United Nations
Educational, Scientific and
Cultural Organization

Organisation
des Nations Unies
pour l'éducation,
la science et la culture

Organización
de las Naciones Unidas
para la Educación,
la Ciencia y la Cultura

Организация
Объединенных Наций по
вопросам образования,
науки и культуры

منظمة الأمم المتحدة
للتربية والعلم والثقافة

联合国教育、
科学及文化组织

Strengthening Capacities for the Reform of Science and Innovation System of Tanzania[1]

The Scientific Production of Tanzania: "Preliminary Results" from a Bibliometric Analysis (1966-2011)[2]

February 17, 2012

[1] Project supported by the Japanese Funds-in-Trust (JFIT). *Beneficial country*: The United Republic of Tanzania. *Implementing Agencies*: Ministry of Communication, Science & Technology (MCST) and Tanzanian National Commission for UNESCO.

[2] This draft was prepared by G. A. Lemarchand, Consultant at the Division of Science Policy and Capacity Building, Natural Sciences Sector (UNESCO) **under UNESCO-Contract 4500165792 which is supported by the Japanese Funds-in-Trust (JFIT)**. This work and the information it contains is the responsibility of its author and is not necessarily the opinion of UNESCO. The designations employed and the presentation of material throughout this article do not imply the expression of any opinion whatsoever on the part of UNESCO concerning the legal status of any country, territory, city or area or its authorities, or concerning the delimitation of its frontiers or boundaries.

1. Introduction:

This research was realized as part of a programme on the reform and repositioning of the science and innovation in Tanzania, which was elaborated and coordinated by UNESCO in response to the request of the President of Tanzania. Particularly, the present work is part of the first component of the project[1] designed to provide policy advice and guidance in the implementation of the reform programme. Here-on we present the preliminary results obtained in a research about the scientific publication´s profile of the United Republic of Tanzania, performed as a consulting work[2] for the Division of Science Policy and Capacity Building of the United Nations Educational, Scientific and Cultural Organization (UNESCO) during February 2012.

The application of bibliometric indicators to estimate the characteristics of international scientific cooperation patterns have been explored by diverse authors (i.e. Davison Frame et. al, 1977; Beaver and Rosen, 1978; Katz and Martin, 1997; Beaver, 2001, 2004; Glänzel and Schubert, 2004; Holmgren and Schnitzer, 2004; Wagner and Leydesdorff, 2005b, Lemarchand, 2007, 2012). Few studies employed them to analyse the cooperation profiles among African countries (Tussen, 2007; Pouris, 2010; Toivanen and Ponomariov, 2012). No specific study about Tanzania was published at the specialized literature to the present date.

We analyse the temporal evolution in the production of mainstream scientific and academic knowledge in all fields. Our analyses cover the period from 1966 to 2011. To study the distribution of published articles by authors living in Tanzania listed at the Science Citation Index (SCI), Social Science Citation Index (SSCI) and Arts and Humanities Citation Index (A&HC), we use Thomson-Reuters' Web-of-Science[3] and the SCOPUS database[4]. Beside the fact that the Web-of-Science covers all the Tanzanian articles published at mainstream journal from the very first one (1966) and that SCOPUS only starts at 1996, the two databases offer complementary information. As it is shown in Figure 1, for the case of Tanzania, the listing of published documents at both databases has a linear relation (they are totally proportional).

We study the bilateral co-authorship of citable articles between Tanzania and the rest of the countries between 1966 and 2011. The analysis of the aggregated temporal evolution of SCI, SSCI and A&HCI shows a homogeneous trend that is independent of any academic discipline and also avoids any substantial change in the national trends, due to the continuous incorporation of new journals to the databases. In this way, we focus our study on a cooperation network analysis within regional and extra-regional countries. Obviously, the publication in mainstream journals (listed by SCI, SSCI and A&HCI) represents only a fraction of all the cooperative research and development (R&D) activities that is taking place within the countries of our sample. The main advantage of using these databases is that they were systematically collected and organized over several decades with similar methodologies, allowing us to perform a long-term analysis with relative good confidence.

[3] http://scientific.thomson.com/products/wos/
[4] http://www.scimagojr.com/

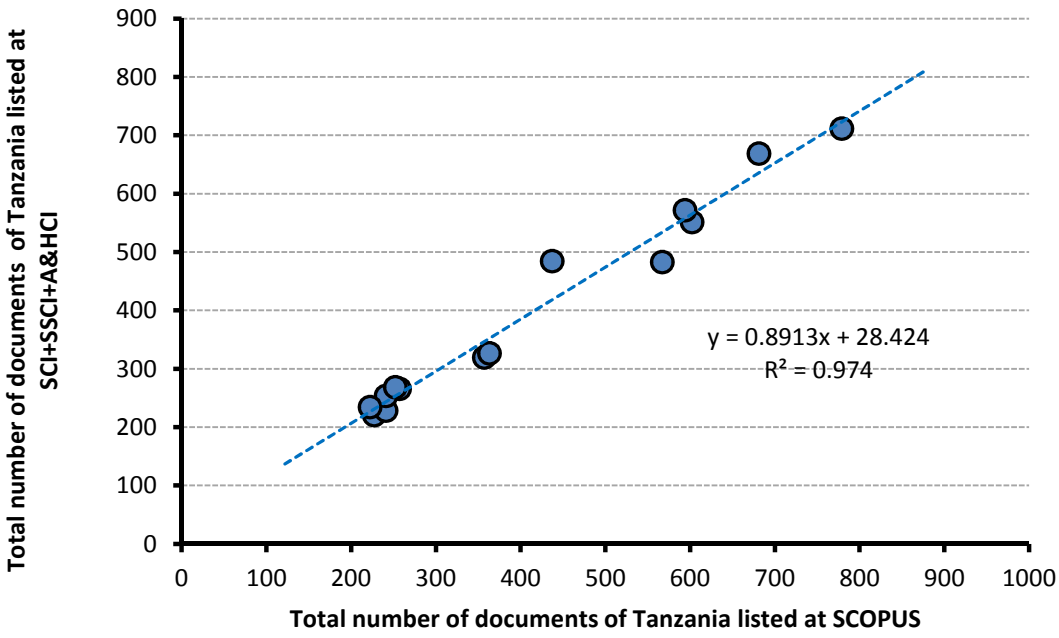

Figure 1: mathematical linear correlation between the total numbers of annual publications from Tanzania listed at the two data bases employed: SCOPUS and WEB-OF-SCIENCE (SCI+SSCI+A&HCI). Source: prepared by the author.

