Bibliometric Analyses on EU-Africa Research Co-publications in Health

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Building Bi-regional Partnerships for Global Challenges

CAAST-Net Plus is funded by the European Union's Seventh Framework Programme for Research and Technological Development (FP7/2007-2013) under grant agreement n° 311806. This document reflects only the author's views and the European Union cannot be held liable for any use that may be made of the information contained herein.

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D23 |PUBLIC / |September 2017

Table of contents

1. Tables and Figures

Figures

Tables

2. List of Abbreviations

DST	Department of Science and Technology
EU	European Union
FP6	Framework Program 6
FP7	Framework Program 7
NFF	New Funding Framework
R&D	Research and Development
SSA	Sub-Saharan Africa
S&T	Science and Technology
STI	Science, Technology and Innovation
USA	United States of America
WHO	World Health Organization
WoS	Web of Science
WP	Work Package

3. Executive Summary

This investigation has been commissioned by the Department of Science and Technology as co-leader in work packages 4 and 5 of CAAST-Net Plus. The investigation aims to undertake a bibliometric analysis of co-publications between Africa and Europe in the field of "health" and to inform relevant policy by revealing the trends in bi-regional research collaborations and the publication of research.

It is stated that the CAAST-Net goal was to contribute towards "an increase in the quality and quantity of bi-regional cooperation in science and technology between Europe and Africa, targeting areas of mutual interest and benefit through greater use of instruments under the FP7, as well as through other instruments of international cooperation, and through lobbying for greater synergy between R&D and development instruments" (CAAST-Net Plus History p2).

The recent report CAAST-Net Plus (2016 a) identifies that bi-regional health R&I cooperation is justified based on four reasons:

- Health challenges, like Ebola, are global in nature;
- International cooperation enables countries and organisations to exploit economies of scale by sharing the costs of producing in the field of health;
- Research cooperation is expected to increase scientific productivity;
- International research cooperation enables countries to access the existing global pool of scientific knowledge and build relevant capacities.

The results and recommendations of the current investigation are based on an in depth literature review and a set of bibliometric analyses. The bibliometric analyses utilise the Web of Science (WoS) and is based on an information retrieval approach of articles published in a number of journal subject categories.

The review related to research collaboration identifies the following:

- International collaboration is an international phenomenon fuelled by a multitude of factors such as access to facilities and funds;
- Historical ties;
- Linguistic preferences;
- Geographical proximity;
- Easiness of communications and others.

A number of authors suggest that international collaboration is replacing other models as the preferred method of building scientific capacity in developing countries. The existence of a critical research basis appears to be a prerequisite.

Collaborative research as it is manifested in co-authored articles including African researchers has increased substantially since 2003.

African collaboration takes place in particular disciplines neglecting scientific and technological disciplines underpinning modern economies and emphasised in other countries (e.g. China). There is limited collaboration among themselves of African researchers.

Individual African countries exhibit substantially higher collaboration patterns than the rest of the World. Twenty-nine African countries published more than 90 % of their research articles in collaboration with other countries.

Apart of the international forces leading to collaborative research, availability of resources appears to lead collaboration in Africa. Local historical and cultural characteristics are further superimposed on the phenomenon.

The literature related to health is succinctly summarised by World Bank et al (2013). They state: "The impressive improvement in SSA's research capacity in the Health Sciences demonstrates that persistent support and funding from development partners and governments pays off. There is clearly a large scientific talent base in Africa, but this needs to be trained and nurtured" (p29). They identify that a very large share of SSA research is the result of international collaboration. The World Bank notes that the high reliance on international collaboration for research, signals a lack of internal research capacity and the critical mass to produce international quality research on its own. Lack of local funding and limited uptake of research results by the governments are identified as weaknesses. It can be argued that both weaknesses are the result of limited understanding and acceptance of the importance of science and technology by the relevant authorities in the Continent.

Furthermore, the literature raises a number of policy questions:

- 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?

It has been argued that while it is difficult to estimate the counterfactual – what would have happened without the EU collaboration – it can be suggested that at least for a number of African countries, lack of international support will have devastating effects for their research systems.

The bibliometric analyses reveal the following:

- The number of health articles with at least one author from Africa and those in collaboration with Europe increased substantially during the period 1993-2015. The number of health articles have increased from 3 265 during 1993 to 16 808 articles during 2015 - a 5 fold increase. The collaborative articles in health increased from 631 articles in 1993 to 5 312 articles during 2015 - an 8.4-fold increase. Identification of the number of health related articles with authors from Africa but without European co-authors shows an increase of 4.3-fold over the period. This growth is almost half of the collaborative African-EU health growth. European collaboration appears to increase the number of collaborative articles over and above the rate of articles without EU partners.

- Thirty one point six percent (31.6%) of health articles in Africa were produced in collaboration with European partners during 2015.

- Health articles constitute 36% of all articles produced in Africa during 2015. This figure is higher than those of China (27%); India (28%) and Russia (13%) indicating the importance and sensitivity of the topic for Africa.

- The activity index of health research for Africa during 2015 is revealing. The activity index is estimated as the ratio of the given field's share in the continent's publication output to the given field's share in world's publication output. An index of 1 indicates that the continent's research effort in the given field corresponds precisely to the world average. The health activity index for Africa 2015 is 0.96. This means that Africa undertakes health research in accordance with its research size and in accordance to international norms.

- The growth rate of health research appears to be accelerating after 2005. Examination of the growth rates of the health articles with other sets of articles shows that the forces leading to increasing the number of health articles in Africa are beyond the influence of Europe and/or South Africa. Furthermore, it seems that the driving forces affect all African scientific disciplines. This issue requires further research.

- Examination of the growth rates of publications over different periods shows that during the FP6 period (plus 1) the average African scientific discipline was growing almost at the same rate as the African-Europe collaborative articles in health. The growth in the African health articles without European co-authors was almost 10% higher. During the FP7 period (plus 1) the growth in the collaborative articles was higher than in the African articles without EU collaboration and in African articles of all disciplines. It is noted that the growth in the collaborative articles during FP7 was substantially higher than in the FP6 period. It appears that FP7 had a positive influence in the production of co-publications in the field of health although causality is always difficult to verify.

- Comparisons of the citation profiles of the African articles in health produced with and without EU collaboration shows that health articles with EU collaboration perform more than twice better in terms of citations per article than the set without EU collaborators. Similarly, the H-Indices of the collaborative sets are 60 to 70 % higher than the indices without the EU collaborators.

- Investigation of the funders (as they acknowledged by the authors) in the set of articles co-authored among African and EU authors shows that the Wellcome Trust was the most often mentioned funder. It was mentioned in 3041 articles. The National Institutes of Health were mentioned 1846 times. The European Union (in its various permutations European Commission, European Union; European Community etc.) was mentioned 1252 times. The Medical Research Council UK followed with references in 1143 articles. Bill and Melinda Foundation were mentioned 805 times and the National Research Foundation 614 times. The Tunisian and Egyptian Government also appeared in approximately 90 articles each. When European collaborators were excluded, the most often active funder was the variety of National Institutes of Health, with more than 4300 references over the period. The National Research Foundation followed with approximately 2500 references.

The report advances the following recommendations:

- CAAST-Net and CAAST-Net Plus supported by the Framework Programmes, appear to have been successful in encouraging more and better bi-regional STI cooperation for enhanced outcomes related to health. The success is particular importance as Africa has the lowest life expectancy (an overarching health indicator for the post-2015 development agenda) in the World and 36% of the Continent's research is health related. It is suggested that similar approaches can be utilised to develop research capacity and cooperation in fields of common interest and priority.

- The collaborative patterns in a variety of African countries reveal dependency of the local research systems on international resources. Furthermore, the high degree of the overall collaboration indicates that there might be limited scope for additional expansion. African governments, multilateral organisations and their international partners should focus in developing research capacity in the Continent. This is probably the most critical factor for the future of STI in Africa. Providing funding rewards for research publications has been proven effective in South Africa (Pouris 2012) and can be used across the Continent.

- The small scientific size of Africa and of African countries makes the issue of research priories of critical importance. Prioritization is required across the broad main domains (e.g. environment research versus health research versus manufacturing research etc.) and within each domain (e.g. neurosciences versus oncology versus immunology). The field of foresight is recognised to be useful in that domain. National and regional exercises can introduce the concept to the relevant authorities. Countries with expertise in the field with the support of multilateral organisations and the African partners can lead in the effort. Such exercises could also guide the European Commission in enhancing its collaborative efforts with Africa.

