3	0.1%	0.00%
30	Niger	31.9	0.1%	0.00%
31	Gabon	30.6	0.1%	0.00%
32	Democratic Republic, Congo	22.1	0.1%	0.00%
33	Eritrea	20.8	0.1%	0.00%
34	Gambia	18.9	0.1%	0.00%
35	Swaziland	16.2	0.0%	0.00%
36	Angola	12.7	0.0%	0.00%
37	Sierra Leone	11.0	0.0%	0.00%
38	Lesotho	10.1	0.0%	0.00%
39	Mauritania	8.9	0.0%	0.00%
40	Guinea	8.4	0.0%	0.00%

41	Chad	7.3	0.0%	0.00%
42	Burundi	7.0	0.0%	0.00%
43	Central African Republic	6.8	0.0%	0.00%
44	Djibouti	3.0	0.0%	0.00%
45	Guinea-Bissau	2.3	0.0%	0.00%
46	Liberia	2.1	0.0%	0.00%
47	Equatorial Guinea	1.7	0.0%	0.00%
48	Somalia	0.5	0.0%	0.00%
	Africa total	**37682**	**100.0%**	**1.45%**
	World total	**2605096**		**100%**

Articles are based on fractional counting and cover 26 out of 310 Scopus narrow subject categories.

The research questions can be answered from Figures 1-10.

RQ1: How have African countries' shares of the world's publications changed since 1996?
Each of the top 10 countries increased their share of the world's Scopus-indexed publications, as can be seen from the Article line (% share of the world's articles) having an upward slope in Figures 1-10. The same is not true for all countries. However, two countries experienced a clear decrease: Zimbabwe and Botswana (since 2005), and there were too few publications to identify a trend for Swaziland and lower ranked countries in Table 1 (see the online supplement).

RQ2: How have African countries' citation impacts changed relative to the world average since 1996?
Seven out of the ten African countries producing the most research output experienced a decline in the citation impact of their research, compared to the rest of the world. In two cases, relative citation impact has remained constant (Tunisia, Algeria); and in one case, it increased (Kenya). For the additional countries in the online supplement, a similar decreasing trend was common, but Zimbabwe's and Burkina Faso's, Malawi's relative citation impacts stayed approximately constant. Congo's and Mali's increased, and patterns are hard to identify for Rwanda and lower ranked countries.

RQ3: Is there evidence that African nations with low academic output tend to produce low quality research?
Although in recent years most countries have relative impact (MNLCS) below the world average of 1, countries that produce the fewest articles do not necessarily have the lowest citation impact (see the online supplement). For example, Tanzania (ranked 11) and Uganda (ranked 12) have MNLCS above the world average of 1 for most years (Figures A1, A2 in the online supplement). Moreover, all countries ranked 11–48 except Senegal, which has at least one year in which their citation impact is above the world average of 1 (Online supplement Figures A1-A38). Even Zimbabwe (ranked 12), with a rapidly declining share of the world's scientific outputs, has an MNLCS value close to 1 for most years covered (Figure A3 in the online supplement).