2. Tanzanian scientific production measured by publications at mainstream journals

If we take into account the ranking of the most productive countries, in terms of scientific publications at mainstream journals, between 1996 and 2010, there are 236 countries in the world leaded by USA, China, UK, Japan, Germany, France, Canada, Italy, Spain and India. Tanzania occupies the 79 position. In Table 1 we represent the list of countries which has a similar scientific production in terms of total number of documents listed at the SCOPUS database between 1996 and 2010. We selected those countries which occupies the position 69 to 90. To make a relievable comparison we include the number of citable documents produced between 1996 and 2010; the number of cites obtained; the average cites per publication; the *h Index*[5]; the 2011 population in millions, the country area and the number of citable documents per million people. The Tanzanian *h*-Index has a better global position (64) and the impact of its publications is comparable with Bangladesh, Cuba, Lebanon, Morocco and Uganda.

In Figure 2 we analyse the long-term evolution in the production of citable scientific publications (articles) and the total number of documents that are listed at SCI + SSCI + A&HCI

[5] The *h*-index is an index that attempts to measure both the productivity and impact of the published work of a scientist or scholar. The index is based on the set of the scientist's most cited papers and the number of citations that they have received in other publications. The index can also be applied to the productivity and impact of a group of scientists, such as a department or university or country. It is based on the distribution of citations received by a given researcher's publications. A scientist has index *h* if *h* of his/her Np papers have at least h citations each, and the other (Np − *h*) papers have no more than h citations each. In other words, a scholar with an index of *h* has published h papers each of which has been cited in other papers at least *h* times (see Hirsch 2005). Thus, the *h*-index reflects both the number of publications and the number of citations per publication. The index is designed to improve upon simpler measures such as the total number of citations or publications. In this case it is used to compare the impact of the national scientific production among countries.

for Tanzania between 1966 and 2010. The first publications at mainstream journals appear on 1966.

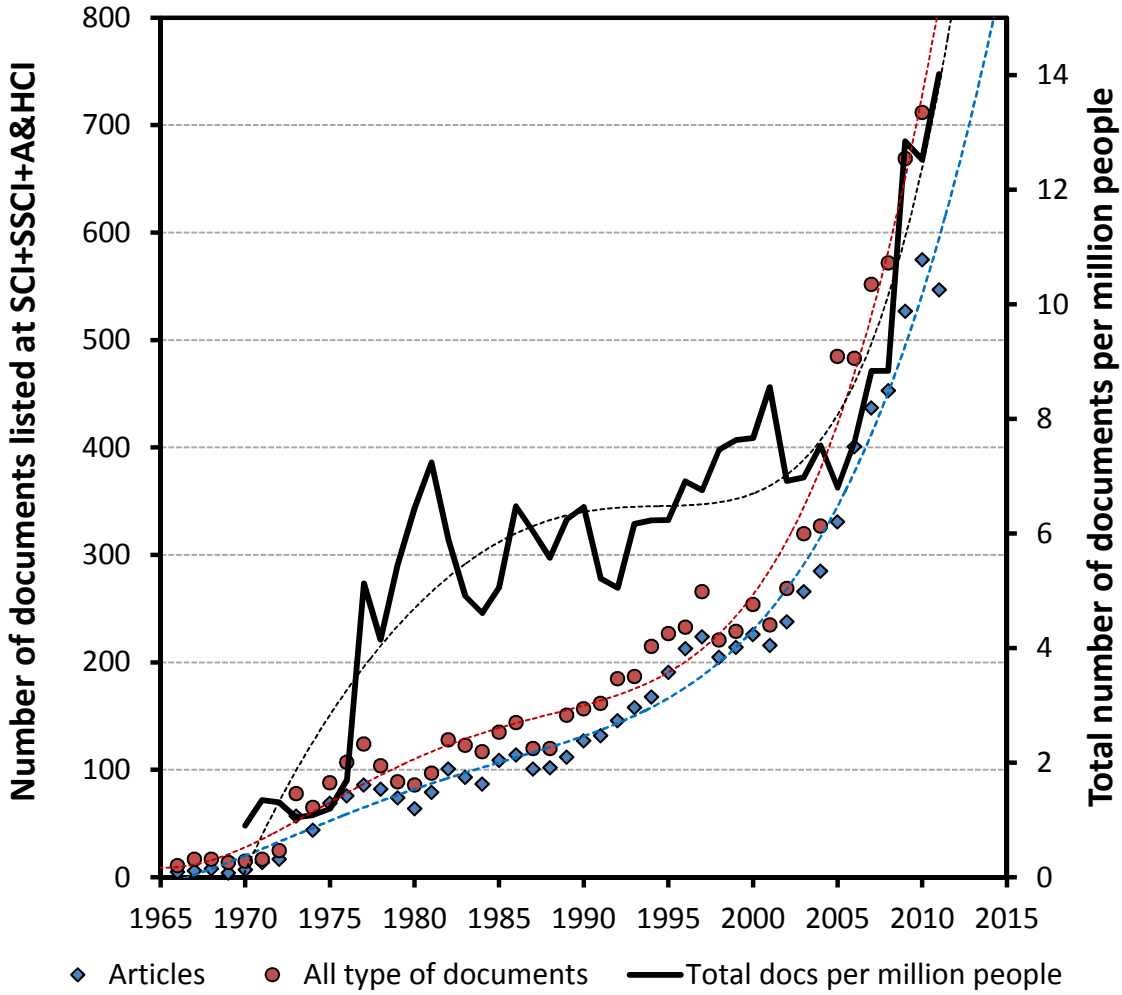

Figure 2: number of scientific publications (articles and all type of documents) at mainstream journal listed at the Science Citation Index (SCI), the Social Sciences Citation Index (SSCI) and Arts and Humanities Citation Index (A&HCI), produced by authors from Tanzania between 1966 and 2011 (related with the left vertical axis) and the total number of publication per million people (black line, related with the right vertical axis). The dash-lines are non-linear fitting curves to represent an extrapolation the long-term behavior of the publication growth. Source: prepared by the author based on data downloaded from Thomson-Reuters Web-of-Science.

We can distinguish two periods, one with a modest quasi-linear growth (1966-1998) and a second period (1999-on) with a quasi-exponential growth. This can be related with the application of new policies in the country (UNESCO, 2011a, 2011c; Irikefe et al 2011) and with the implementation of a new techno-economic paradigm or new social contract of science (Lemarchand, 2010 §13: 100-120). The second period is consistent with the type of growth behaviour that several developing countries were experiencing in the XXI Century (Lemarchand, 2012). It is very well known that the number of published research articles scales very well the number of researchers (Mabe, 2003). This growth shows, in an indirect way, the increase in the number of scientists in Tanzania over the last decade[6]. This is consistent with the growth in the number of publications per million people (see Figure 2).

