



GLOBAL RESEARCH REPORT **AFRICA**

APRIL 2010

JONATHAN ADAMS
CHRISTOPHER KING
DANIEL HOOK

EVIDENCE



THOMSON REUTERS™



THE AUTHORS

Dr. Jonathan Adams is Director, Research Evaluation.

He was a founding Director of Evidence Ltd, the UK specialist on research performance analysis and interpretation.

Christopher King is Editor of Science Watch (ScienceWatch.com),

a newsletter and web resource tracking trends and performance in basic research.

Dr Daniel Hook is Managing Director of Symplectic Limited, the UK-based research management information company, and holds visiting academic positions at Imperial College London and Washington University in St Louis.

This report has been published by
Evidence, a Thomson Reuters business
103 Clarendon Road, Leeds LS2 9DF, UK
T/ +44 113 384 5680
F/ +44 113 384 5874
E/ enquiries@evidence.co.uk

Copyright © 2010 Thomson Reuters

ISBN: 1-904431-25-9

GLOBAL RESEARCH REPORT AFRICA

APRIL 2010

INTRODUCTION

This report is part of a series launched by Thomson Reuters to inform policymakers and others about the landscape and dynamics of the global research base.

The global research landscape is changing. Our previous reports have described this as 'the new geography of science', borrowing from UK think-tank Demos which published a prescient analysis in 2005 pointing out the growth of research alongside emergent economies.

Our previous reports have separately examined the scientific enterprise in the so-called 'BRIC' bloc of nations, consisting of Brazil, Russia, India, and China. Three of these countries have rapidly emerged into prominence among the world's economies, at a rate historically unparalleled and with pervasive implications for the traditional science leaders on the trans-Atlantic axis. Another report assessed Australia and New Zealand, a stable node linked to both old and new geographies.

But there are other sides to the world picture. One of these, inevitably, is the countries that have certainly been involved in research networks but seem to have benefitted less from the new dynamics. They have had less policy attention, perhaps because they demand reflective consideration rather than provoking easy headlines. The present report therefore undertakes the daunting task of describing — albeit only at a preliminary level — an entire continent: Africa.

More than 50 nations, hundreds of languages, and a welter of ethnic and cultural diversity. A continent possessed of abundant natural resources but also perennially wracked by a now-familiar litany of post-colonial woes: poverty, want, political instability and corruption, disease, and armed conflicts frequently driven by ethnic and tribal divisions but supplied by more mature economies. OECD's recent African Economic Outlook sets out in stark detail the challenge, and the extent to which current global economic problems may make this worse and further compromise the commitment made in 2005 at Gleneagles, to double official development assistance to Africa by 2010. More than half the African nations are off-track or

regressing on objectives to achieve universal primary education by 2015. Internet penetration is good only in North Africa, constraining communication and access to knowledge.ⁱ

Yet the continent is also home to a rich history of higher education and knowledge creation. The University of Al-Karaouine, at Fez in Morocco, was founded in CE 859 as a madrasa and is identified by many as the oldest degree-awarding institution in the world.ⁱⁱ It was followed in 970 by Al-Azhar University in Egypt. While it was some centuries before the curriculum expanded from religious instruction into the sciences this makes a very early marker for learning. Today, the Association of African Universities lists 225 member institutions in 44 countries and, as Thomson Reuters data demonstrate, African research has a network of ties to the international community.

A problem for Africa as a whole, as it has been for China and India, is the hemorrhage of talent. Many of its best students take their higher degrees at universities in Europe, Asia and North America. Too few return. The African diaspora provides powerful intellectual input to the research achievements of other countries but returns less benefit to the countries of birth. That is at least in part because of a chronic lack of investment in facilities for research and teaching, a deficit that must be remedied. As was noted in a 2007 UNESCO report, science and technology are critical not only to the continent's economic prosperity but to such matters as food security, disease control, access to clean water, and environmental sustainability.ⁱⁱⁱ One measure of international support for the fostering of African higher education is a proposal, expected to go before the G8+5 nations in summer 2010, for the funding of 1,000 research chairs whose holders would train and mentor a new generation of academics while also stemming the drain of scientific talent from the continent.^{iv}

RESEARCH AND COLLABORATION IN AFRICA

More than 50 nations, hundreds of languages, and a welter of ethnic and cultural diversity. A continent possessed of abundant natural resources but also perennially wracked by a now-familiar litany of post-colonial woes: poverty, want, political instability and corruption, disease, and armed conflicts frequently driven by ethnic and tribal divisions but supplied by more mature economies.