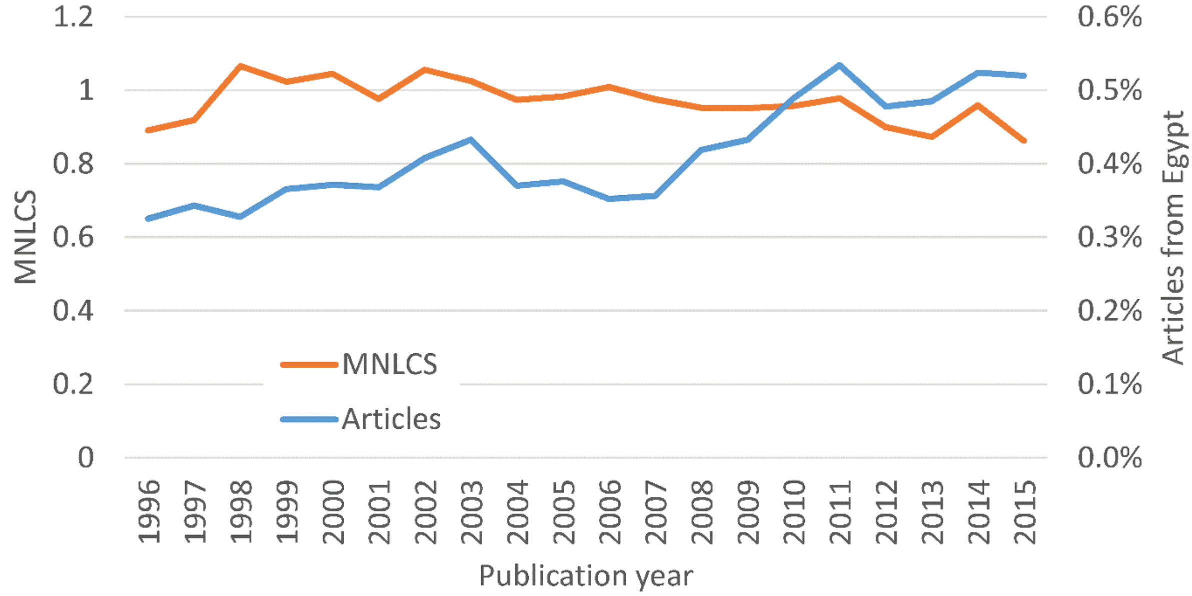

Figure 1: Egypt's percentage share of the world's journal articles (right hand y-axis and Articles line) and relative citation rate compared to the world average of 1 (left side y-axis and MNLCS line) based on Scopus data from 26 out of its 310 fields.

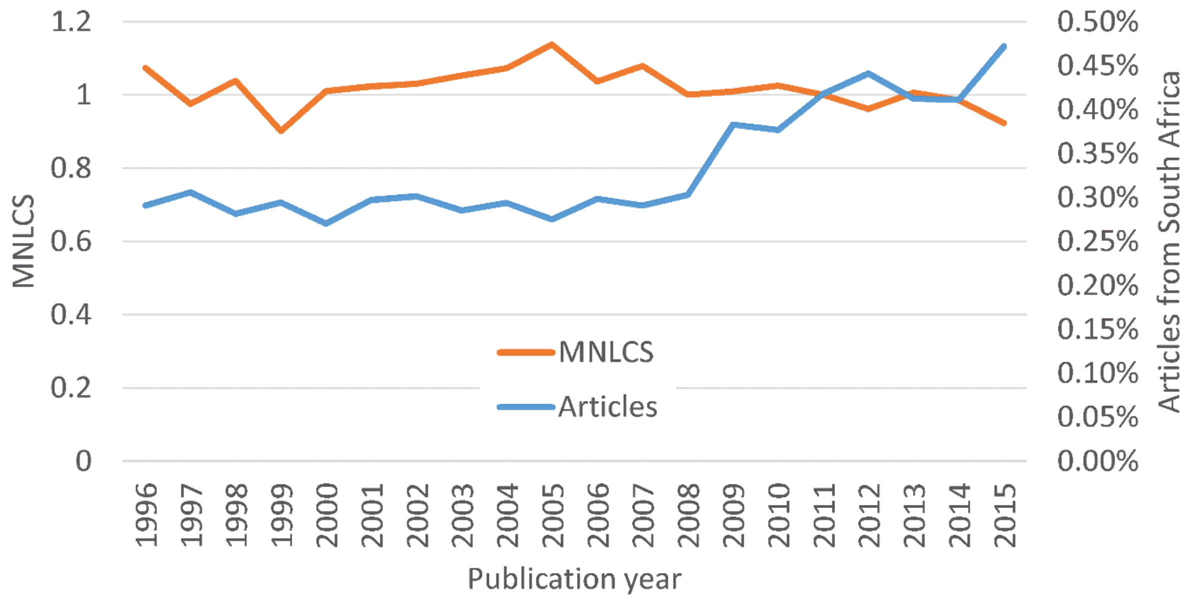

Figure 2: South Africa's Percentage Share of the World's Journal Articles and Relative Citation Rate (MNLCS)