[6] The Tanzanian National Commission for Science and Technology (COSTECH) and many research institutes have been elaborating strategic plans which they review periodically. A sub-master plan for 2003-2018 was drafted for

Besides the exponential growth that the number of Tanzanian scientific publications had during the last decade (multiplying their production by a factor of 3) their production is still very modest. Another way to study the long-term behaviour of mainstream scientific publications can be performed by analysing the evolution of the societal knowledge productivity, in terms of number of publications per million inhabitants. Considering the number of publications per million people, Tanzania is at the bottom of this list (Table 1), just over Ethiopia and the Philippines. Over the last decade the total number of publication per million people was doubled. On the other hand the number of cites per document is higher than most of the countries of this particular sample (see Table 1).

Table 1

Global Rank[7]	Country	Citable documents 1996-2010[8]	Citations 1996-2010	Citations per doc	H Index	Population in millions (2011)	Country Area km^2	Citable doc per million people
69	Lebanon	9,319	69,103	8,98	82	4.259	10,452	2,188.1
70	Philippines	9,440	103,428	12.29	100	94.013	300,000	100.4
71	Puerto Rico	8,315	111,175	14.65	110	3.725	8,870	2,232.2
72	Iceland	7,736	147,819	22.31	139	0.319	103,000	24,250.8
73	Uruguay	7,093	81,838	13.51	94	3.203	176,215	2,214.5
74	Latvia	7,012	51,951	8.24	76	2.067	64,559	3,392.4
75	Armenia	6,970	50,175	7.64	90	3.266	29,743	2,134.1
76	Cyprus	6,706	50,519	11.47	72	0.839	9,251	7,992.8
77	Peru	5,995	67,623	13.97	92	29.797	1,285,216	201.2
78	Georgia	5,939	40,074	7.67	70	4.469	69,700	1,328.9
79	Tanzania	5,826	66,073	12.11	83	43.188	945,087	134.9
80	Uzbekistan	5,972	21,656	3.76	47	28.001	447,400	213.3
81	Sri Lanka	5,678	43,827	9.33	70	20.653	65,610	274.9
82	Oman	5,488	30,617	6.64	52	2.773	309,500	1,979.1
83	Cameroon	5,493	43,666	9.75	63	19.406	475,442	283.1
84	Ethiopia	5,517	42,972	9.36	36	84.321	1,104,300	65.4
85	Azerbaijan	5,221	11,749	2.73	83	9.111	86,600	573.0
86	Uganda	4,948	62,314	15.73	91	32.939	241,550	150.2
87	Costa Rica	4,904	64,864	14.48	61	4.301	51,100	1,140.2
88	Ghana	4,622	37,795	9.81	62	24.233	238,533	190.7
89	Nepal	4,023	30,325	9,00	63	26.620	147,181	151.1
90	Zimbabwe	4,260	42,515	9.61	44	12.754	390,357	334.0

SOURCE: calculations by the author based on primary data obtained at SCOPUS database and UN Statistics Division.

the entire science system. Particularly, the number of publications per million people started its exponential growth with the application of this plan (see figure2). In 2010, the country's president Jakaya Kikwete announced a financial boost for science. Funding for COSTECH, which gives out research grants, increased thirty-fold last year to $20 million. This funding will support 200 new PhD and master's students, agricultural research and technology transfer projects.

[7] Based-on the total number documents listed at the SCOPUS database between 1996 and 2010.

[8] Here we present the numbers corresponding "only" to those citable documents which represent only a fraction of the total number of documents listed at the SCOPUS database.

3. Co-authorship patterns

Co-authorship is one of the most tangible and well documented forms of scientific collaboration (Glänzel & Schubert, 2004). Almost every aspect of scientific cooperative networks can be studied by analysing co-authorship patterns with the employment of bibliometric methods.

We use a simple mathematical model of social networks applied to the study of the temporal evolution of co-authorship among countries (Lemarchand, 2012). The model predicts a quadratic growth of co-publications (links) against time, among countries (nodes). Lemarchand (2012) showed that this type of networks behaves with a self-organizing dynamics and he derived the conditions from which this process is triggered. Here we use this mathematical model and the empirically determined growth constants, to deduce a methodology to predict the near-future behaviour of the co-authorship patterns.