The current research landscape in Africa is most certainly affected by ongoing continental conflicts, but can analysis of research performance and trends help them transcend such limitations? And what might they do to become emerging leaders on the world stage... like Brazil, India and China are quickly becoming?

DATA SOURCES

Volume and subject area analyses used the 2008 editions of the Thomson Reuters *National Science Indicators*. Collaboration analyses were carried out using *Research Performance Profiles* data in *InCites*[™], the new web-based platform for research evaluation from Thomson Reuters. Database years were used to delineate years, and only article, note and review document types were considered. To analyze performance at a category level the 21 main fields in Thomson Reuters *Essential Science Indicators*SM were used. *National Science Indicators*, *Essential Science Indicators* and *InCites* use publication and citation data derived from the citation data found in *Web of Science*SM, also from Thomson Reuters.

Analysis was extended and illustrated by Symplectic using *Wolfram Mathematica*[®] 7 to create maps and collaboration diagrams.

RESEARCH PUBLICATIONS

For our analysis we have taken the broadest possible view as a starting point and we then progressively move in on more specific aspects of Africa’s research activity.

Our first approach to assessing African science is to divide the continent into major regions and see how each fares in terms of output. Figure 1 does this, plotting the annual number of papers for African nations aggregated into three very broad regional groups: north, central and south.

These regional groups broadly correspond to the regional scheme employed by the United Nations, although the five UN groups have been compressed into three, with the nations designated by the UN as “eastern,” “middle,” and “western” generally placed into the “central” region for the purposes of this survey. (See adjoining box.)

African Nations by Region (Listed within each region by descending order of publication volume, 1999-2008)	
North	Egypt, Tunisia, Morocco, Algeria, Sudan
Central	Nigeria, Kenya, Cameroon, Ethiopia, Uganda, Ghana, Senegal, Cote Ivoire, Burkina Faso, Madagascar, Benin, Gambia, Reunion, Gabon, Mali, Niger, Republic of the Congo, Togo, Eritrea, Guinea Bissau, Rwanda, Mauritania, Central African Republic, Guinea, Chad, Burundi, Sierra Leone, Liberia, Comoros, Equatorial Guinea, Cape Verde, Djibouti, Sao Tome & Principe, Somalia
South	South Africa, Tanzania, Zimbabwe, Botswana, Malawi, Zambia, Namibia, Mozambique, Mauritius, Democratic Republic of the Congo, Swaziland, Seychelles, Angola, Lesotho

The “south” region corresponds to the member nations of the Southern African Development Community (SADC), an inter-governmental body devoted to economic development and other measures to raise the standard of living in its constituent countries.

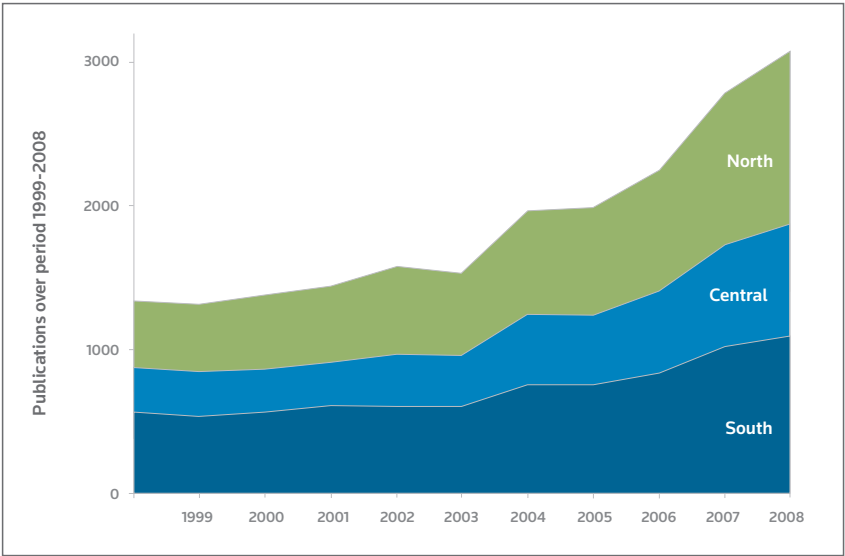
Two nations listed by the UN — Saint Helena and Western Sahara — are not currently included in the Thomson Reuters *National Science Indicators* database, from which these figures were derived.