- The sub-critical size of research systems, lack of funds for co-financing and dependence on international resources are manifestations of the refusal or neglect of African governments to accept that innovation is the fundamental cornerstone of economic growth, employment, international competitiveness and development. African governments, multilateral organisations and their international partners should aim to institutionalize the governance and support of science, technology and innovation. The establishment of high level Ministerial Committees responsible for the management of the innovation systems (as in Korea, China and elsewhere); the establishment of extra-budgetary funds for research (as in Brazil) and the institutionalisation of relevant advocacy activities are possible approaches to be followed.

4. Introduction

The Network for the Coordination and Advancement of Sub-Saharan Africa-EU Science and Technology Cooperation (CAAST-Net) was a project funded by the European Commission. The establishment of the Network followed the development of the Joint Africa-EU Strategy during 2007. The purpose of the Joint Strategy is to take the Africa-EU partnership to a new strategic level with a strengthened political dialogue and enhanced cooperation at all levels.
Under the Joint Africa-EU Strategy, eight so-called partnerships made up the priority areas. These were1:

1. Peace and security;
2. Democratic governance and human rights;
3. Regional economic integration, trade and infrastructure;
4. Millennium Development Goals;
5. Climate change;
6. Energy;
7. Migration, mobility and employment;
8. Science, information society and space.

Partnership 8 as it came to be known carried a specific mandate to advance bi-regional collaboration in the domains of science, information society, and space.

CAAST-Net was conceived against the background of a global consensus that capacity in science and technology is essential to economic competitiveness, sustainable development and poverty reduction. This new geo-political relationship reflects the global trend towards seeing scientific and technological RDI as a driver of economic growth, a move away from a 20th century focus on capital, natural resources and labour (EC 2002).

The CAAST-Net goal statement was as follows:
“An increase in the quality and quantity of bi-regional cooperation in science and technology between Europe and Africa, targeting areas of mutual interest and benefit through greater use of instruments under the FP7, as well as through other instruments of international cooperation, and through lobbying for greater synergy between R&D and development instruments”. (CAAST-Net Plus History p2).

A challenge for P8 has been establishing the modalities for translating the proposed P8 activities into concrete projects, which can accomplish the articulated objectives. This challenge was tackled in 2008 through the design of 19 large outline projects which constituted the so-called Book of Lighthouse Projects such as the Africa Research Grants Programme, the African Virtual Campus, African Leadership in ICT, and Global Monitoring for Environment and Security for Africa.
CAAST-Net period 2008-2012 and it was followed by CAAST-Net Plus. CAAST-Net Plus is a network of 26 partner organizations from Europe and sub-Saharan Africa working together to support bi-regional cooperation in research and innovation.

CAAST-Net Plus aims to:
“Encourage more and better bi-regional STI cooperation for enhanced outcomes around topics of mutual interest, and particularly in relation to the global societal challenges of climate change, food security and health.

[1] EU (2014) “The Africa-EU Partnership: 2 Unions, 1 Vision” at http://www.africa-eu-partnership.org/sites/default/files/documents/jaes_summit_edition2014_en_electronic_final.pdf

Foster discussion among stakeholders for gathering informed opinion and experience about the bi-regional cooperation process, formulating and disseminating it in such a way as to be admissible to the formal bi-regional STI policy dialogue process and to programme owners."(p1)[2]

DST is co-leader in work packages 4 and 5. The objectives of WP 4 are as follows:

- To provide a knowledge base to enrich formal and informal policy dialogue processes, including analytical evidence drawn from monitoring and analysing the progress and results of bi-regional science, technology and innovation (STI) cooperation;
- To develop and implement concepts for bi-regional STI policy stakeholder forums;
- To support and monitor the implementation of policy dialogue recommendations at the request of the Bureau of the Africa-EU STI policy dialogue platform;
- To consult a wide base of stakeholders to gather and consolidate evidence to inform international cooperation policies and/or instruments.
-

In the above context, DST commissioned this bibliometric analysis, which aims to monitor research co-publications between Africa and the EU. The bibliometric studies on co-publications will provide analyses that aim to inform policy by revealing the trends in bi-regional research collaborations and the publication of research thereof.

5. Objectives

The terms of reference state that the studies will:

- Analyse national, regional and global discourse and policy imperatives on climate change, health and to an extent food security and topics related to these societal grand challenges which are of both national, regional and global interest;
- Provide an analysis on the impact of co-publications within the bi-regional research and innovation landscape;
- Uncover and provide a critical analysis of the factors which have driven collaborative research between African researchers and their European counterparts;
- Highlight the financing trends of health and climate change research (as they are revealed by the authors of research);
- Compare research co-publications outputs between EU-Africa;
- Review literature related to EU-Africa research and innovation collaboration landscape;
- Identify the trends in health research and climate research co-publications between EU and Africa from 1993-2015;
- Compare trends in FP6 and FP7 funded research and innovation co-publications, as well as preceding R&I funding instruments;
- Analyse the rate in co-publications between the years 1993 and 2015 and
- Provide policy recommendations that will influence the numbers and activity of research co-publications.

6. Methodology

The results and recommendations of the current investigation are based on an in depth literature review and a set of bibliometric analyses. The literature review is distinguished into literature related

[2] CAAST-Net Plus "Science, Technology and Innovation Cooperation between Sub-Sahara Africa and Europe" accessed at https://caast-net-plus.org/about/goals

to research collaboration: definition and types; collaboration motives, objectives and impacts; collaborative R&D&I patterns in Africa; and climate change.

Bibliometric analyses require the identification of a relevant database and a methodological approach for identifying the under examination (target) documents.

There are a number of specialized databases (e.g. Chemical Abstracts covering physics and chemistry; Compendex covering engineering and technology; Embase covering medical sciences, etc.). However, these databases cannot be used for scientometrics purposes as their coverage is not homogeneous –they include different types of data or no data at all for particular topics and they usually contain monographs, theses; books and articles – and/or they incorporate in the databases documents which are not examined for quality. Furthermore, not all databases include all authors' addresses, documents from other countries (for comparative purposes) and so on and hence, the identification of all contributors to the research is not possible. Similarly, citation incorporation is necessary for the identification of the impact of the different sets of publications.

The most frequently used databases for bibliometrics are the Web of Science and Scopus. The two databases compete with each other and internationally published comparisons find small differences. For this investigation, we propose to utilise the Thomson-Reuters (WoS) databases as they cover all the important journals in the world and data are available for the period under investigation.

The WoS classifies the various journals to more than 250 journal subject categories. A subset of the categories cover health research and are referred to by a number of researchers for various bibliometric analyses (RAND 2015). Together, these subject categories constitute a comprehensive database of scientific literature in which biomedical and health research is very prominent and relatively well covered.

Table 1 shows the 80 journal subject categories that are used in order to identify the relevant health research publications.

Collaborative articles were identified from the authors' addresses. Data are identified per annum for the period 1993-2015 and hence, time trends can be discerned. Two different sets of articles are identified – collaborative articles between Africa-Europe in health – and African only articles (without European collaborators). Comparisons of the two sets can provide evidence of the European influence on Africa's related research. Furthermore, comparisons with the broad growth of research articles in Africa can reveal the impact of the collaboration.

Trend analysis of the collaborative efforts during the Sixth Framework Programme (FP6) for Research and Technological Development (2002-2006), the Seventh Framework Programme (FP7) for Research and Technological Development (2007-2013) and most recently, the Horizon 2020 Framework Programme for Research and Innovation (2014-2020) can provide indication of impact, changes in emphasis/support and similar.

Table 1: Health journal subject categories

Allergy	**Neuroimaging**
Anatomy & morphology	Neurosciences
Andrology	**Nursing**
Anaesthesiology	Nutrition & diabetics
Audiology & speech-language pathology	**Obstetrics & gynecology**
Behavioural sciences	Oncology
Biochemical research method	**Ophthalmology**
Biophysics	Orthopedics
Biotechnology & applied microbiology	**Otorhinolaryngology**
Cardiac & cardiovascular systems	Parasitology
Cell & tissue engineering	**Pathology**
Cell & tissue engineering	Pediatrics
Cell biology	**Peripheral vascular disease**
Chemistry, medicinal	Physiology
Clinical neurology	**Primary health care**
Critical care medicine	Psychiatry
Dentistry/oral surgery & medicine	**Psychology, applied**
Dermatology	Psychology, biological
Developmental biology	**Psychology, clinical**
Emergency medicine	Psychology, developmental
Endocrinology & metabolism	**Psychology, multidisciplinary**
Engineering, biomedical	Psychology, psychoanalysis
Food science & technology	**Public, environmental & occupational health**
Gastroenterology & hepatology	Radiology, nuclear medicine & medical imaging
Genetics & heredity	**Rehabilitation**
Geriatrics & gerontology	Reproductive biology
Gerontology	**Respiratory system**
Health care sciences & services	Rheumatology
Health policy & services	**Social work**
Hematology	Sport sciences
Immunology	**Substance abuse**
Infectious diseases	Surgery
Integrative & computational biology	**Toxicology**
Medical informatics	Transplantation
Medical laboratory technology	**Tropical medicine**
Medicine, general & internal	Urology & nephrology
Medicine, research & experimental	**Veterinary sciences**
Microbiology	Virology

As Thomson Reuters indexes the funders of research as they appear in the various publications, bibliometric analysis can identify the frequency of appearance of the various funders of collaborative bi-regional research.