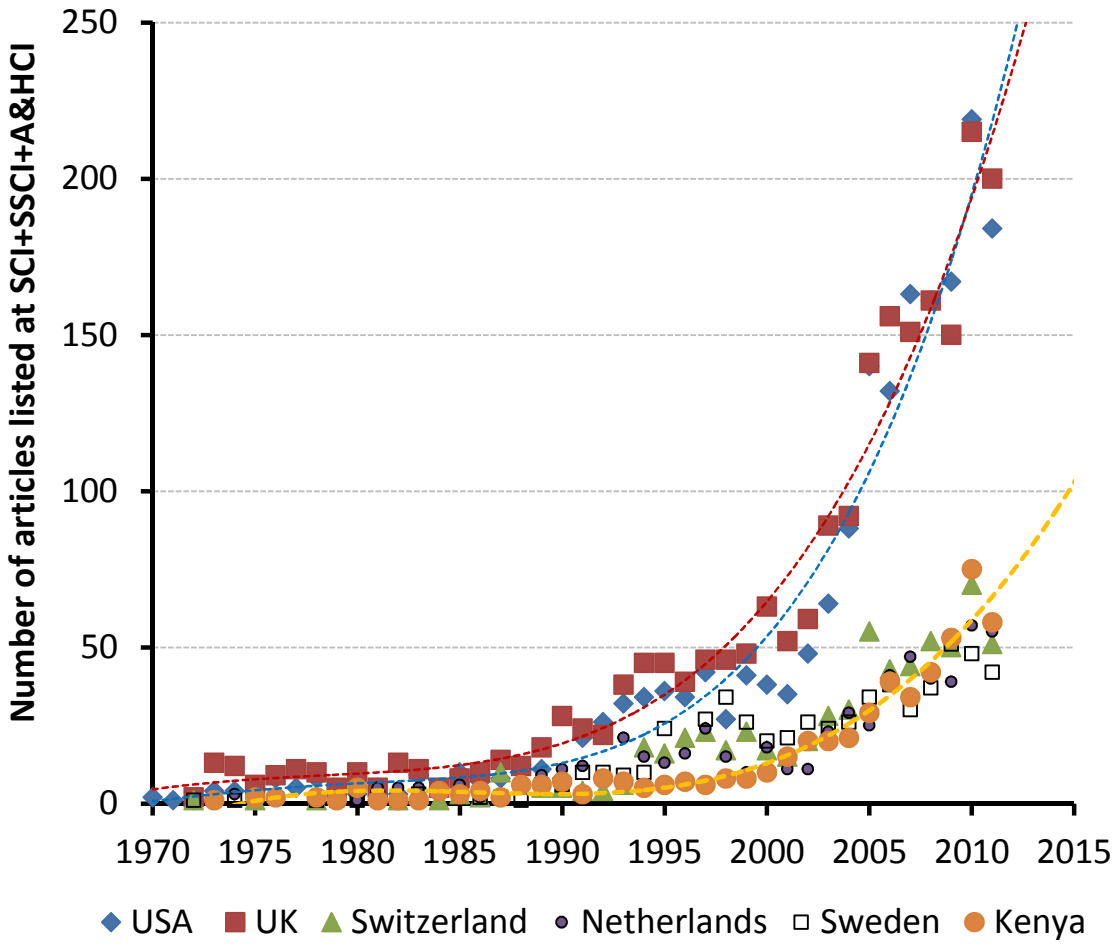

Figure 3: Evolution of the number of scientific co-publications at mainstream journal listed at the Science Citation Index (SCI), the Social Sciences Citation Index (SSCI) and Arts and Humanities Citation Index (A&HCI), produced by authors from Tanzania and USA, UK, Switzerland, Netherlands, Sweden and Kenya (main scientific co-authorship networks) between 1966 and 2011. The dash lines are extrapolations using the mathematical model developed by Lemarchand (2012). Source: prepared by the author based on data downloaded from Thomson-Reuters Web of Science.

We use the World-of-Science resources to analyse the number of bilateral co-publications Tanzania and each other co-authorship country per year, between 1966 and 2011. The complete list on nations that co-published a scientific document listed at SCI+SSCI+A&HCI are shown in Table 2. The 1966-2011 data were downloaded in February 2012. Table 2 shows the total number of articles co-published with authors living in Tanzania between 1966 and 2011 as well as the percentage that those articles represent over the total number of Tanzanian publications in that period.

Our focus is the study of the "links between pairs of countries". For doing so, we only need to know the existence of connectivity, or not, between Tanzania and each other country. In this preliminary study we show the self-organized behaviour of the six most important co-authorship networks from Tanzania: UK, USA, Switzerland, Netherlands, Sweden and Kenya. Figure 3 shows an account of this behaviour. It is interesting to note, that besides the traditional leadership of UK as the most important co-authorship scientific network of Tanzania, recently (2010) this position was displaced by the USA. From this figure, Kenya appears as the most important African partner of Tanzania. Its relation started in the early seventies. During the last decade, South Africa became the second most important network in Africa, followed by Uganda, Malawi and Ghana.

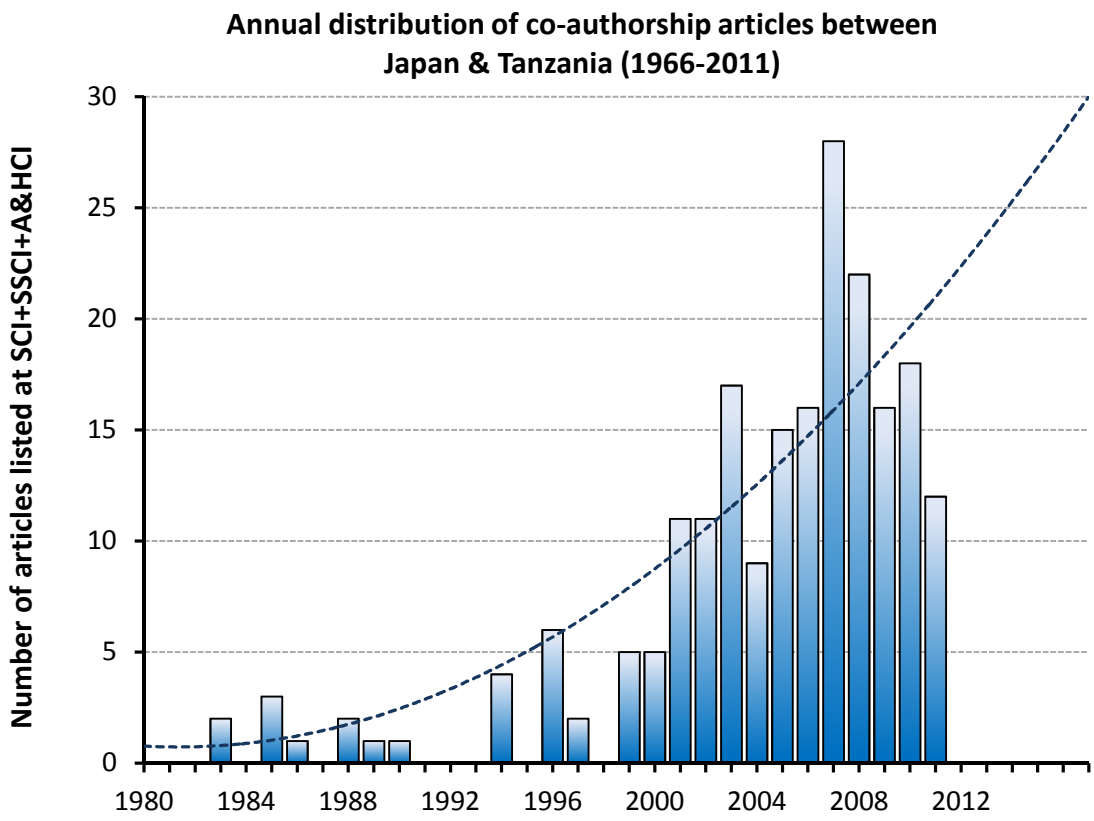

Figure 4: Evolution of the number of scientific co-publications at mainstream journal listed at the Science Citation Index (SCI), the Social Sciences Citation Index (SSCI) and Arts and Humanities Citation Index (A&HCI), produced by authors from Tanzania and Japan between 1980 and 2011. The first co-publication appeared in 1983. The dash line represents a fitting extrapolation using the mathematical model developed by Lemarchand (2012). Source: prepared by the author based on data downloaded from Thomson-Reuters Web of Science.