For the years 1999 to 2008, the central region of Africa produced the smallest quantity of papers, roughly 7,100 per year, despite being the region with the greatest number of countries: more than 30. The north region actually accounted for the highest number of papers in recent years, with more than 10,500 in 2008, even though the region consists of only six countries. Similarly, the south region, although made up of only 14 countries, also produced more than 10,000 papers. This immediately points to an uneven distribution of research and innovative capacity at both country and regional levels.

For scale, it should be appreciated that the total of about 27,000 papers per year is about the same volume of published output as The Netherlands.

A breakdown of these figures demonstrates the extent to which each region — and African science as a whole — is dominated by three nations: Egypt in the north, Nigeria in the middle, and South Africa in the south. In the ten years between 1999 and 2008, for example, Egypt produced nearly 30,000 papers which was about three times the total for Tunisia, its next-place and regional neighbor. In west-central Africa, Nigeria’s total for the same period was over 10,000, compared to roughly 6,500 for Kenya which is the leading research economy in the east of the continent. South Africa’s dominance, as might be expected, is even more pronounced: nearly 47,000 papers during 1999-2008, compared to the southern region’s next-most-prolific nation, Tanzania, which fielded just over 3,000.

FIGURE 1
Africa’s output of publications indexed on Thomson Reuters *Web of Science*SM databases between 1999 and 2008, with papers grouped by region (see box above for index of countries by region)



Source: *Web of Science*SM

FIELDS OF RESEARCH

What happens when we break the Thomson Reuters data down by field of research?

Table 1 provides a closer look at African output, presenting the five most-prolific nations in each of 21 main fields, according to the classification scheme employed for Thomson Reuters *Essential Science Indicators*. Here we have also looked at a more recent slice of activity and the analysis reflects papers indexed in the five-year window between 2004 and 2008.

A discernible pattern in Table 1 is Africa's relatively high representation — as a share of world publications — in fields that are relevant to natural resources. The highest percentage of any field, for example, is South Africa's 1.55% share of Plant & Animal Science. Not far behind is the same country's 1.29% portion of Environment/Ecology. A review of the more detailed analyses in Thomson Reuters *Essential Science*

TABLE 1

The most prolific African nations during the five-year period 2004-2008 in the 21 main fields used in Thomson Reuters *Essential Science Indicators*SM database. The top five nations are highlighted below by color.

Most Prolific African Nations in 21 Main Fields, 2004-08 Top five nations ranked by number of papers / percent of papers in field					
FIELD	1	2	3	4	5
Agricultural Sciences	Nigeria 952 / 0.95	South Africa 692 / 0.69	Egypt 461 / 0.46	Kenya 380 / 0.38	Tunisia 247 / 0.25
Biology & Biochemistry	South Africa 1,242 / 0.46	Nigeria 1,004 / 0.37	Egypt 521 / 0.19	Tunisia 505 / 0.19	Morocco 200 / 0.07
Chemistry	Egypt 3,634 / 0.62	South Africa 2,059 / 0.35	Algeria 1,065 / 0.18	Tunisia 980 / 0.17	Morocco 866 / 0.15
Clinical Medicine	South Africa 4,183 / 0.41	Egypt 2,584 / 0.26	Tunisia 1,587 / 0.16	Nigeria 1,392 / 0.14	Morocco 867 / 0.09
Computer Science	South Africa 359 / 0.24	Egypt 240 / 0.16	Algeria 170 / 0.11	Tunisia 163 / 0.11	Morocco 74 / 0.05
Economics & Business	South Africa 507 / 0.69	Kenya 54 / 0.07	Ethiopia 42 / 0.06	Nigeria 39 / 0.05	Tunisia 29 / 0.04
Engineering	Egypt 2,311 / 0.58	South Africa 1,385 / 0.35	Algeria 800 / 0.20	Tunisia 752 / 0.19	Morocco 459 / 0.12
Environment/Ecology	South Africa 1,707 / 1.29	Kenya 420 / 0.32	Egypt 367 / 0.28	Nigeria 351 / 0.27	Tanzania 206 / 0.16
Geosciences	South Africa 1,534 / 1.13	Egypt 434 / 0.32	Morocco 294 / 0.22	Algeria 148 / 0.11	Tunisia 141 / 0.10
Immunology	South Africa 518 / 0.86	Kenya 269 / 0.45	Uganda 207 / 0.34	Tanzania 110 / 0.18	Egypt 89 / 0.15
Materials Science	Egypt 1,421 / 0.61	Tunisia 575 / 0.23	Algeria 572 / 0.25	South Africa 524 / 0.23	Morocco 294 / 0.13
Mathematics	South Africa 652 / 0.52	Morocco 444 / 0.35	Tunisia 444 / 0.35	Egypt 368 / 0.29	Algeria 297 / 0.24
Microbiology	South Africa 534 / 0.66	Egypt 243 / 0.30	Tunisia 213 / 0.26	Kenya 147 / 0.18	Cameroon 76 / 0.09
Molecular Biology & Genetics	South Africa 276 / 0.20	Egypt 139 / 0.10	Tunisia 113 / 0.08	Kenya 58 / 0.04	Morocco 45 / 0.03
Neuroscience & Behaviour	South Africa 310 / 0.21	Egypt 75 / 0.05	Tunisia 58 / 0.04	Morocco 45 / 0.03	Nigeria 37 / 0.03
Pharmacology & Toxicology	Egypt 600 / 0.66	South Africa 375 / 0.41	Nigeria 235 / 0.26	Morocco 101 / 0.11	Tunisia 90 / 0.10
Physics	Egypt 1,880 / 0.40	South Africa 1,194 / 0.26	Algeria 933 / 0.20	Morocco 646 / 0.14	Tunisia 601 / 0.13
Plant & Animal Science	South Africa 4,179 / 1.55	Egypt 798 / 0.30	Kenya 784 / 0.29	Nigeria 602 / 0.22	Tunisia 527 / 0.19
Psychiatry/Psychology	South Africa 667 / 0.56	Nigeria 102 / 0.09	Egypt 43 / 0.04	Uganda 38 / 0.03	Kenya 30 / 0.03
Social Sciences, General	South Africa 2,107 / 1.06	Nigeria 331 / 0.17	Kenya 222 / 0.11	Tanzania 179 / 0.09	Ghana 140 / 0.07
Space Science	South Africa 556 / 0.93	Egypt 86 / 0.14	Namibia 51 / 0.09	Morocco 31 / 0.05	Algeria 24 / 0.04