For the assessment of the citation impact of the collaborative articles, we will develop two sets of articles – health articles in collaboration with European researchers – and African articles in the field without European collaboration. For the two sets, we estimate their H-Index for recent years and

make comparisons. The h-index for an author, country or set of articles is the number *h* of papers among an author's or a country's/set's number of publications that have at least *h* citations each (Hirsch 2005). Similarly, the average number of citations received per article and citations without self-citations per article will be estimated for the same periods of two sets of articles. As both sets have been identified through the same process (subject discipline and publishing period) and differ only in the co-authors the comparison will be valid and revealing.

The convergence of the finding in the literature review and the bibliometric analyses lead to the development of a set of recommendations.

7. Literature Review

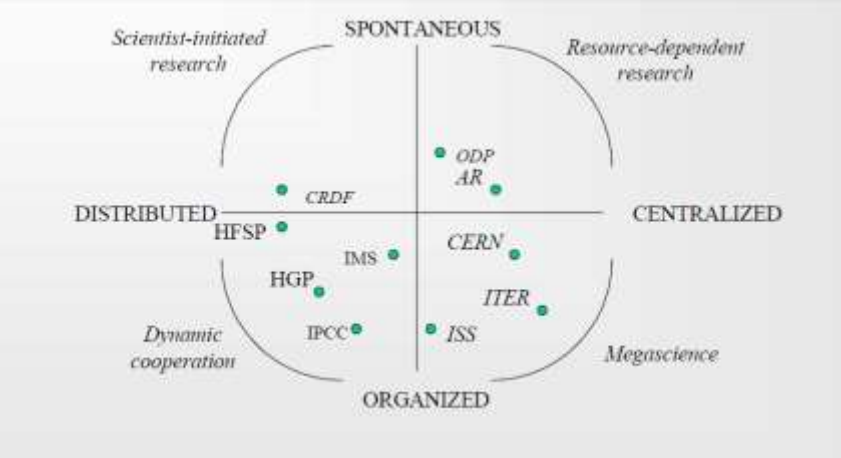
7.1. Research collaboration: Definition and Types

There are limited efforts internationally to answer the question what constitute research collaboration even though common sense defines collaboration as the 'working together of individuals to achieve a common goal of producing new scientific knowledge'. This however, raises the question of how closely researchers have to work together in order to constitute a collaboration. On the one extreme, it can be argued that anyone providing an input to a particular piece of research should be considered a collaborator. On the other extreme, it can be argued that only those who contributed directly to all the main research tasks over the duration of a project should be termed as collaborators/co-investigators.

The precise nature and magnitude of any collaboration cannot be easily determined by the usual methods of observation, interviews or questionnaires due to the complex nature of human interactions. For example, Katz et al (1997) argued that the line separating informal links between scientists, and more formal collaboration, is also blurry. Moreover, both the nature and magnitude of the contribution of the various participants are likely to change during the course of a research project.

Katz et al, (1997) elaborating on the issue concluded that research collaboration has a very fuzzy or ill-defined border.

There are different types of collaboration that in turn create different management requirements. Figure 1 presents the different types of collaboration. The Figure shows two axes that can describe different organisational forms of collaboration. One axis runs from spontaneous ("bottom-up") research deriving from the interests of scientists, to highly organised research defined by a funding party. The other axis defines degree of centralization of the effort. These two axes form four quadrants, which characterize collaborative research. Activities on the left-hand side of the diagram might be described as "dynamic", in that the collaboration requires active learning and sharing of tasks and information among researchers who are often geographically dispersed. Activities on the right-hand side might be described as material/institutional research in that collaboration relies on a shared resource or common research location. Mega-science projects could be placed in the bottom right quadrant, organised and centralised. Scientist-initiated research would be placed in the upper left quadrant.



*Key: **HFSP**=Human Frontiers Science Program; **HGP**=Human Genome Project; **AR**=Arctic Research; **IMS**=Intelligent Manufacturing Systems; **IPCC**=Intergovernmental Panel on Climate Change; **CERN**=European Organisation for Nuclear Research; **ITER** (fusion research); **ISS**=International Space Station; **ODP**=Ocean Drilling Program; **CRDF**=Cooperative Research and Development Fund.*

Figure 1: Types of Collaboration. Source: RAND 2002

Similarly, multinational collaborations are characterised according to the participants. There are:

- National programmes open to foreign participation
- Bilateral programmes
- Multilateral programmes
- Regional programmes (e.g. EU Framework programmes)
- Bi-regional programmes (e.g. EU-Africa programme)

Programmes do not need to be static. For example, they can start as bilateral activities and subsequently become multilateral by allowing additional partners.

Furthermore, the programmes may vary in terms of scope. For example, they can vary with regard to scientific or technological domain they cover or according to a spectrum from basic research to technology transfer and near market deployment.

The disciplinary character of collaboration presents another interesting dimension. Empirical studies show an increase in research joining together several disciplines (Wagner et al 2011) and a number of policy authorities including at the EU, have increasingly supported this mode of research (Van Rijnsoever et al 2011).

Publications with multiple authors are considered the natural output of any research collaboration. De Solla Price (1963) was among the early proponents of using multiple-author papers as a measure of changes in collaboration.

Currently there is a consensus that co-authorship is reflective of collaboration and organisations like the National Science Foundation (NSF) in the USA and the European Commission in Europe publish regularly relevant statistics and analyses.

Although the assessment of collaboration using co-authorship is by no means perfect, it nevertheless has certain advantages. Firstly, it is invariant and verifiable. Secondly, it is a practical method for quantifying collaboration. Thirdly, the approach is viable for large samples (in contrast to case studies), and finally, the approach is unobtrusive and non-reactive (does not affect the collaboration process).

7.2. Collaboration motives, objectives and impacts

Research collaboration is a sociological phenomenon receiving attention by researchers and governments internationally (Yeung *et al*. 2005). Researchers investigate the effects, modes, dynamics and motives of collaborations, while governments utilise research collaboration as a policy instrument for technology transfer from universities and research councils to industry (intra-collaboration); for knowledge transfer from abroad (inter-collaboration); as means to improve diplomatic relations with other countries by creating good will; and gain political capital (RAND 2002), and others.

Researchers collaborate with each other for various reasons. They do so in order to improve their visibility and recognition (Narin *et al.,* 1991), in order to utilise expensive equipment and facilities which are not under their control (Meadows *et al.,* 1971; Schubert *et al.* 2010); to acquire expertise and new ideas (de B Beaver *et al.* 1978) needed for their research and others. Among the other reasons are included historical ties; linguistic preferences; geographical proximity; and specific problem issues (e.g. disease control or natural disaster mitigation) (Adams et al. 2013). The substantial fall in the costs of air travel and communication, advances in effective information and communication methodologies further accelerated collaborative activities during the recent decades. Finally Wagner et al. (2005) argued that patterns in international collaboration in science can be considered as network effects and that only the European FPs noted by Georghiou (1998) mediated relationships at that level.

In the policy domain, scientific collaboration has become an important component of science, technology and innovation policy internationally with substantial resources allocated by governments for this objective. Government involvement in collaboration programmes is based on the recognition that research does not stand alone. It is one aspect of an intensively competitive ecosystem of knowledge development and commerce. Recognition of this context sets the basis for multinational collaborations. Governments are becoming active supporters of research collaboration and institutionalize such efforts. Examples include Australia (Australian Government, 2011); Canada (NSERC, 2013) and others.

National strategies for participation in that ecosystem can have one or more of several bases. For example, they may be based on the desire to develop the country's S&T competence with a view to its future exploitation. A government strategy might have the aim to open their researchers to external ideas and then to induce them to compete with their peers internationally. Another might be based on developing the attractiveness of the country for inward investment – not just on R&D. (CISTRANA 2006).

It should be emphasised that every country will have different motivations for collaboration in different sectors and technical fields based on the perceived potentials and anticipated developments in science and technology.