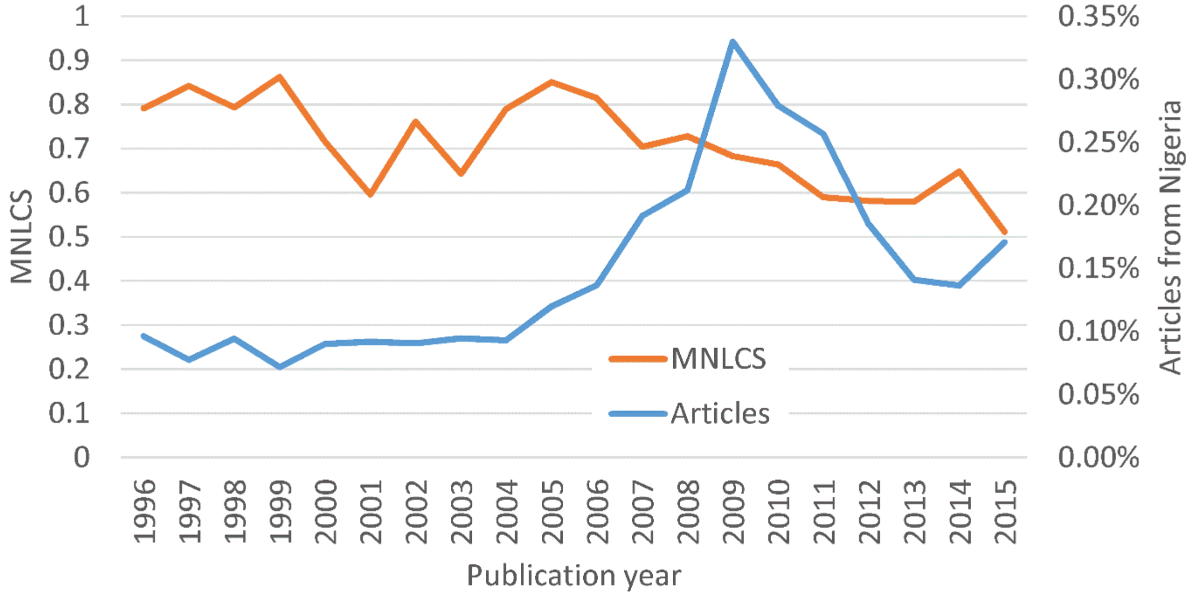

Figure 3: Nigeria's Percentage Share of the World's Journal Articles and Relative Citation Rate (MNLCS)