Source: *Web of Science*SM

Indicators shows that many of South Africa's most highly-cited papers in this field pertain to climate change and its effects on plant propagation. Following this theme, South Africa's 1.13% share of Geosciences is in keeping with the region's mineral richness.

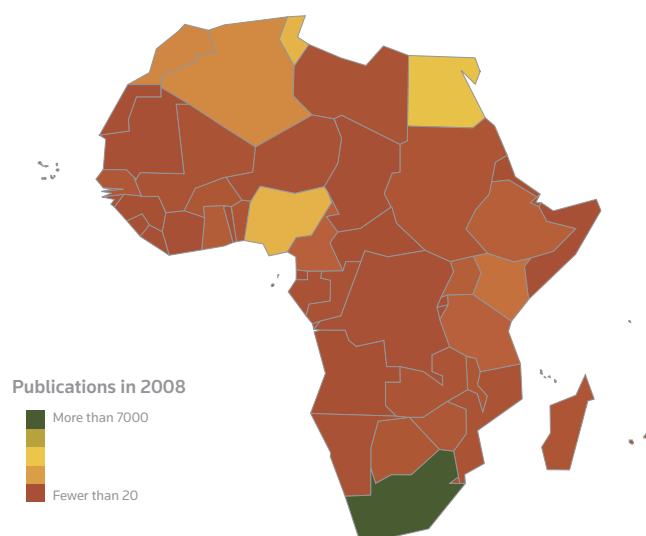
In short, Africa, as was noted above, is a continent abundant in natural resources. The question, of course, is how much does Africa itself benefit from those resources?

RESEARCH AND ECONOMIC PRODUCTIVITY IN AFRICA

Absolute volume of published papers is one indicator of research activity and — indirectly — of research capacity. It will therefore be obvious that the output of a country reflects how much money is going in to its research system, and that is likely to be partly dependent on its general economy. Bigger countries with a larger economy should be producing more papers, if they invest at the same level as smaller countries. However, land area and population density vary a great deal. We have compared publications with Gross Domestic Product (GDP) for each country, reasoning that proportionate investment in the knowledge economy is a good index of a government's commitment to maximize the longer term benefit of resource development and exploitation for the general wealth of its people.