Russell, (1995) and Wagner et al. (2001) suggested that international collaboration is replacing other models as the preferred method of building scientific capacity in developing countries. However, they qualified their findings by stating "Nevertheless, S&T capacity building does not automatically result from these activities" (Wagner, *et al.* 2001 pXV). More specifically the authors suggest that "if the country lacks the ability to absorb that knowledge and put it to good use, its potential positive and lasting effects will simply drain away... In the case of scientific research, this requirement constitutes a baseline level of scientific infrastructure to make collaboration an effective mode of capacity building. Nations, having capacity below this baseline level, cannot measurably use collaboration to build capacity. Above the baseline, collaboration becomes a viable (if not entirely sufficient) mechanism for augmenting capacity... The required baseline level of capacity is not fixed

and likely differs among countries, field of studies and even among specific research problems within fields" (p62).

A number of authors (Narin et al. 1991), hypothesised that smaller countries may have smaller single country publications due to the scarcity of collaboration opportunities at the national level. 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 of the investigation 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. Georgiou (1998) suggested that researchers in less developed countries could participate in collaboration only when a formal framework and budget is in existence. Similarly, Boshoff (2009) identified that north–south collaboration takes place in a particular format with the south collaborator assisting in field wok and data collection. In other words, the developed countries' researchers seek collaboration in order to access data and conditions available in the developing countries.

From a theoretical, utilitarian perspective, international collaboration is not without its challenges. S&T policy aims to maximize the benefits of a particular group/institution or nation. However, 'advantageous' collaboration may not be easily achievable (or feasible) among different partners and similarly, approaches that maximize national benefits may not achieve the same effects at a multi-country or regional context. A second issue that is apparent in the policy context is that collaboration is an instrument of S&T policy aiming at achieving a variety of different policy objectives (targets). The most often mentioned objectives are:

- to get access to knowledge unavailable locally;
- to share costs and risks; to get access to partners' markets;
- to achieve standardization and to fulfill political considerations.

Gaining access to knowledge and sharing costs and risks are objectives internal to S&T policy, while the other objectives should be seen as external to science and technology but achieving objectives in other spheres of governance. Obviously, there is no reason why collaboration cannot be formulated in such a way as to achieve more than one objective (e.g. one internal to S&T and one external) but building such instruments may be challenging. Other concerns expressed include the argument that the spending in 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 may subordinate 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 additional line of research argues that international collaboration is a self-organising system with its own dynamics. Leydesdorff, *et al.* (2008) suggests that international collaboration can be considered as a communications network that is different from national systems, and has its own internal dynamics and exists primarily as a self-organising system.

The authors argue that the new order of things means that nations must take careful stock of the conduct of science at the global level as well as at the national and regional levels. As the system expands, useful innovation can increasingly occur somewhere else. Identifying innovations and making them locally available will be a major challenge for policy makers. The authors further argue that finding ways to evaluate distributed scientific research and local absorptive capacity is another. Furthermore, they suggest that it may become increasingly difficult to track spending and attach it to outputs and outcomes, which has been the model for much of public accountability for science in

the past and that managing a complex, open system requires constructing new incentives to encourage knowledge flows and participation that favours the peripheral members.

Empirical evidence shows that research is increasingly collaborative (Gibbons et al 1994, Van Rijnsoever et al. 2011). The EC (2015) states " Whereas fewer than 5% of the papers in 1980 comprised authors' addresses from at least two countries, this figure is now closer to 25%, a remarkable fivefold growth in 35 years" (p8). However, despite this body of evidence there is no any theoretical satisfying explanation for the phenomenon. Wagner (2005) suggested that "the theoretically satisfying explanation may be elusive in part because we have an incomplete understanding of the dynamics of collaboration at the global level and how it differs from nationally or institutionally based research or localized collaboration" (p1).

The literature on the effects of collaboration focuses on issues of productivity and impact. The findings related to productivity are that scientific output, as measured by publications in the open literature, is closely dependent on the frequency of collaboration among authors (Radhamany, 2014, Eslami, *et al.* 2013, Abramo, G et al. 2009).

As far as impact is concerned, Narin, *et al*. (1991) and Gomez, *et al*. (1995) identified that internationally co-authored papers tend to have on average higher citation rates. However, Moed (2005) identified that citation depends on who is collaborating with whom. He suggests that when scientifically advanced countries collaborate with each other the citation impact of those papers is higher than it is the case for the purely domestic papers. When scientifically advanced countries collaborate with scientifically less advanced countries, the outcome may affect negatively the citation rates of the advanced country.

7.3. Collaborative RDI patterns in Africa

Relatively few investigations examine the collaborative patterns of research in the African Continent. A recent World Bank report provides general background information about research and collaboration in Africa. The World Bank report (WB and ELSEVIER 2013) examines the research enterprise over a decade from 2003 to 2012 of three different geographies in sub-Saharan Africa (SSA): West & Central Africa (WC), East Africa (EA), and Southern Africa (SA). Some of the findings are as follows:

- Sub-Saharan Africa has greatly increased both the quantity and quality of its research output.
- SSA research output in Science, Technology, Engineering and Mathematics lags that of other subject areas significantly.
- SSA, especially East Africa and Southern Africa, relies heavily on international collaboration and visiting faculty for their research output.
- Research collaboration in Africa features a number of particular characteristics that are critical to understand for the design of successful policies. Some of the characteristics are as follows: SSA's research capacity appears fragmented across regions with each region collaborating very little with one another. There appears to be little knowledge transfer and collaboration between African academics and the corporate sector.

The authors make a number of statements that we quote here:
"The impressive improvement in SSA's research capacity in the Health Sciences demonstrates that persistent support and funding from development partners and governments pays off. There is clearly a large scientific talent base in Africa, but this needs to be trained and nurtured." (P3)

"A very large share of SSA research is the result of international collaboration" (P4). The World Bank notes that the high reliance on international collaboration for research signals a lack of internal research capacity and the critical mass to produce international quality research on its own. These results echo to a certain extent previous investigations (Thomson Reuters 2010; Boshoff 2009; Radhamany 2009). Similarly, Onyancha et al (2011) identified that collaborative production of knowledge among sub-Saharan African countries is minimal.

An EC (2014) investigation focused in mapping best practice in STI initiatives between Africa and Europe. The investigation aimed to assess existing bi-regional STI cooperation initiatives and to identify successful, best practice models of cooperation between Africa and Europe, as well as to identify gaps and effective financial mechanisms that have a positive impact.

The report identifies features and components of collaboration viewed as good practice and which appear to be key to effective collaboration. The report states: "Partnerships and personal relations are supremely important, and effective partnerships are seen as a key criterion for effective collaboration. Joint funding, strong leadership and effective governance; clarity and understanding of joint objectives; strong interpersonal relations; equitable resource and benefits sharing; and full transparency and communication all build mutual trust and foster co-ownership, which are necessary conditions for optimal efficiency" (p8).

The authors identify that co-ownership is a core value of bi-regional cooperation. They further state: "The single most important factor in fostering co-ownership is co-financing, whether through joint financing with existing instruments or through the creation of new, dedicated co-funded instruments" (p7). The European Developing Countries Clinical Trials Partnership (EDCTP) and the Product Development Partnership Programme are provided as examples of good practice co-financing model.

The authors suggest that the highest priorities for collaboration are design, piloting and scale-up of co-financing arrangements using existing instruments and the joint financing of new instruments. At this point, it should be emphasised that the lack of co-financing and research financing in general is the result of the fact that African governments do not recognise the importance and priority of science and technology for development. This is in contrast to international recognition of innovation as the cornerstone of economic growth. During the 2008 crisis, support for innovation was suggested as a remedy. The European Union has urged member countries to increase investment in R&D and consider ways to increase private sector R&D investments. Similarly, in the USA the Government, as part of the *American Reinvestment and Recovery Act* of 2009, has increased its spending on R&D related to climate change by US$ 26.1 billion and to energy by US$ 6.36 billion.

A recent article (Pouris et al. 2014) investigated the research emphasis and collaboration in Africa during the 2007-11 period. The authors' findings indicate that the Continent emphasises research in medical and natural resources disciplines to the detriment of disciplines supporting knowledge based economies and societies. Furthermore, they identify that the collaborative patterns in Africa are substantial higher than in the rest of the world.

More specifically the authors identified 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.). Disciplines underpinning modern technologies and economies (i.e. engineering, physics, material sciences, instrumentation and similar were identified to be

underemphasised. The authors compare African priorities with those of China and ask rhetorically why Africa does not follow international examples.