Table 2

Country	Publications (1966-2011)	%
Tanzania (1966-2011)	9618	100%
USA	1854	19,28%
ENGLAND	1844	19,17%
SWITZERLAND	641	6,67%
NETHERLANDS	598	6,22%
SWEDEN	595	6,19%
KENYA	527	5,48%
DENMARK	481	5,00%
GERMANY	392	4,08%
NORWAY	361	3,75%
SOUTH AFRICA	316	3,29%
BELGIUM	290	3,02%
CANADA	277	2,88%
UGANDA	274	2,85%
SCOTLAND	216	2,25%
JAPAN	209	2,17%
FRANCE	185	1,92%
ITALY	170	1,77%
AUSTRALIA	156	1,62%
SPAIN	144	1,50%
MALAWI	131	1,36%
NIGERIA	111	1,15%
AUSTRIA	108	1,12%
GHANA	106	1,10%
FINLAND	94	0,98%
THAILAND	94	0,98%
ZIMBABWE	94	0,98%
INDIA	90	0,94%
ZAMBIA	90	0,94%
MOZAMBIQUE	76	0,79%
BRAZIL	74	0,77%
ETHIOPIA	71	0,74%
CAMEROON	55	0,57%
GAMBIA	48	0,50%
PEOPLES R CHINA	46	0,48%
BURKINA FASO	42	0,44%
SENEGAL	41	0,43%
BOTSWANA	38	0,40%
WALES	38	0,40%
SOUTH KOREA	36	0,37%
MALI	35	0,36%
NEW ZEALAND	34	0,35%
PORTUGAL	34	0,35%
BENIN	33	0,34%
IRELAND	33	0,34%
BANGLADESH	31	0,32%

Country	Publications (1966-2011)	%
ISRAEL	29	0,30%
EGYPT	28	0,29%
INDONESIA	28	0,29%
RUSSIA	28	0,29%
RWANDA	28	0,29%
MEXICO	26	0,27%
FED REP GER	25	0,26%
PHILIPPINES	25	0,26%
PAPUA N GUINEA	24	0,25%
SUDAN	24	0,25%
CZECH REPUBLIC	23	0,24%
PERU	23	0,24%
GABON	22	0,23%
TAIWAN	22	0,23%
COLOMBIA	20	0,21%
MADAGASCAR	20	0,21%
VIETNAM	20	0,21%
SWAZILAND	17	0,18%
ARGENTINA	16	0,17%
COTE IVOIRE	16	0,17%
MALAYSIA	15	0,16%
PAKISTAN	15	0,16%
GREECE	14	0,15%
LESOTHO	13	0,14%
NAMIBIA	13	0,14%
SINGAPORE	13	0,14%
CONGO	12	0,13%
IRAN	12	0,13%
POLAND	12	0,13%
HUNGARY	10	0,10%
BURUNDI	9	0,09%
NORTH IRELAND	9	0,09%
SRI LANKA	9	0,09%
ZAIRE	9	0,09%
CAMBODIA	8	0,08%
CHILE	8	0,08%
ECUADOR	8	0,08%
ESTONIA	8	0,08%
NEPAL	8	0,08%
NIGER	8	0,08%
HONG KONG	7	0,07%
JORDAN	7	0,07%
SAUDI ARABIA	7	0,07%
SLOVENIA	7	0,07%
TOGO	7	0,07%
TURKEY	7	0,07%

Country	Publications (1966-2011)	%
ALGERIA	6	0,06%
COSTA RICA	6	0,06%
MOROCCO	6	0,06%
SYRIA	6	0,06%
VENEZUELA	6	0,06%
DOMINICAN REP	5	0,05%
ERITREA	5	0,05%
GUINEA BISSAU	5	0,05%
KUWAIT	5	0,05%
QATAR	5	0,05%
ROMANIA	5	0,05%
SERBIA	5	0,05%
SEYCHELLES	5	0,05%
U ARAB EMIRATES	5	0,05%
ANGOLA	4	0,04%
GUATEMALA	4	0,04%
LITHUANIA	4	0,04%
MALTA	4	0,04%
MYANMAR	4	0,04%
NICARAGUA	4	0,04%
SLOVAKIA	4	0,04%
TRINID TOBAGO	4	0,04%
TUNISIA	4	0,04%
WEST GERMANY	4	0,04%
BARBADOS	3	0,03%
BOLIVIA	3	0,03%
BOSNIA HERCEG	3	0,03%
CENT AFR REPUBL	3	0,03%
CYPRUS	3	0,03%
ICELAND	3	0,03%
JAMAICA	3	0,03%
LAOS	3	0,03%
LATVIA	3	0,03%
LEBANON	3	0,03%
LIBERIA	3	0,03%
LUXEMBOURG	3	0,03%
MAURITIUS	3	0,03%
OMAN	3	0,03%
SENEGAMBIA	3	0,03%
SIERRA LEONE	3	0,03%
SURINAM	3	0,03%

Country	Publications (1966-2011)	%
YEMEN	3	0,03%
AFGHANISTAN	2	0,02%
BAHRAIN	2	0,02%
BULGARIA	2	0,02%
CHAD	2	0,02%
CROATIA	2	0,02%
CUBA	2	0,02%
GREENLAND	2	0,02%
HAITI	2	0,02%
HONDURAS	2	0,02%
MACEDONIA	2	0,02%
MALAGASY REPUBL	2	0,02%
PANAMA	2	0,02%
PARAGUAY	2	0,02%
REUNION	2	0,02%
SOMALIA	2	0,02%
USSR	2	0,02%
W IND ASSOC ST	2	0,02%
YUGOSLAVIA	2	0,02%
BHUTAN	1	0,01%
CZECHOSLOVAKIA	1	0,01%
EL SALVADOR	1	0,01%
EQUAT GUINEA	1	0,01%
FIJI	1	0,01%
FRENCH GUIANA	1	0,01%
GUINEA	1	0,01%
IRAQ	1	0,01%
MAURITANIA	1	0,01%
MICRONESIA	1	0,01%
PALAU	1	0,01%
PAPUA NEW GUIN	1	0,01%
S WEST AFRICA	1	0,01%
SAO TOME PRIN	1	0,01%
SOLOMON ISLANDS	1	0,01%
ST LUCIA	1	0,01%
TRINID TABAGO	1	0,01%
UNITED ARAB REP	1	0,01%
UPPER VOLTA	1	0,01%
URUGUAY	1	0,01%
WESTERN SAHARA	1	0,01%
YEMEN ARAB REP	1	0,01%

SOURCE: Table prepared by the author based on primary information provided by the Science Citation Index (SCI); Social Science Citation Index (SSCI) and Arts and Humanities Citation Index (A&HCI).

Table 2 (cont.)

If we take into account all those co-publications produced by Tanzania with other countries between 1966 and 2011, which represent 1% or more, from the total number of Tanzanian publications within the same period, we are able to find 12 co-authorship networks with European countries (UK, Switzerland, Netherlands, Sweden, Denmark, Germany, Norway, Belgium, France, Italy, Spain and Austria), 2 from North America (USA and Canada), 5 from Africa (Kenya, South Africa, Uganda, Malawi and Ghana) and finally 2 from Asia-Pacific (Japan and Australia).