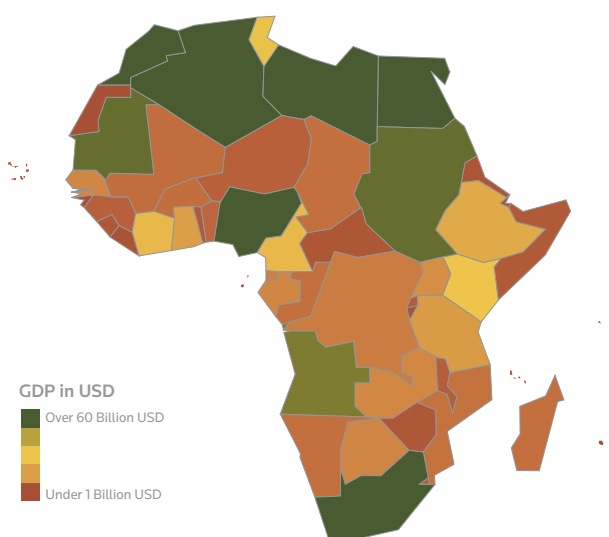
MAPS OF GDP AND OUTPUT

FIGURE 2: Output by country



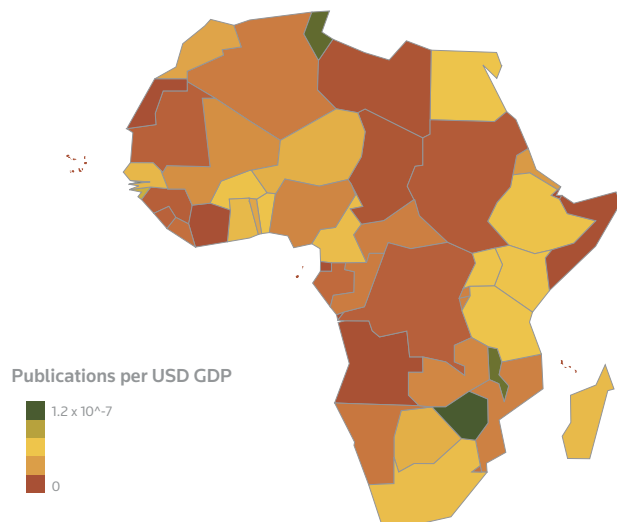
Source: Web of ScienceSM; Analysis: Wolfram Mathematica[®] 7

FIGURE 3: GDP by country



Source: Web of ScienceSM; Analysis: Wolfram Mathematica[®] 7

FIGURE 4: Output / GDP by country



Source: Web of ScienceSM; Analysis: Wolfram Mathematica[®] 7

The leading countries by output (Figure 2) are South Africa, Egypt, Nigeria, Tunisia, Algeria and Kenya. Four of these are also leading countries in terms of GDP (Figure 3) (South Africa, Egypt, Nigeria and Algeria) while Kenya and Tunisia fall in the second GDP tier. Indexing output against GDP (Figure 4) provides further interpretation. Zimbabwe is relatively the most productive country but this is anomalous because it retains its legacy research base despite a collapsing economy and very low current GDP. The real leaders are Tunisia and Malawi with very different economic bases but strong relative productivity in both cases. South Africa, Kenya and Egypt all have significant relative productivity, as do a number of other countries in East Africa (Ethiopia, Uganda, Tanzania) and West Africa. (Cameroon, Ghana).

It is clear, however, that despite Nigeria's high volume output it is not returning as much research as would be expected given the size of its economy. The value of its resources is not yet being felt in its knowledge base. In fact, the same research productivity gap between resources and investment applies to several other countries. This is an area where Africa is not yet benefitting from the best use of its own natural resources.

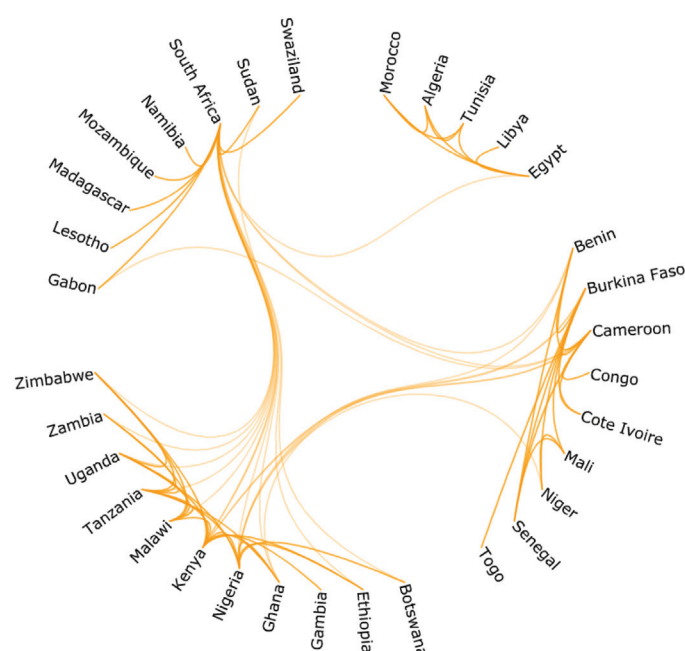
COLLABORATION WITHIN AFRICA

In this analysis we have counted all the collaborations between countries represented by co-authorship on the publications we have collated from within Thomson Reuters *Web of Science*. The counts are by paper not by number of researchers. For example, a paper co-authored by two researchers from Ghana, three from Nigeria and one from Kenya counts as a single paper in each country's total and as one link between each pair of countries.