The authors compare the share of internationally collaborative articles for Africa (**54%**) with those of a number of other countries. 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%**). The authors state: "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" (p2177). A sample update for 2014-15 indicated the same pattern. Examples include Zambia **6%** without international collaborators; Gambia **2.6%**; Mozambique **5.4%**; Angola **9.8%** and Burundi **7.3%.**

The authors note that the number of collaborative articles with authors outside Africa is many times bigger than the African collaborative articles. The authors ask:

a. 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.
b. Similarly, why does Egypt collaborate almost exclusively with non-African countries?" (p2184). They suggest that African collaboration is not driven by local researchers searching for collaborators, but by the availability of resources and interests outside the Continent.

The authors conclude: "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?" (p2184).

Confraria et al. (2015) estimated that the number of African publications increased from a share of **1.4%** in the 1990s to **2.6%** of the World literature during the 2010s. Furthermore, they have summarised the forces enabling collaboration. They suggest that Algeria and Tunisia have unique links with France and that the share of international co-authorship with France is 42 and **33%** respectively. The same happens with the UK's former colonies. Malawi and Kenya have collaboration shares with the UK of 45 and **24%**, respectively. Similarly, they quote Adams et al. (2010) who speculates that the USA is a main collaborating country mainly because of the researchers who have studied in the USA. Other examples mentioned refer to Gambia as the site for long-term research into tropical diseases for the UK's Medical Research Council, the Wellcome Foundation with similar, major research investments in Kenya and Malawi and similar.

To summarize, the literature review identifies the following:

- Research collaboration does not have an exact definition. It has "a very fuzzy or ill-defined border".
- International collaboration is an international phenomenon fuelled by a multitude of factors such as access to facilities and funds; historical ties; linguistic preferences; geographical proximity; easiness of communications and others.
- A number of authors suggest that international collaboration is replacing other models as the preferred method of building scientific capacity in developing countries. However, there

are a number of caveats linked to the above statement. The existence of a critical research basis appears to be a prerequisite.
- Collaborative research as it is manifested in co-authored articles including African researchers has increased substantially since 2003.
- African collaboration takes place in particular disciplines neglecting scientific and technological disciplines underpinning modern economies and emphasised in other countries (e.g. China).
- There is limited collaboration among themselves of African researchers.
- Individual African countries exhibit substantially higher collaboration patterns than the rest of the World. Twenty-nine African countries published more than 90 % of their research articles in collaboration with other countries.
- Apart of the international forces leading to collaborative research, availability of resources appears to lead collaboration in Africa. Local historical and cultural characteristics are further superimposed on the phenomenon

7.4. Health Research

Health research collaboration has a long history across borders, and has drawn the attention of many researchers and policy makers. In such efforts, it is expected that the partners from the *developed* country contributes expertise as well as sophisticated laboratory and other special resources that are not available in the less developed countries. The partners in the *developing* country provide local clinical and other contextual knowledge. Contributions in-kind from the host institutions in the developing country may complement the financial donation from the developed country partner. While the benefits are profound there are always concerns related mainly to the prioritization mechanism in such collaborations (Swingler et al. 2005).

Cooperation between Africa and Europe has a long history and it is guided by a number of instruments and modus operandi. The Joint Africa –Europe Strategy (2007) and AU's Africa Health Strategy 2007-2015 cover also health issues and set relevant priorities.

The recent report CAAST-Net Plus "Africa-EU Research Collaboration on Health: A Critical Analysis of the Scope, Coordination and Uptake of Findings" (2016 a) identifies that bi-regional health R&I cooperation is justified based on four reasons:

- Health challenges, like Ebola, are global in nature.
- International cooperation enables countries and organisations to exploit economies of scale by sharing the costs of producing in the field of health.
- Research cooperation is expected to increase scientific productivity.
- International research cooperation enables countries to access the existing global pool of scientific knowledge and build relevant capacities.

Furthermore, the report identifies that presently collaboration is realised using a variety of financing mechanisms, policy frameworks and institutional arrangements. Examples include bilateral cooperation initiatives and EU programmes, such as the Sixth Framework Programme (FP6) for Research and Technological Development (2002-2006), the Seventh Framework Programme (FP7) for Research and Technological Development (2007-2013) and most recently, the Horizon 2020 Framework Programme for Research and Innovation (2014-2020). The report also refers to global initiatives such as the Global Fund to Fight AIDS, Tuberculosis and Malaria ('the Global Fund'), the Global Alliance for Vaccines and Immunization, the Global Alliance for Chronic Diseases, the World Health Organization Special Programme for Research and Training in Tropical Diseases (WHO/TDR).

It also includes private sector actors, both for-profit and non-profit organisations e.g. Wellcome Trust (UK) and the Bill and Melinda Gates Foundation.

The overall assessment of the study is that Africa-EU health R&I cooperation needs a much clearer framework setting out shared priorities and funding mechanisms.

A recent report of the World Bank and Elsevier (2013) concludes that Sub-Saharan Africa's share of global health research increased from 0.44% to 0.72% during the decade 2003-2012. It is suggested that this is the result of international cooperation.

Similarly, Breugelmans et al (2015) investigated bibliometrically to measure research from Europe and Africa related to poverty related diseases. They conclude that the volume and citation impact of papers from sub-Saharan Africa has increased since 2003, as has collaborative research between Europe and sub-Saharan Africa. Similarly, they suggested that the European & Developing Countries Clinical Trials Partnership contributes to high-impact, collaborative research published in high-impact journals.

Chuang et al (2011) investigated public health research in Africa during the period 1991-2005. They identified an increasing trend in the number of publications in the field as well as an increasing trend in the number of co-authored publications with researchers from abroad. Collaborations were mainly with European and North American countries. Regional analysis identified that the northern countries were more diversified disciplinary than the rest of Africa. The authors identified that the extent of collaboration with researchers in Asian countries, compared to European or North American countries, is much lower. They suggested that because of similarities in public health concerns, it might be beneficial for both African and Asian countries to engage in more frequent exchanges on knowledge, expertise and research ideas.

Particular aspects of health research have been examined based on bibliometric approaches in the context of African countries. Pouris et al (2010) investigated the issue of HIV/AIDS. The authors identified that that South Africa spends considerable research effort in the field, well above what is expected from its relative scientific size. South Africa focuses almost 5.5% of its national research effort on HIV/AIDS research, while the European countries spend less than 2% of their relevant efforts and Japan only 0.5%. It was argued that despite increasing South African efforts, the country produced only 3.15% of the world's research in the field and hence it was doubtful that the HIV/AIDS epidemic could be resolved by South Africa alone without the support of the rest of the world.

Furthermore, it was identified that the country's universities were sub-critical in terms of research outputs. The authors discussed a number of policy implications.

8. Findings

In order to set the scene, we identified all articles dealing with Health from the period 1993 – 2015. Figure 2 shows the time evolution of the publication output in the field as they are indexed in the WoS database. The figure indicates that during the period 1993 to 2015, the number of health articles published per year increased by a factor of 2.4 whereas in the same time period the overall number of papers covered by the WoS databases increased also by a factor of approximately two (Bornmann et al. 2015). The figure shows that the rate of increase changed in the after the early 2000s.

It is important to note that during 2015 there were indexed more than 600 000 articles.

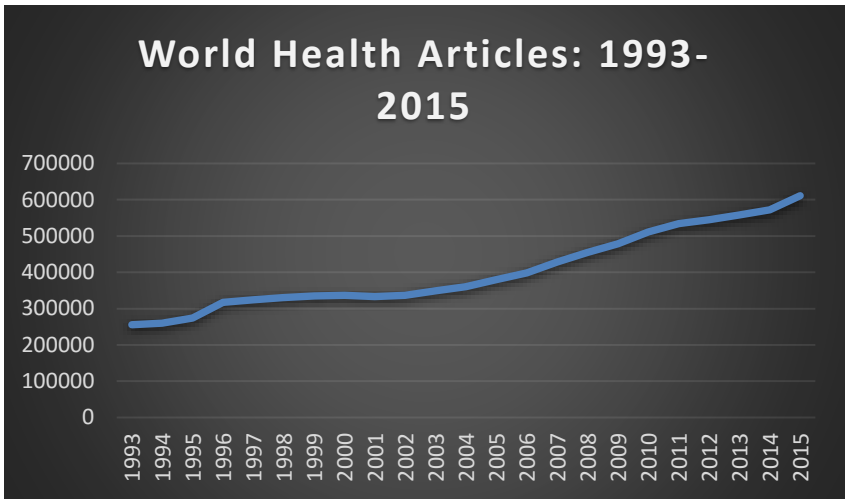


Figure 2: Health articles- World 1993-2015.

Identification of the most prolific health disciplines shows that during the period biochemistry molecular biology were on top of the list contributing 11.1%. The followers were:

- neurosciences 6.5%;
- surgery 6.0%;
- pharmacology-pharmacy 6.0%; and,
- oncology 5.3%.