Figure 4 shows the evolution of co-publications between **Tanzania** and **Japan** that are listed at the SCI, SSCI and A&HCI. As it is shown here, besides the fact of the modest number of co-publications (207 publications or 2,17% of the total number of scientific documents published by Tanzania), the co-operation shows an parabolic increase over the last 30 years.

In order to understand the co-authorship patterns with different regions of the world, we prepared the following figure 5. Here we represent the co-authorship patterns (1966-2011) of Tanzania with Europe, North America, Asia-Pacific, Africa and Latin America and the Caribbean (LAC). Clearly the dominant region is Europe, but in recent years the co-authorship with the rest of countries in Africa is increasing with a higher growth rate. Using the mathematical model of self-organizing co-authorship networks (Lemarchand, 2012) it is possible to predict – using the present growth rates- that by year 2025 the co-authorship with African countries will be higher than with European countries.

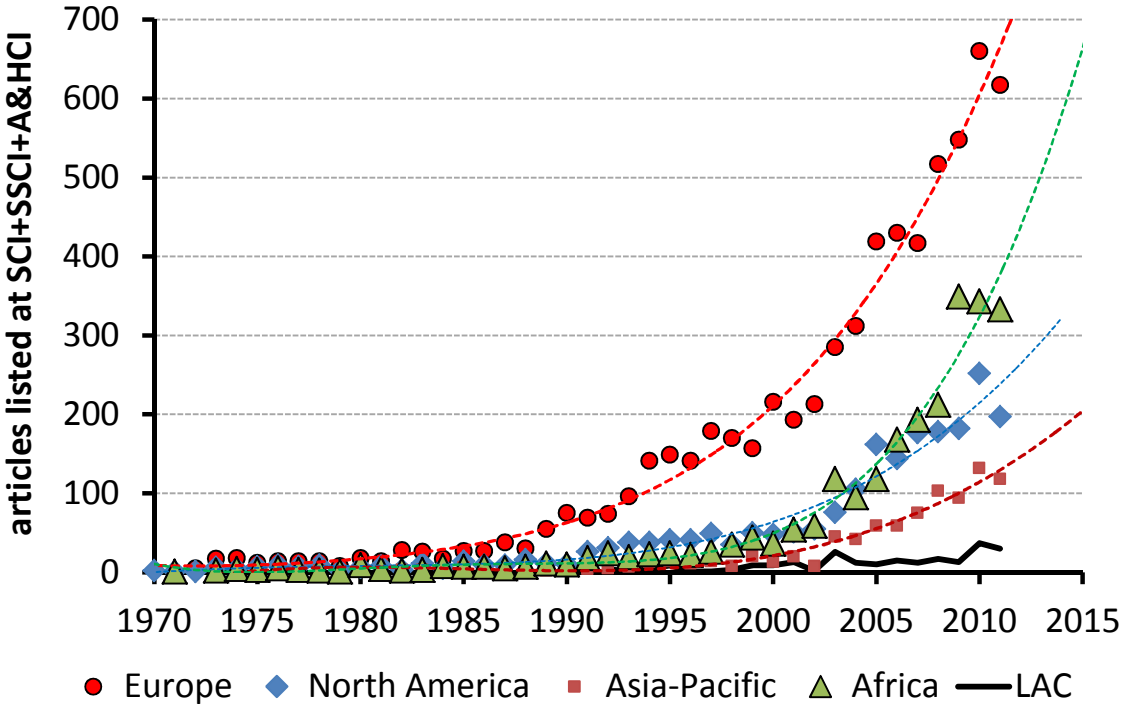

Figure 5: Evolution of the number of scientific co-publications at mainstream journal listed at the Science Citation Index (SCI), the Social Sciences Citation Index (SSCI) and Arts and Humanities Citation Index (A&HCI), produced by authors from Tanzania with countries from Europe, North America (USA + Canada), Asia-Pacific, Africa and Latin America and the Caribbean (LAC) between 1966 and 2011. The dash lines are extrapolations using the mathematical model developed by Lemarchand (2012). Source: prepared by the author based on data downloaded from Thomson-Reuters Web of Science.

Another interesting result is the fact that the co-operation with Latin American and Caribbean countries is totally negligible. Taking into account the level of development in agricultural sciences that Argentina and Brazil already have, allowing them to have one of the most important productive systems for the exportation of agricultural products, and considering that as part of the strategic STI plan developed by Tanzania (UNESCO 2011a, 2011b, 2011c) the agricultural system is a priority, some measurements should be taken to promote South-South cooperation with this region of the world.

4. Disciplinary distribution of publications

The following Figure 6 shows the distributions of publications among the most important disciplines that accounts for more than 89% of the total Tanzanian publications listed at SCOPUS between 1996 and 2010.