We set a threshold, to clarify where the stronger collaborations occurred. This was set at a minimum of five papers per year, or 25 papers in total over the five-year period 2004-2008. This meant that some countries did not appear at all in the analysis because they had too low a level of recent collaboration. We then moved the countries around the rim of the wheel until groups with strongest cross-links were placed close together.

NETWORK OF COLLABORATION:

A new visual interpretation of collaboration, by paper not by number of researchers, reveals clusters of countries with the strongest partnerships.



Source: *Web of Science*SM; Analysis: Daniel Hook^v

There is a marked interaction between the countries in North Africa which share both language and culture and are also relatively prolific across the fields analyzed in Table 1. Thus this network is probably the strongest group overall since it links countries which are individually research active across multiple fields. The group does little research with the rest of Africa, however, other than through the Egypt-South Africa link.

A West Africa group (Benin-Togo) pivots around Cameroon, a relatively research-productive country. The common factor within this group is almost certainly their common use of French as the cross-national business language. Language also gives us the clue to the large group which includes Kenya and geographical neighbors in East Africa but also includes Nigeria, Ghana and Gambia. Those countries appear to have English as a common language or a strong Anglophone influence. The SADC economic grouping does not emerge as a research network since it is split between that group linked to Kenya and Nigeria and a second group most closely linked to South Africa, but which also includes Sudan and Gabon. The overall collaboration network, to the extent that one exists at all, is dependent on a small number of key players linking these regional and cultural groupings.

Nigeria, despite its disappointing level of research investment, nonetheless has an important connecting role. Not only is it a part of the Anglophone collaborative network but it also has significant — albeit weaker — connections with its West African neighbors, and it connects strongly to South Africa. South Africa is a similarly strong node with a spread of links into other groups. These two, with Kenya and Egypt, create the strongest cross-continent links and are also key nodes into global research networks.

AFRICA'S EXTERNAL COLLABORATION

For each of six key countries we have analyzed collaborative research links by collating co-authorships with other countries and analyzing collaboration with the USA and the UK (Figure 5), which are globally the most frequent partner for most countries, and three other frequent partners.

For almost every country the most frequent collaborative partner is the USA. Often this is a consequence of researchers who have studied in the USA maintaining links with those research groups when they return home. The UK and Germany are the other common partners to the five countries featured here. Between them the USA, UK and Germany have authors on almost half the world's research papers recorded on Thomson Reuters databases every year.