The most prolific countries were:

- USA 35.9%;
- Germany 7.7%;
- England 7.6%;
- Japan 7.5%; and
- China 5.2%.

Figure 3 shows the growth in the number of articles (all disciplines) with at least one author from the African Continent. The number of articles in WoS increased from 8 269 during 1993 to 46 908 during 2015. This is a substantial growth in comparison with the general growth of science. During the period the number of articles from Africa increased by a factor of 5.6.

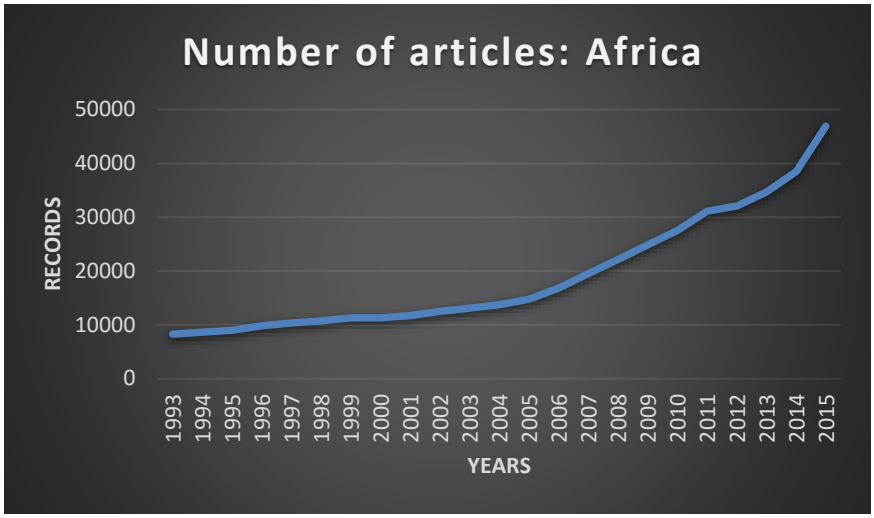


Figure 3: Number of articles from Africa 1993-2015.

South Africa is the most prolific African country having produced 31.8% of the Continent's articles. Egypt (21.4%); Tunisia (7.8%) and Nigeria (7.3%) follow in the list. The most emphasised research areas are chemistry (10.4%); engineering (7.6%); physics (7.2%); and environmental sciences ecology (5.6%).

The main collaborating countries during the period were: USA (12.9%); France (11.3%); England (7.3%); Germany (4.9%); Canada (2.7%); Australia (2.4%); Netherlands (2.4%); Italy (2.4%); and Spain (2.2%).

It is important to re-emphasise here that 54% of the African articles are produced with an international co-author and twenty-nine African countries published more than 90 % of their articles in collaboration with other countries (Pouris et al 2014). As we have argued this indicates a high dependency on international resources for research in Africa.

In contrast with Africa, Europe is the major producer of research internationally (27.5% of the World literature during 2013) and produces the majority of its research (~75%) without international partners. Europe's major partners are USA (10.8%); Canada (2%); China (1.7%); Australia (1.67%) and Africa (1.6%).

In the EU-Africa collaboration (134 180 articles over the period) the most prolific collaborative research areas were: chemistry (10.2%); physics (9.1%); environmental sciences ecology (6.5%); engineering (6.4%) and infectious diseases (5.5%).

Africa – EU collaboration increased from 1452 articles during 1993 to 14 608 articles during 2015. Examination of the revealed priorities during the 1993-1997 and 2011-2015 periods shows that chemistry and physics were topping the revealed priorities in both periods. In the earlier period, the above scientific disciplines were followed by public environmental occupational health; materials science; tropical medicine and biochemistry molecular biology.

During the most recent period, the scientific disciplines following chemistry and physics were: environmental sciences ecology; engineering; science technology other topics and infectious diseases. It is emphasised that the increase in co-authorship is reflected in the majority of scientific disciplines.

The countries most often active in the collaboration are France, South Africa, England, Germany, USA, Tunisia, Egypt, Morocco and Algeria.

The most often collaborating organisations are the Centre National de la Recherche Scientifique, University of London, University of Cape Town, Sorbonne Universites Comue, Institut de recherché pour le developpement, and University of Witwatersrand.

The most often mentioned funders (among the top 25 funders) are the Wellcome Trust (3222); European Union/Commission/ EU (2457); Medical Research Council (871); CERN (776); FCT Portugal (763) and National Research Foundation/South Africa (1284).

Figure 4 shows the number of health articles with at least one author from Africa during the period 1993-2015. The number of relevant articles increased from 3 265 during 1993 to 16 808 articles during 2015. This is a 5-fold increase during the period and it is of the same magnitude as the total number of publications from the Continent.

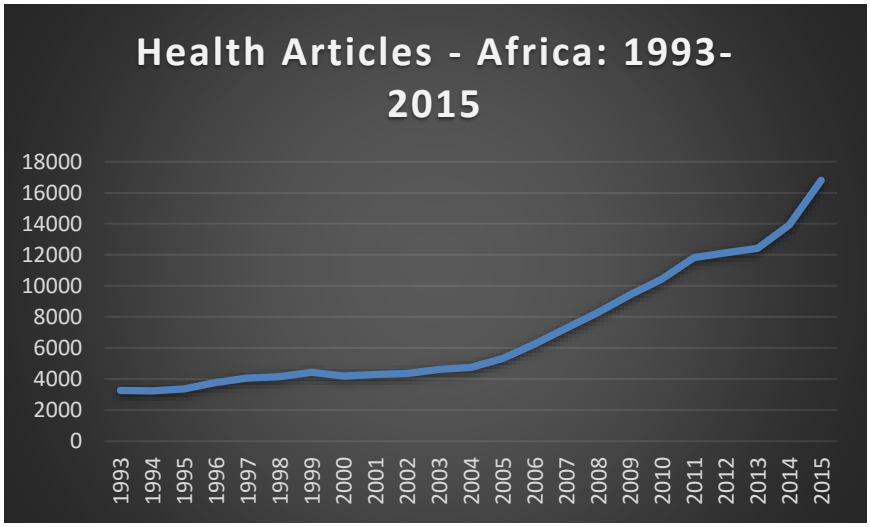


Figure 4: Health articles – Africa 1993-2015.

We estimated the activity index of health research for Africa during 2015. The activity index is estimated as the ratio of the given field's share in the continent's publication output to the given field's share in world's publication output. An index of 1 indicates that the continent's research effort in the given field corresponds precisely to the world average. The Health activity index for Africa 2015 is 0.96. This means that Africa undertakes health research in accordance with its research size and in accordance to international norms.

Figure 5 shows the number of health articles that have at least one author from Africa and one from the European Union. The numbers have increased from 631 articles in 1993 to 5312 articles during 2015 - an 8.4-fold increase. The disciplines emphasised are: infectious diseases; public environmental occupational health; immunology; tropical medicine and microbiology.

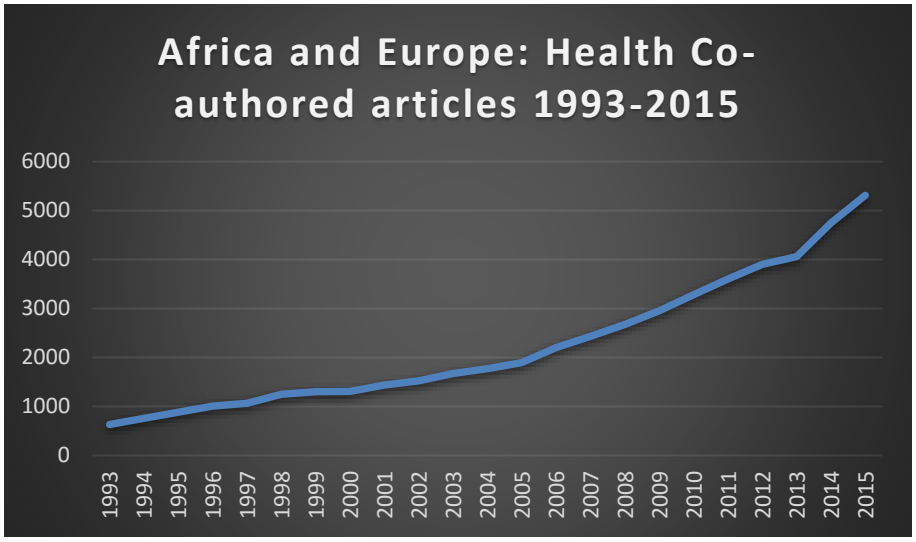


Figure 5: Health articles: Africa and EU in collaboration 1993-2015

The slope appears to have changed after 2005 and after 2013. During 2015, 31.6% of health articles in Africa were produced in collaboration with European partners.
Figure 6 shows the number of health related articles with authors from Africa but without European co-authors. The increase has been 4.3-fold over the period. This growth is almost half of the collaborative African-EU health growth.