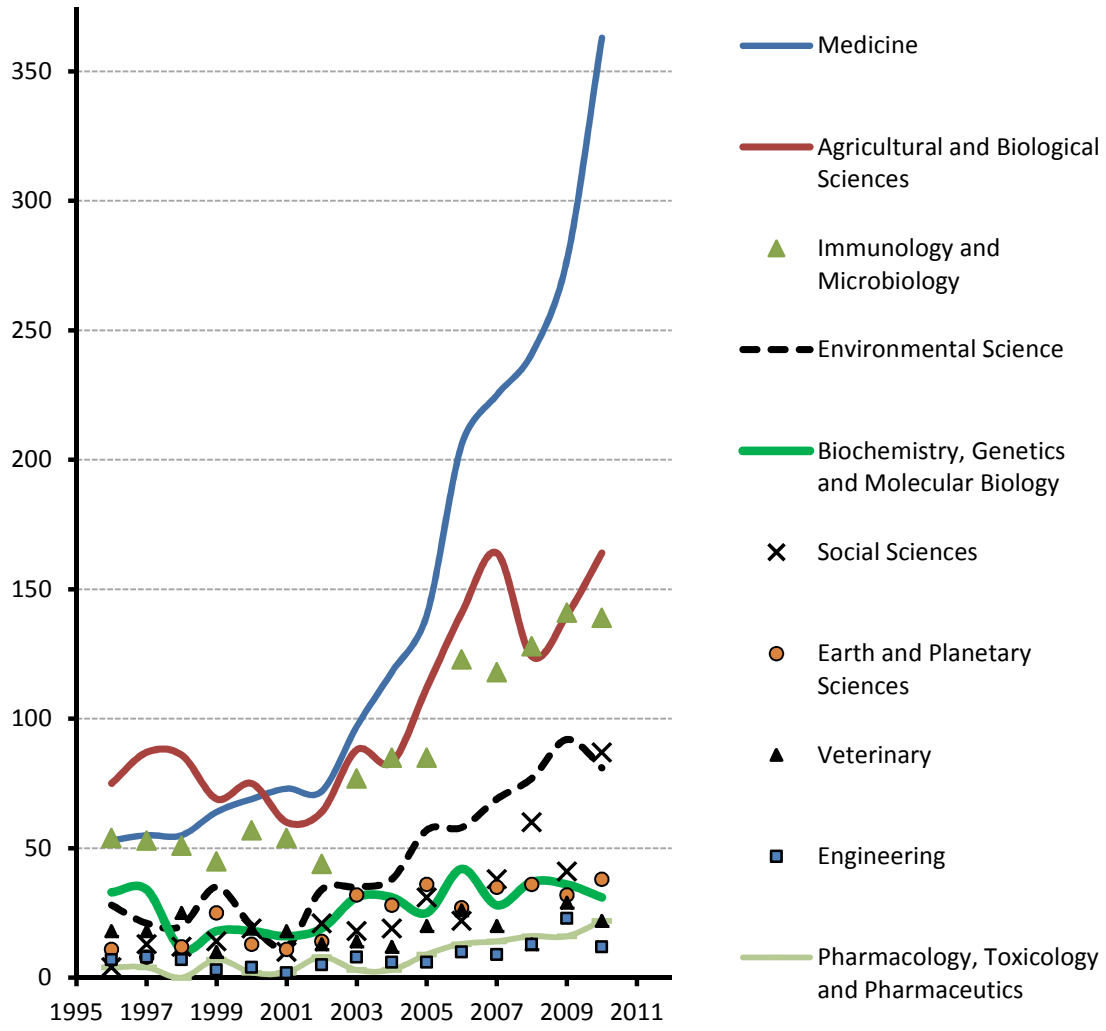

Figure 6: Evolution in the number of Tanzanian scientific publications listed at SCOPUS (1996-2010) by discipline. Here we represent only the 9 most representative disciplines (which account for more than 89% of the total number of publications during the same period). Source: prepared by the author based on data downloaded from SCOPUS.

According to Figure 6, the publications on medicine and their related disciplines are the dominant ones. One of the explanations can be founded on the fact that the Health Institute (IHI), a jewel of Tanzanian science grew out of a partnership with the Swiss Tropical Institute and remains almost entirely funded by foreign partners. Researchers there have studied malaria in central Tanzania since the 1950s, and in 2009 it became the first institution in Africa to start clinical trials of RTS,S a promising malaria vaccine. The IHI's prominent malaria research is one reason why Tanzania scores as one of Africa's top five countries in terms of immunology publications (Irikefe et al 2011).

The agricultural research —the field in which more than half of the country's researchers work— is the second most productive discipline. Over the last decade, the country also ranks highly in social sciences and environmental science. It is very important to notice the low production of research publications on engineering, taking into account that this is consider one of the priorities (UNESCO, 2011d).

Figure 7 shows the complete disciplinary aggregated distribution of Tanzanian scientific publications between 1996 and 2011. This type of graph can provide an indirect indicator of the type of scientific qualified human resources available and Tanzania today and the need to generate new resources in those areas which were detected as a priority for the country (Ministry of Communication, Science and Technology, 2010 and MKUKUTA Secretariat, 2010).

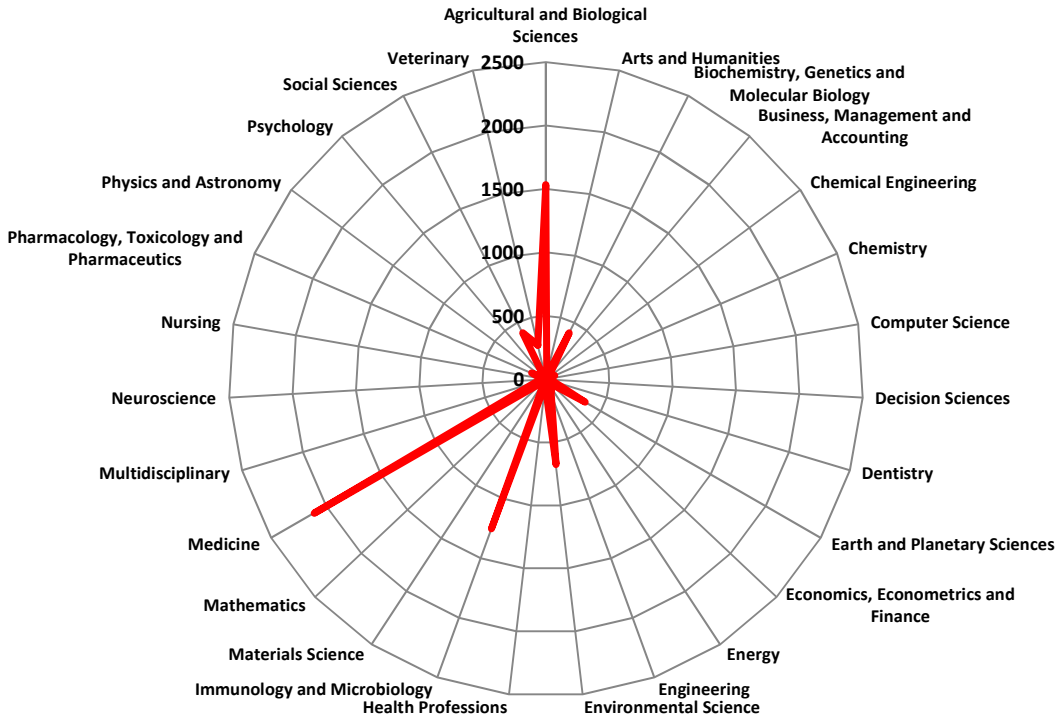

Figure 7: Disciplinary distribution in the number of Tanzanian scientific publications listed at SCOPUS (1996-2010). Source: prepared by the author based on data downloaded from SCOPUS.

5. Key findings:

According to UNESCO's Institute for Statistics, Tanzania's research spending in 2007, reached a total investment of $234 million, or 0.48% of its GDP. This was on a par with Kenya's as a proportion of GDP, but 38% of its R&D funding comes from abroad — as opposed to 18% in Kenya. For this reason, understanding the international research and innovation links should be a key issue for the implementation of a coherent STI policy in the country. From the empirical and theoretical preliminary analysis presented here, we are able to infer the following findings:

- During the last 46 years, the total scientific productivity at mainstream journals from Tanzania has been very modest, several times lower than other developing countries with similar population and natural resources.