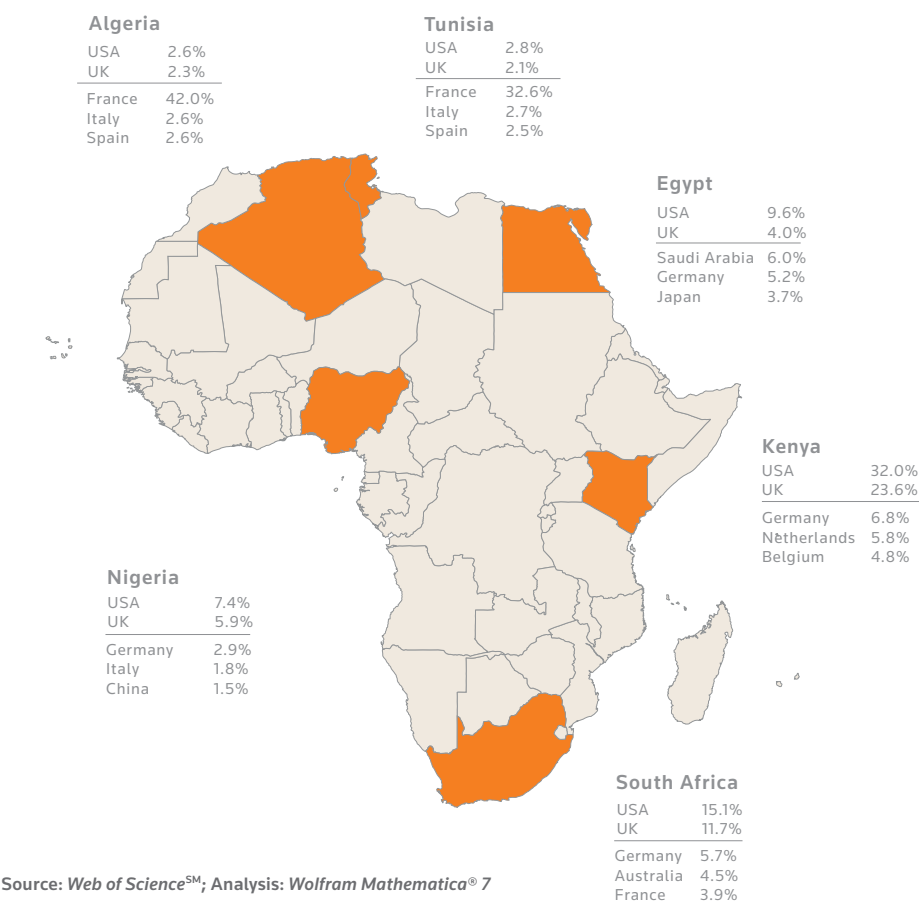
There is a striking difference between the three countries pulled out in North Africa and those in other regions. Globally, the most frequent collaborative partner is the USA. Often this is a consequence of researchers who have studied in the USA maintaining links with those research groups when they return home. The UK and Germany are the other common partners to the countries featured here and France has a major role. Between them the USA, UK, Germany and France have authors on half the world's research papers recorded on Thomson Reuters databases every year.

For many countries the UK is the second most important partner, but this is not the case in North Africa which also supplies the exception to the USA's normal role. Algeria and Tunisia have unique links with France, which has a co-author on an exceptional share of their publications. There is, in fact, a similar example for the UK which is a co-author on no less than 45% of research publications from Malawi. Algeria is linked to Egypt which itself has strong links to Saudi Arabia, signaling an extension of this local network into the broader Islamic research world. Egypt also produces a link further east, to Japan.

Nigeria's global reach is marked by its collaboration with China. It is of course well-positioned to extend its links westwards and partner with the emerging Brazilian research base. It could thus serve as a key doorway into the West African and into Anglophone African research base for some of the most exciting research now appearing in Asia and Latin America.

What we have not analyzed here is the underlying nature of the partnerships we are describing at a general, national level. Many of these links will be mediated through health and agricultural programs. The Gambia, which we referred to above, is the site for long-term research into tropical diseases for the UK's Medical Research Council, which also works in Uganda. The Wellcome Foundation has similar, major research investments in Kenya and Malawi. A significant intellectual benefit is thus secured outside Africa, often then with subsequent returns in medical programs deployed within the continent.

FIGURE 5: TOP COLLABORATING COUNTRIES FOR SIX KEY AFRICAN COUNTRIES



Source: Web of ScienceSM; Analysis: Wolfram Mathematica[®] 7

SUMMARY

This report can provide only an introduction to the patterns of research activity in Africa. The volume of activity remains small, much smaller than is desirable if the potential contribution of Africa's researchers is to be realized for the benefit of its populations. The challenges that the continent faces are enormous and indigenous research could help provide both effective and focused responses. The resources that are available in some countries are substantial, but they are not being invested in the research base. But other countries with limited resources are making notable and effective contributions of a high standard. Other analyses show that Malawi, with one-tenth the annual research output of Nigeria, produces research of a quality that exceeds the world average benchmark while Nigeria hovers around half that impact level.

Some countries are already mounting research programs with capacity across a range disciplines. The North Africa network of collaboration is strong both in the activity of individual countries, notably Egypt, and the close collaboration between them that will help to address larger challenges. Strong historical ties to France, and also to Germany, Italy, Spain and the UK, ensure a high level of external input and links to European programs while new links to Saudi Arabia and to Japan provide the opportunity for participation in emerging networks elsewhere.

The historical legacy of past ties is reflected in the collaborative networks associated with Francophone and Anglophone groups of nations. The Francophone group has the benefit of proximity in West Africa, and this could prove an important regional focus and development opportunity. The Anglophone group has good links to the USA and UK, and its common language base means that it already accesses and is exposed to the international community that uses English for research publication. However, the extent to which collaboration reflects long-term research links or current research interests for G7 partners is not clear. The test will be whether the research activity reflected in these links is maintained when economic constraints start to bite in Europe and North America.