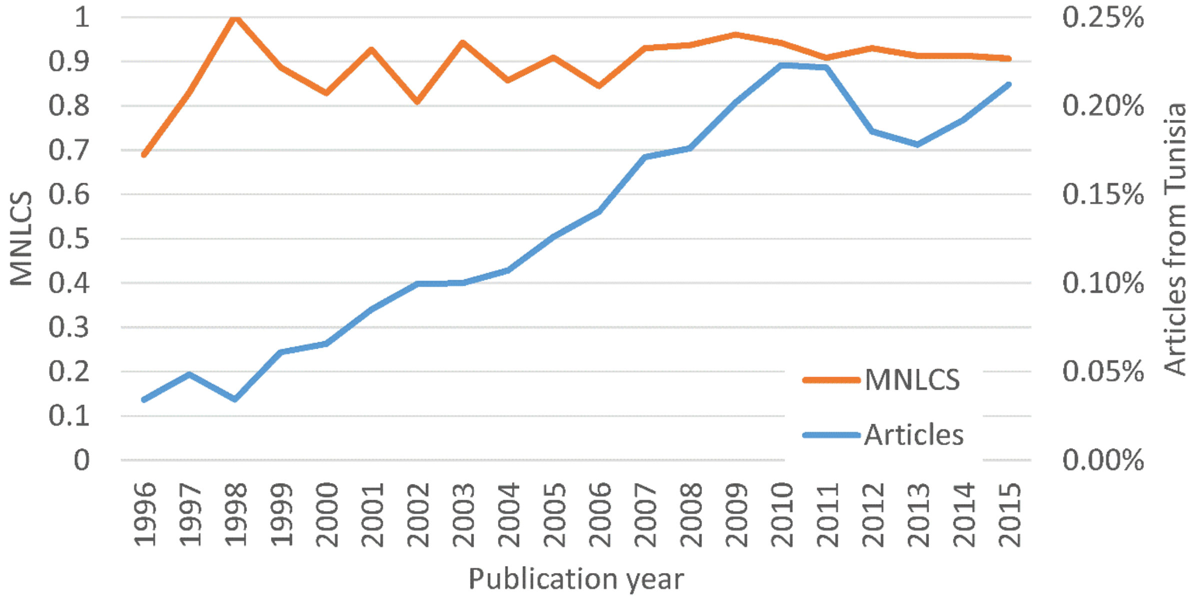

Figure 4: Tunisia's Percentage Share of the World's Journal Articles and Relative Citation Rate (MNLCS)

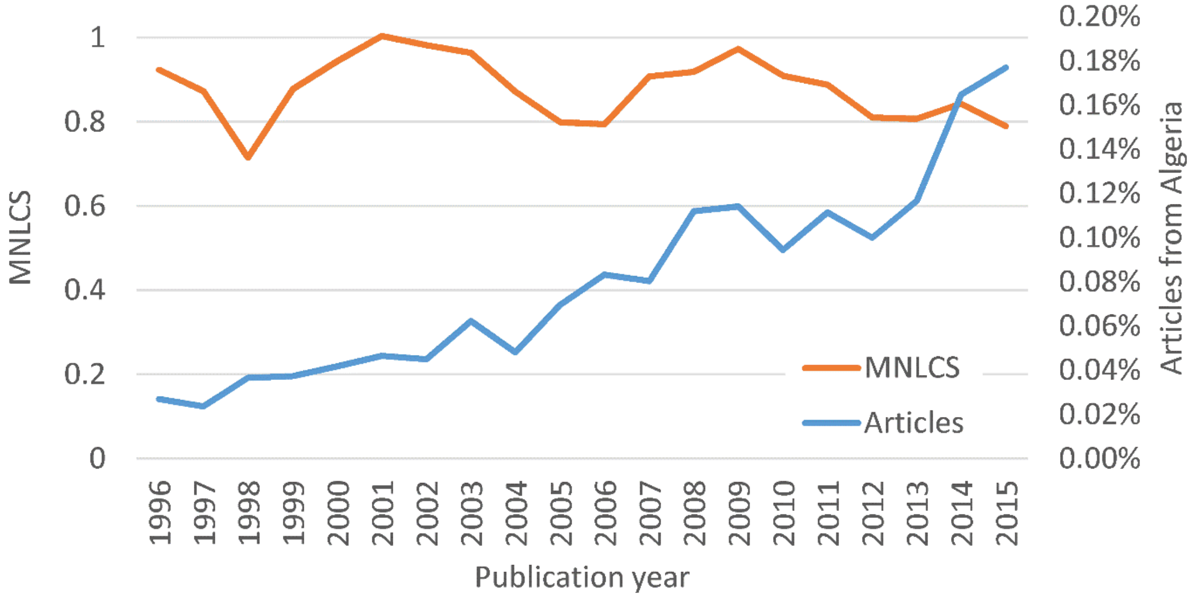

Figure 5: Algeria's Percentage Share of the World's Journal Articles and Relative Citation Rate (MNLCS)