The disciplines emphasised are: public environmental occupational health; pharmacology pharmacy; infectious diseases; medicine general internal and biotechnology applied microbiology.

It is interesting to note that infectious diseases was on top of the list of health articles produced in collaboration between Europe and Africa (14.3% of total). The relevant figure of Africa without Europe was 7.4% of the total and in the world health articles was 2%. Similarly, immunology is third in the list of Africa Europe collaboration with a contribution of 10% while in the list of Africa without Europe the contribution is 5.4% and in the world list 4.3%. In this context, it should be emphasised that the European emphasis on health is in biochemistry molecular biology (11%); neurosciences (7%); surgery (5.6%); pharmacology pharmacy (5.6%) and oncology (5.4%). The European list coincides with the world-wide list.

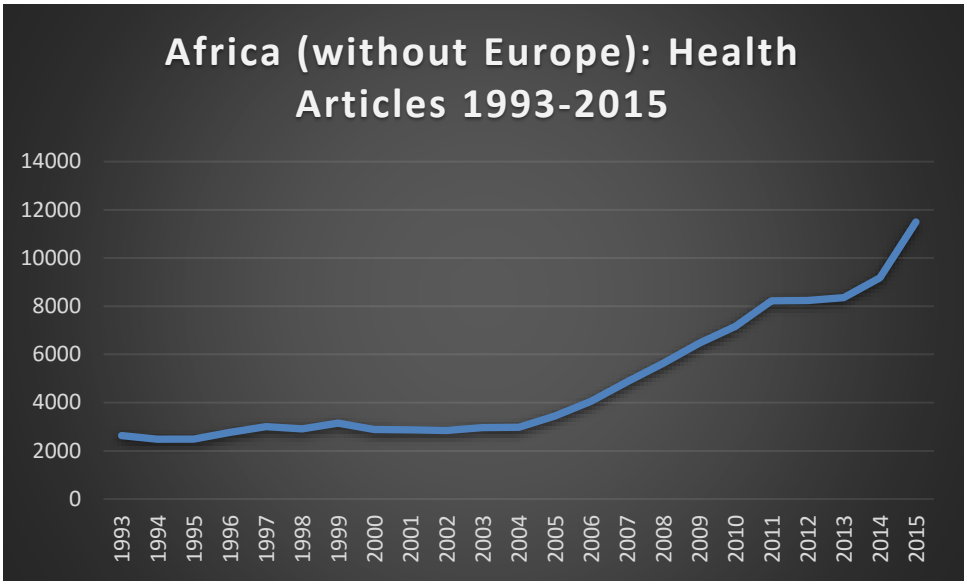


Figure 6: Health articles: Africa without EU 1993-2015.

Comparisons of figure 5 and 6 show, that the collaboration between Africa and Europe contributes 31.6% of the Continents health articles. It is estimated that only 45% of Africa's health articles are without international co-authors. The increase in the health articles without European co-authors and the size of the set may also indicate that the health discipline in Africa is not dependent to the same degree as other disciplines in international collaboration. It should be mentioned however, that there may be spill-over from African researchers collaborating with Europeans to independent research and hence, indirect influence of the bi-regional collaboration.

We have examined the changes in growth in different relevant sets of health articles before and after 2005 (year of inflection). Table 2 shows the relevant growth rates for the periods 2003-2005 and 2005 to 2007.

Table 2: Health articles growth before and after 2005.

Groups	2003-2005	2005-2007
World: Health	8.8%	12.8%
Africa and EU: Health	13%	28%
Africa not EU; Health	16%	41%
Africa not SA: Health	12.5%	42%
Africa all disciplines	12.6%	32.2%

The table reveals that after 2005 the rate of growth increased across all groups. The growth in the African groups was higher that the global growth during the 2003-2005 period. During the 2005-07 period, the growth in the African articles groups was substantially higher than the earlier period. It should be noted that the growth in health articles in Africa was growing substantially even when we took away the articles with EU collaborators and South Africa. South Africa was contributing 51% of the Continents health article during 1993; 44% during 2005 and 35% during 2015.

It is apparent that the forces leading to increasing the number of health articles in Africa are beyond Europe and/or South Africa. Furthermore, it seems that the driving forces affect all African scientific disciplines (as the row Africa all disciplines shows). This issue will require further research.

The growth in the number of publications in South Africa has been investigated (Pouris 2012). It was identified that even though a variety of forces were in interplay "The across the board increases in the number of publications indicates that the increases were the result of a factor which was introduced during the early 2000s and was affecting all scientific disciplines. The obvious intervention was the new funding framework (NFF) for higher education institutions. The NFF for higher education institutions was published in terms of the Higher Education Act, No. 101 of 1997, in the Government Gazette (No. 1791) on 9 December 2003 and was implemented in the 2004/05 financial year"(p323). The NFF supports financially the higher education institutions according to their research outputs (number of publications and number of post-graduates). It is apparent that the particular policy instrument was bringing the desirable effect—an increase in the number of the country's publications.

In order to estimate the effects of FP6 (2002-2006), and FP7 (2007-2013) on the number of articles, we estimated the growth in the period of the two programmes. The figures cover the period of the duration of each program plus one year in order to take into account the delay from the initiation of the support until the publication of the articles.

Table 3: Growth of health articles during the support of FP6 and FP7.

Program	Growth in Africa+ EU Health articles	Growth in African without EU Health articles	Growth in African articles (all disciplines)
FP6	45.6%	64%	48.9%
FP7	77.6%	62%	73.8%

Table 3 shows the growth in the number of publications for the two programmes and the growth in all African articles during the period. The table shows that during the FP6 period (plus 1) the average African scientific discipline was growing almost at the same rate as the African-Europe collaborative articles in health. The growth in the African health articles without European co-authors was almost 10% higher. During the FP7 period, (plus 1) the growth in the collaborative articles was higher than in the other two categories. It is noted that the growth in the collaborative articles during FP7 was substantially higher than in the FP6 period. It appears that FP7 had a positive influence in the production of co-publications in the field of health.

Table 4: H-Index and Citation comparisons of African health articles with and without EU collaboration.

Set	H-Index	Average citations per article	Average citations per article without self-citations
African health articles (without EU) 2013	46	5.89	5.82
African health articles (without EU) 2014	39	4.13	4.04
Health collaborative articles: Africa and EU 2013	74	12.58	12.46
Health collaborative articles: Africa and EU 2014	70	9.62	9.49

Table 4 compares the citation profiles of the African articles in health produced with and without EU collaboration (up to April 2017). The table shows that health articles with EU collaboration perform more than twice better in terms of citations per article than the set without EU collaborators. Similarly, the H-Indices of the collaborative sets are 60 to 70 % higher than the indices without the EU collaborators.

We have investigated the funders (as they acknowledged by the authors) in the set of articles co-authored among African and EU authors. The Wellcome Trust was the most often mentioned funder. It was mentioned in 3041 articles. The National Institutes of Health were mentioned 1846 times. The European Union (in its various permutations European Commission, European Union; European Community etc) was mentioned 1252 times. The Medical Research Council UK followed with references in 1143 articles. Bill and Melinda Foundation were mentioned 805 times and the National Research Foundation 614 times. A variety of National Institutes of Health appeared in the list as well. The Tunisian and Egyptian Government also appeared in approximately 90 articles each.
When we exclude European collaborators the most often appearing funder is the variety of National Institutes of Health with more than 4300 references over the period. The National Research Foundation followed with approximately 2500 references.

It is apparent that the major funders of health research are the Wellcome Trust, the National Institutes of Health and the European Union. The increase in references to NIH when Africa-Europe collaboration is excluded should be noted.

We have also examined the production of relevant research of the geographic regions in the Continent. Table 5 shows the regional outputs and the relevant research emphasis. It should be noted that Northern Africa is the most productive in the field and Central Africa the least productive region. Similarly, the research emphasis of Northern Africa is in pharmacology-pharmacy, which is different from the rest of Africa.