The translation of the emergent SADC regional economic grouping into a research network has not yet happened. The research focus for many members remains further north. South Africa is the outstanding research leader in the region, has by far the greatest research output of any country, well ahead of Egypt in second place, and has high impact for much of its research. Indeed, its capacity and diversity stimulates a comprehensive and diverse portfolio which supports both peaks and platforms in its research base.^{vi} By comparison, it is only the peak of other countries' research activity that emerges into the international literature.

The activity map and collaborative networks make evident a potential transformational role for specific countries. This report has identified a pair of axes, running between Egypt and South Africa and between Nigeria and Kenya, which engage a high proportion of Africa's research and which link the rest of the continent in collaborative networks. The essential regional role of other countries, such as Cameroon and Tunisia, is also marked. The future of the African research enterprise must depend to some significant extent on the ability of these countries to help facilitate further growth, through leadership, strong local investment and the creation and support of key facilities and centers to draw in and assist currently less well resourced partners.

It would be inappropriate to suggest that the preliminary analysis in this report can provide a clear direction. The information may, however, help to provide a further context to that set by the OECD's economic reports, while also furnishing background against which to view the pertinent regional dispatches in the UNESCO Science Report 2010, due at mid-year.

REFERENCES

Recent publications about research policy and developments in Africa

- A. Pouris, "Still a way to go for South Africa's science revolution," *Nature*, 463 (7282): 729, 2010.
- I. Scoones and D. Glover, "Starved for Science: How Biotechnology Is Being Kept Out of Africa," *Nature*, 460 (7257): 797-8, 2009.
- Anon., "Strengthening research capacity in Africa," *Lancet*, 374 (9683): 1, 2009.
- O. Oukem-Boyer, et al., "Tackling human resources in Africa: How one institute leverages overseas talent to develop its research strategy," *Scientist*, 23 (1): 24, 2009.
- P. Kagame, "Challenges and prospects of advancing science and technology in Africa: The case of Rwanda," *Science*, 322 (5901): 545, 2008.
- R. Gallagher, "Africa needs basic science," *Scientist*, 22 (7): 13, 2008.
- J.N.A. Matthews, "Institute nurtures African math and science graduate students," *Physics Today*, 61 (5): 25-6, 2008.
- J. Van Den Brink and I. Snyman, "Advancing science in Africa," *Nature Materials*, 6 (11): 792-3, 2007.
- M.H.A. Hassan, "A new dawn for science in Africa," *Science*, 316 (5833): 1813, 2007.
- M.H.A. Hassan and D. Schaffer, "Building scientific capacity in sub-Saharan Africa: From despair to hope," *Discovery and Innovation*, 18 (4): 279-87, 2006.
- E. Masood, "Africa pursues goal of scientific unity," *Nature*, 445 (7128): 576, 2007.
- M. Cherry, "Science in Africa: Conscious of change," *Nature*, 444 (7118): 416-7, 2006.
- Anon., "A foundation for Africa," *Nature*, 442 (7102): 486, 2007.
- Anon., "A scramble for Africa," *Nature*, 440 (7083): 383-4, 2006.
- Anon., "Networks for Africa," *Nature*, 438 (7067): 395, 2005.
- M.H.A. Hassan, "Can science save Africa?" *Science*, 292 (5522): 1609, 2001.

END-NOTES

ⁱ OECD (2009). African Economic Outlook: overview. AfDB/OECD. ISBN 978-92-64-06170-5

ⁱⁱ The Guinness Book Of Records (1998), ISBN 0 5535 7895 2, p 242

ⁱⁱⁱ UNESCO (2007), Science in Africa (<http://www.unesco.org/science>)

^{iv} Research Europe, 25 February 2010

^v **This analysis was completed making use of methodology described in:**

Danny Holten and Jarke J. van Wijk, (2009). 11th Eurographics/IEEE-VGTC Symposium on Visualization (Computer Graphics Forum; Proceedings of EuroVis 2009), Pages 983-990.

A. Clauset. (2005). "Finding Local Community Structure in Networks," *Physical Review E*, 72, 026132.

^{vi} The May/June edition of the Thomson Reuters publication *Science Watch* examines South Africa's recent scientific output and impact in greater detail; www.sciencewatch.com.

Science Head Offices

Americas

Philadelphia +1 800 336 4474
+1 215 386 0100

Europe, Middle East and Africa

London +44 20 7433 4000

Asia Pacific

Singapore +65 6411 6888
Tokyo +81 3 5218 6500

For a complete office list visit:
science.thomsonreuters.com/contact