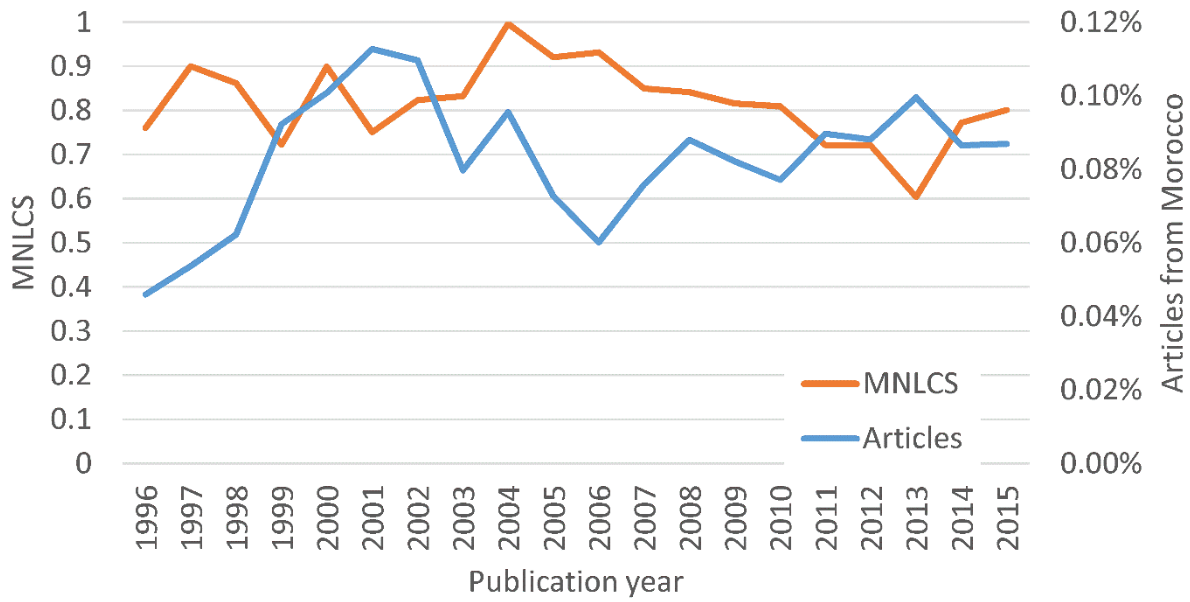

Figure 6: Morocco's Percentage Share of the World's Journal Articles and Relative Citation Rate (MNLCS)

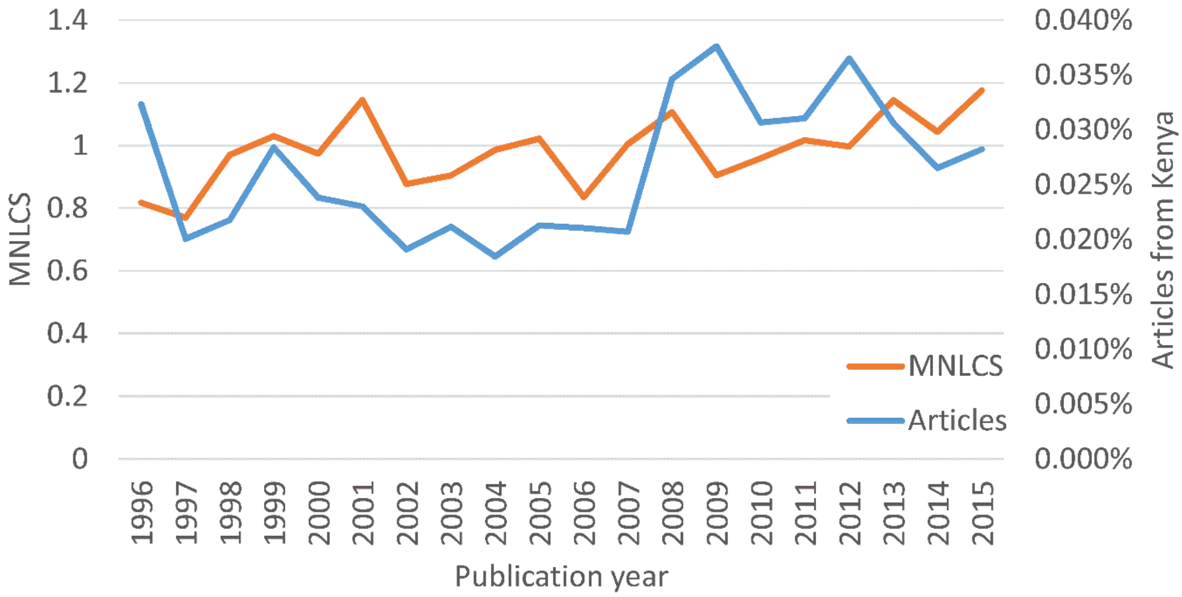

Figure 7: Kenya's Percentage Share of the World's Journal Articles and Relative Citation Rate (MNLCS)