Table 5: Regional outputs and research emphasis

Region	Number of Articles	Research Emphasis
Northern Africa	53713	Pharmacology Pharmacy Biochemistry molecular biology
Eastern Africa	30871	Public Environmental Occupational Health Infectious Diseases
Western Africa	32177	Public Environmental Occupational Health Tropical Medicine
Central Africa	5235	Infectious Diseases Tropical Medicine
Southern Africa	47746	Public Environmental Occupational Health Infectious Diseases

9. Discussion and Recommendations

Health is a critical issue in Africa. Issues of health affect economic growth; development; productivity etc. While the gap between African life expectancy and European life expectancy (an overarching health indicator for the post-2015 development agenda) has narrowed by 4.9 years since the year 2000, there are still 22 African counties with life expectancies lower than 60 years. These countries are at the lower end of the relevant range internationally (WHO 2016).

Africa is a scientifically small Continent. Its scientific contribution has increased from 1.4% of the world's scientific literature in the 1990s to approximately 2.6 % in the current decade, but it is still very small particularly if the size of population is taken into account. The small research size of the Continent makes of critical importance the issue of priorities. What approaches can optimize the limited capabilities in the Continent?

Collaborative research as it is manifested in co-authored articles including African researchers has increased substantially since 2003. Individual African countries exhibit substantially higher collaboration patterns than the rest of the World.

The literature review shows that collaboration is a critical factor in the development of research systems in Africa. Fifty four percent of the African articles are produced with an international co-author and twenty-nine African countries publish more than 90 % of their articles in collaboration with other countries. This finding means that there are very few publishing researchers that may be added in the collaborative cohort. It interesting to mention, that the collaboration share in India is 20 %; in China 23% and in USA 33%.

The Africa-EU collaboration contributes 30% of the total research output of the African Continent. While it is difficult to estimate the counterfactual – what would have happened without the EU collaboration – it can be argued that at least for a number of African countries, lack of international support will have devastating effects for their research systems.

The analysis shows a 10-fold increase in the co-authorship set (all disciplines) between Africa and Europe during the 1993-2015 period. The disciplines emphasised during the period are chemistry and physics (approximately 20% of the co-authorship set).

The literature review identifies that there are a number of forces that lead to collaborative research internationally (easiness of communications; growth of big science etc). Apart of the international forces leading to collaborative research, availability of resources appears to lead to collaboration in Africa. This line of argument can explain the across all the African countries increase in collaboration, the preference for non-African collaborators and the emphasis on research disciplines of interest to international partners. Local historical and cultural characteristics and the small size of African countries (smaller countries may have smaller single country publications due to the scarcity of collaboration opportunities at the national level) are additional factors superimposed on the phenomenon. Certain researchers even suggested that international collaboration is replacing other models as the preferred method of building scientific capacity in developing countries.

There is substantial evidence that internationally co-authored papers tend to have on average higher citation rates. However, there is also evidence that when scientifically advanced countries collaborate with scientifically less advanced countries, the outcome may affect negatively the citation rates of the advanced country.

Our analysis indicates that collaborative research emphasises different scientific disciplines than health research without European partners. This may be indicative of the priorities of the leading researchers.

In summary, it is evident that EU collaboration is critical for Africa both in terms of research activity and citation impact. An issue that is of importance is related to research priorities. International partners may not always have the same priorities as the local system and may "misdirect" the local researchers. Research priorities related to health are of particular concern for Africa as the burden of disease, which may provide indication of priorities, varies from country to country, over different

developmental paths; preferences on emphasis on prevention and cure, communicable versus non-communicable diseases etc. This critical issue should always be in the radar of African authorities.

Our bibliometric analysis identifies the following:

- Identification of the number of health articles with at least one author from Africa during the period 1993-2015 shows that the number increased from 3265 during 1993 to 16 808 articles during 2015. This is a 5-fold increase during the period and it is of the same magnitude as the total number of articles from the Continent.
- The number of health articles with at least one author from Africa and one from the European Union increased from 631 articles in 1993 to 5312 articles during 2015 - an 8.4-fold increase.
- The increase in the number of health related articles with authors from Africa but without European co-authors has been 4.3-fold over the period. This growth is almost half of the collaborative African-EU growth in health. The higher growth rate of collaborative articles is indicative of the impact of Europe in the Continent.
- After 2005, the rate of growth in the health articles increased. Detailed analysis shows that the forces leading to increasing the number of health articles in Africa are beyond the influence by Europe and/or South Africa. Furthermore, it seems that the driving forces affect all African scientific disciplines. It can be suggested that this is a broad issue in need of further research.
- In order to estimate the effects of FP6 (2002-2006), and FP7 (2007-2013) on the number of articles, we estimated the growth in the period of the two programmes. The figures cover the period of the duration of each program plus one year in order to take into account the delay from the initiation of the support until the publication of the articles.

- The analysis shows that during the FP7 period (plus 1) the growth in the collaborative articles was higher than in the non-collaborative number of articles and the all-scientific disciplines category. It is noted that the growth in the collaborative articles during FP7 was substantially higher than in the FP6 period. It appears that FP7 had a positive influence in the production of co-publications in the field of health. It should be emphasised that causality is always difficult to prove.

- Comparison of the citation profiles of the African articles in health produced with and without EU collaboration confirms the findings of the literature review that health articles with EU collaboration perform more than twice better in terms of citations per article than the set without EU collaborators. Similarly, the H-Indices of the collaborative sets are 60% to 70 % higher than the indices without the EU collaborators.

- Investigation of the funders, as they acknowledged by the authors, in the set of articles co-authored among African and EU authors reveals that the field is supported by a multiplicity of funders.

- The Wellcome Trust was the most often mentioned funder. It was mentioned in 3041 articles. The National Institutes of Health were mentioned 1846 times. The European Union (in its various permutations European Commission, European Union; European Community etc.) was mentioned 1252 times. The Medical Research Council UK followed with references in 1143 articles. Bill and Melinda Foundation were mentioned 805 times and the National Research Foundation 614 times. A variety of National Institutes of Health appeared in the list as well. The Tunisian and Egyptian Government also appeared in approximately 90 articles each.

- When we exclude European collaborators, the most popular funder is the variety of National Institutes of Health with more than 4300 references over the period. The National Research Foundation followed with approximately 2500 references.

- It is apparent that the major funders of health research are the Wellcome Trust, the National Institutes of Health and the European Union. The increase in references to NIH when Africa-Europe collaboration is excluded should be noted. The availability of more than one dominant funder is advantageous for the Continent as different funders may provide different funding models, different priorities etc. The lack of African funders however, is of concern.

- Examination of the production of relevant research according to geographic regions in the Continent shows that Northern Africa is the most productive in the field and Central Africa the least productive region. Similarly, the research emphasis of Northern Africa is in pharmacology-pharmacy, which is different from the rest of Africa, which emphasises public environmental occupational health and infectious diseases. It should be mentioned here that the research categories emphasised internationally are: biochemistry molecular biology; neurosciences; surgery and pharmacology pharmacy and oncology. Public environmental occupational health was 10th in the list internationally during the period. This issue needs further clarification. For example, are the African priorities beneficial for the African Continent?

The above lead to following recommendations:

- The CAAST-Net and CAAST-Net Plus supported by the Framework Programmes appear to have been successful in encouraging more and better bi-regional STI cooperation for enhanced outcomes related to health. This success is particular important as Africa has the lowest life expectancy (an overarching health indicator for the post-2015 development agenda) in the World. It is suggested that similar approaches can be utilised to develop research capacity and cooperation in other fields of common interest and priority.

- The collaborative patterns in a variety of African countries reveal dependency of the local research systems on international resources. Furthermore, the high degree of collaboration indicates that there might be limited scope for additional expansion. African governments, multilateral organisations and their international partners should focus in developing research capacity in the Continent. This is probably the most critical factor for the future of STI in Africa. Providing funding rewards for research publications has been proven effective in South Africa (Pouris 2012) and can be used across the Continent.

- The small scientific size of Africa and of African countries makes the issue of research priories of critical importance. Prioritization is required across the broad main domains (e.g. environment research versus health research versus manufacturing research) and within each domain (e.g. neurosciences versus oncology versus immunology). The field of foresight has been identified to be useful in that domain. National and regional exercises can introduce the concept to the relevant authorities. Countries with expertise in the field with the support of multilateral organisations and the African partners can lead in the effort. Such exercises could also guide the European Commission in enhancing its collaborative efforts with Africa.

- The sub-critical size of research systems, lack of funds for co-financing and dependence on international resources are manifestations of the refusal or neglect of African governments to accept that innovation is the fundamental cornerstone of economic growth, employment,

international competitiveness and development. African governments, multilateral organisations and their international partners should aim to institutionalize the governance and support of science, technology and innovation in Africa. The establishment of high level Ministerial Committees responsible for the management of the innovation systems (as in Korea, China and elsewhere); the establishment of extra-budgetary funds (as in Brazil) for research and the institutionalisation of relevant advocacy activities are possible approaches to be followed.

10. References

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