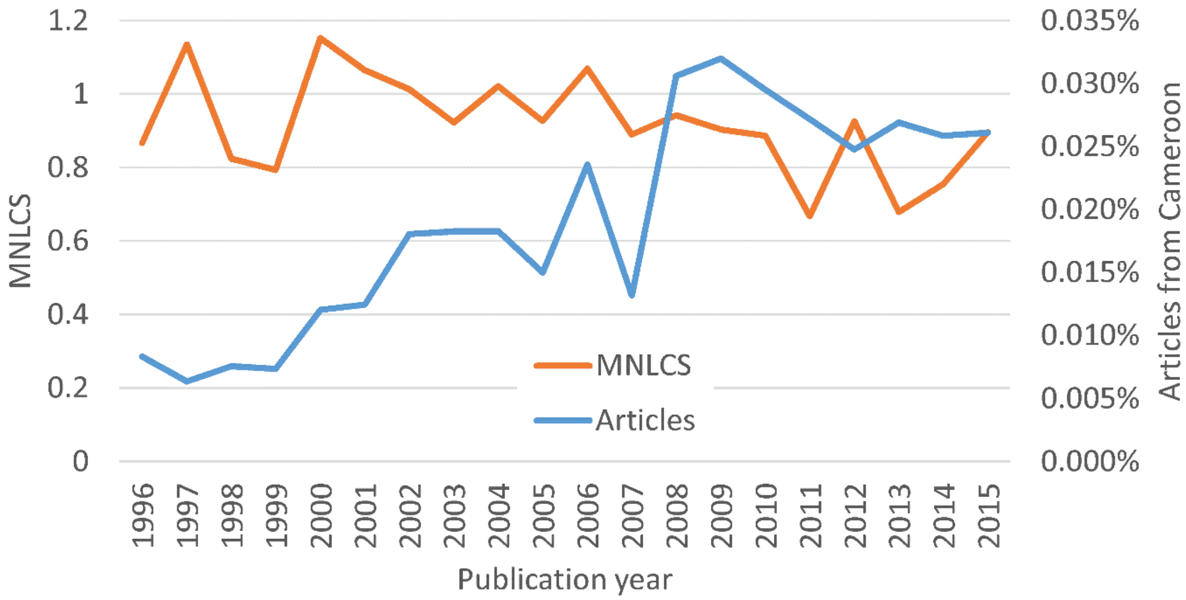

Figure 8: Cameroon's Percentage Share of the World's Journal Articles and Relative Citation Rate (MNLCS)

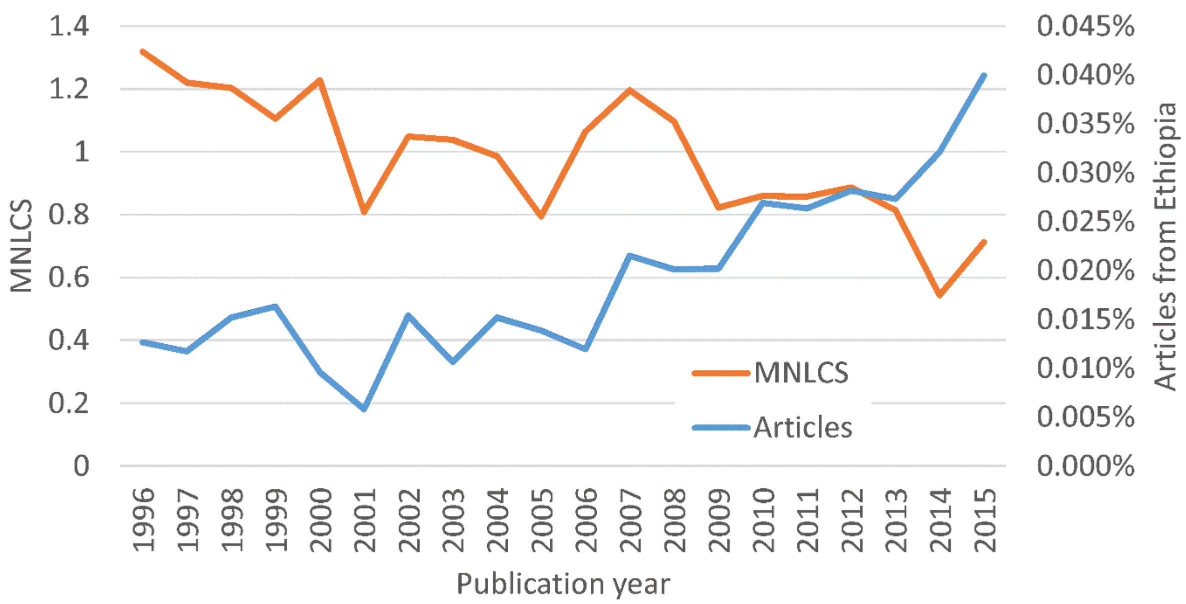

Figure 9: Ethiopia's Percentage Share of the World's Journal Articles and Relative Citation Rate (MNLCS)

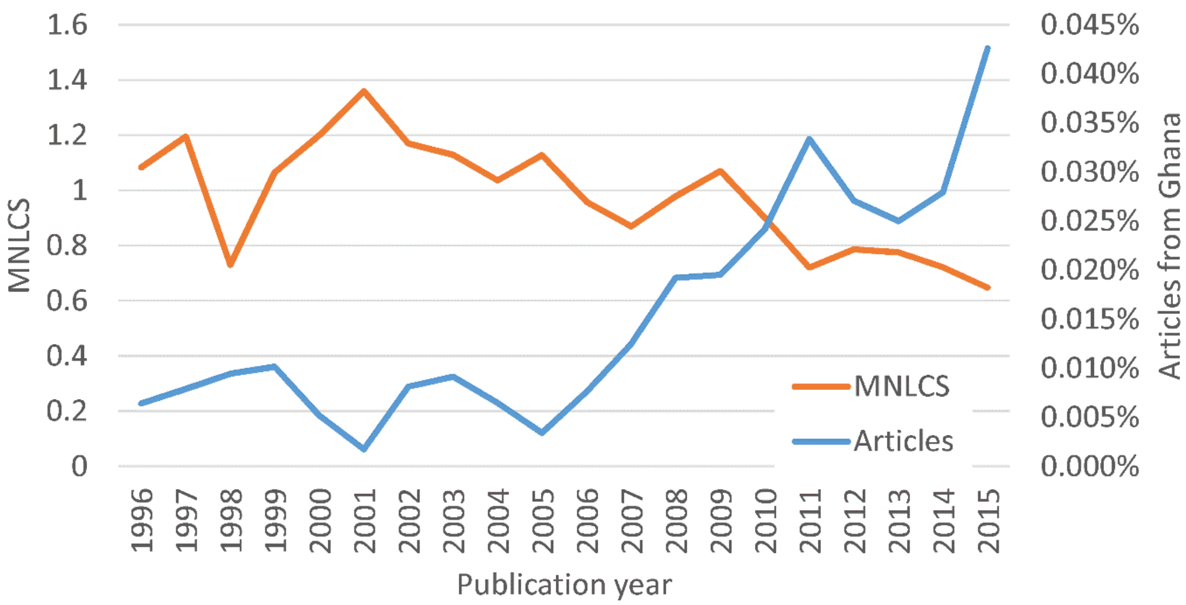

Figure 10: Ghana's Percentage Share of the World's Journal Articles and Relative Citation Rate (MNLCS)

Discussion and Limitations

The answer to the first research question is not surprising, since the increase in the relative share of the world's research from Africa has been previously noticed (Confraria and Godinho, 2015). In the context of the general increase in publishing output across Africa, the decreases for Zimbabwe and Botswana are worrying. However, in Zimbabwe, political or economic instability is presumably the cause. In Botswana, science and technology has been considered important by the government for a long time (CREST, 2007), but it is possible that funding is not reaching researchers because of delays in setting up research councils (Mouton, Gaillard, and Van Lill, 2014).

For the second research question, the reduction in the citation impact of African research in most countries relative to the world average is a major concern. A possible reason for some countries is a decrease in collaboration with experienced researchers from the USA, UK and France, which may affect the quality of the work produced. Despite this, the increase in self-reliance in Africa seems likely to generate long–term benefits that will eventually reverse this decline.

Since, in answer to the third research question, research in countries that produce little Scopus-indexed output do not tend to produce low impact outputs, an explanation is needed. This may be due to the predominance of international collaboration for articles in countries that produce little Scopus-indexed research (e.g., for Central Africa, see: Boshoff, 2009), so the quality of the articles may not fully reflect the international publishing capacity of the authors from the African countries involved. In Ghana, for instance, the need for international collaboration outside Africa for successful research is widely recognised (Owusu-Nimo and Boshoff, 2017). This is also supported by the data here. For example, the citation impact of forestry research from Madagascar was mostly above the world average (i.e., MNLCS values above 1, which is always the world average for MNLCS); but during 1996-2015, 36 out of its 39 forestry articles included international collaboration, as recorded in Scopus. Of these 36 international collaborations, 35 involved at least one European country or the USA, and one included only African collaborators (from Senegal). Of the two Madagascar-only articles, "Forest aboveground biomass estimates in a tropical rainforest in Madagascar: new insights from the use of wood specific gravity data" and "The evolution of cropping systems in the Lake Alaotra region of Madagascar. An approach based on temporalities", both had at least one author with a secondary affiliation in France (not shown in Scopus). Thus, only one of the 39 articles of Madagascar in this area did not have collaboration with researchers associated with the USA or Europe, "Vegetative propagation of Ziziphus mauritiana var. Gola by micrografting and its potential for dissemination in the Sahelian Zone". The average citation impact of research in countries with a low level of scientific productivity may therefore be primarily due to the contributions of their collaborators. This would explain why low productivity does not coincide with low citation impact.

The results are limited by being restricted to 26 out of the 310 Scopus categories and being incomplete for categories and years with more than 10,000 articles. The numbers therefore account for less than 10% of Scopus-indexed content. Since less developed nations tend to have more specialised science systems (Siddiqi, Stoppani, Anadon, and Narayanamurti, 2016) and this can be important for success (Confraria, Godinho, and Wang, 2017), it is likely that the strengths of many countries have been ignored, and that the results are therefore misleading for them. The Scopus classification system is also a limitation for the citation counts: a more accurate article-based classification (e.g., Waltman, and van Eck, 2012) might have normalised the citations more effectively. The low numbers of articles produced each year by the countries ranked 11–48 make their graphs in the online supplement difficult to draw robust conclusions from. This is because MNLCS values can be due to individual articles and cannot therefore directly reflect the national research capacity. Research outputs are not restricted to journal articles but can also include books, conference papers and reports, which were not covered here, and may have more impact. In addition, scholars can make valuable contributions to the national economy in other ways, such as consultancy (Wight, Ahikire, and Kwesiga, 2014), advising governments, or introducing state of the art technologies or techniques to local industries or the public. Thus, citation impact is not a direct indicator of the contribution that researchers make to the well-being, culture or prosperity of their country.

Conclusion

The almost universal increases in the share of Scopus-indexed publications are encouraging for African countries, suggesting growth in research capability. In contrast, reductions in impact per publication relative to the world average are worrying, but have a reasonable explanation (see the discussion above), and this trend may reverse in the long term.

Thus, except in Botswana, policymakers in Africa should be encouraged by the findings because they suggest that current policies are helping Africa to increase its scientific productivity. This increase has occurred against a background of a very low share of the world's scientific publications at the start of the period (1996), and will need to be sustained to ensure that African scientists can make increasingly major contributions to technology, education, arts and culture. In the longer term, it is important to keep a careful watch on average research impact. Although the decreases in average citation impact relative to the world average could be a side-effect of a decreasing reliance on international collaboration to produce Scopus-indexed research, the decreasing trend needs to be eventually reversed.

At the level of indicators, the current article is the first analysis of African research impact using an indicator, the MNLCS, that is not unduly influenced by the skewed nature of citation count data (Thelwall, 2017a). Its findings are therefore more statistically robust than those of previous analyses. This is a particularly important issue because of the low total numbers of articles produced in some countries (e.g., see: Thelwall and Fairclough, 2017).

A complete set of graphs for all 48 countries is available in the online supplement, as well as a separate graph for each country and field (48x26=1248 graphs) https://figshare.com/s/a35f858adb73488a1c0a. These can be consulted by scientists and policy makers in individual countries to check trends in their areas of interest.

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