- It is possible to recognize at least two periods: (a) between 1966 and 1998 with a low quasi-linear growth and (b) between 1999 and the present, where we are able to detect a quasi-exponential growth. The second period might be associated to the application of a strongest STI policy and the wish of the government to connect science and technological activities with their development strategy (MKUKUTA Secretariat, 2010 and Ministry of Communication, Science and Technology, 2010). At global level, after the World Science Conference (UNESCO, 2000), a new social contract for science and techno-economic paradigm was formulated (Lemarchand, 2010). The last is in agreement with the publication characteristics observed during the second period. The proposed national STI reform that has been implemented by the government of the United Republic of Tanzania is also in agreement with the characteristics of this new social contract of science.

- The quasi-exponential growth of international scientific publications during the last decade is an indirect indicator that the number of researchers increased over the same period (Mabe, 2003 and Lemarchand, 2012). This fact is consistent with the quasi-exponential increase in the number of scientific publications per million people and the reforms implemented at the National STI system since 2003.

- Applying a mathematical model of self-organized co-authorship networks to the data analysis of the Tanzanian co-publications, it is possible to identify at least 19 co-authorship networks (12 in Europe, 5 in Africa, 2 in North America and 2 in Asia Pacific). This number is sensible smaller than the number of networks found in other regions (e.g. Iberoamerica) for countries with similar number of publications than Tanzania (Lemarchand, 2012).

- Over the years, the most important co-authorship network was UK, which was recently displaced by USA in 2010.

- The most important African co-authorship network is Kenya, followed by South Africa (with a highest growth rate over recent years), Uganda, Malawi and Ghana.

- The analysis of co-authorship networks by regions shows that the scientific co-publication with Europe have been the most important one, but due to the fact that the co-authorship with African countries has a higher growth rate, it was estimated that by the year 2025, the co-publications with African countries will be more important than with Europe (assuming that the growth rates will remain the same).

- Following the findings of Lemarchand (2012) it is possible to associate the self-organized co-authorship networks with the existence of Diasporas in those countries. In this case, we can assume with high confidence that the most important Tanzanian scientific Diasporas are living in UK, USA, Switzerland, Netherland and Sweden. This might be useful information in order to design specific STI policy instruments to transform the "brain-drain" into a "gain-brain."

- The analysis on the disciplinary distribution of publications, over the last 15 years, shows that Tanzania should have a critical mass of specialized scientists on (1) medicine, (2) agricultural and biological sciences, (3) immunology and microbiology, (4) environmental sciences and (5) biochemistry, genetics and molecular biology. The scientific production on the rest of the disciplines is still very low. This is key information which can be considered very useful to design new capacity-building strategies, new higher education policies and new STI policy instruments.

6. References

Beaver, D. de B., Rosen, R. 1978. Studies in Scientific Collaboration. Part I, II and III, *Scientometrics*, 1(1), 65-84; 1(2), 133-149; 1(3), 231-245.

Beaver, D. deB. 2001 Reflections on Scientific Collaboration (and its study): Past, Present, and Future, *Scientometrics,* 52 (3), 365-377.

Beaver, D. deB. 2004. Does collaborative research have greater epistemic authority? *Scientometrics*, 60 (3): 399-408.

Davison Frame, J.; Narin, F. and Carpenter, M.P. 1977. The Distribution of World Science, *Social Studies of Science*, 7, 501-516.

Glänzel, W. and Schubert, A. 2004. Analyzing Scientific Networks Through Co-authorship in H.F. Moed et al. (eds.), *Handbook of Quantitative Science and Technology Research*, pp. 257-276; Dordrecht: Kluwer Academic Publishers.

Hirsch, J. E. 2005. An index to quantify an individual's scientific research output. *PNAS* 102 (46): 16569–16572.

Holmgren, M. and Schnitzer, S.A. 2004. Science on the Rise in Developing Countries. *PLoS Biology*, 2 (1), 10-13.

Irikefe, V. ; Vaidyanathan, G.; Nordling, L. ; Twahirwa, A.; Nakkazi, E. and Monastersky, R. 2011. The View from the front line, *Nature*, vol. 474: 556-559.

Katz, J.S. and Martin, B.R.; 1997. What is research collaboration? *Research Policy*, 26, 1-18.

Lemarchand, G.A. 2007. Science Indicators of Cooperation in Iberoamerica: The co-authorship of main-stream scientific articles. In: A long-term temporal evolution's study (1966–2006), *VII Congreso Iberoamericano de Indicadores de Ciencia y Tecnología* – Sao Paulo (Brazil) May 23–25, 2007.

Lemarchand, G.A. 2010. Science, technology and innovation policies in Latin America and the Caribbean during the past six decades. In: Lemarchand, G.A. (ed.) National Science, Technology and Innovation Systems in Latin America and the Caribbean, *Science Policy Studies and Documents*, vol. 1, Montevideo, UNESCO, pp. 15–139. http://spin.unesco.org.uy/subida/referencias/ref 794.pdf.

Lemarchand, G. A. 2012. The long-term dynamics of co-authorship scientific networks: Iberoamerican countries (1973–2010), *Research Policy*, vol. 41: 291– 305.

Ministry of Communication, Science and Technology. 2010. *The National Research and Development Policy,* MCST, The United Republic of Tanzania. http://www.mst.go.tz/index.php?option=com_phocadownload&view=category&id=2:national-research&Itemid=66

MKUKUTA Secretariat, 2010. *National Strategy for Growth and Reduction of Poverty II*, NSGRP II, Ministry of Finance and Economics, United Republic of Tanzania. http://www.povertymonitoring.go.tz/Mkukuta/MKUKUTA%20BOOK%20II%202010.pdf

Pouris, A. 2010. A scientometrics assessment of the Southern Africa Development Community: Science in the tip of Africa, *Scientometrics*, vol. 85: 145-154.

Toivanen, H. and Ponomariov, N. 2012. African regional innovation systems: analysis of research collaboration patterns 2005-2009, *Scientometrics*, DOI 10.1007/s11192-011-0390-1

Tussen, R.J.W. 2007. Africa´s contribution to the worldwide research literature: New analytical perspectives, trends and performance indicators, *Scientometrics*, vol.71: 303-327.

UNESCO, 2000, *World Conference of Science. Science for the Twenty-First Century: A New Commitment*, London: Banson. http://unesdoc.unesco.org/images/0012/001207/120706e.pdf

UNESCO, 2011a. *UNESCO Country Programming Document 2011-2015: United Republic of Tanzania*. http://www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/SC/pdf/sc_biotechnology-bioentrepreneurship_Tanzania.pdf

UNESCO, 2011b. *Biotechnology and Bioentrepreneurship in Tanzania*, IHI_UNESCO Survey & Stakeholders Meeting Report 2011. http://www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/SC/pdf/sc_biotechnology-bioentrepreneurship_Tanzania.pdf

UNESCO, 2011c. *Research-Policy Linkages of Science: Related Ministries and their Research Organizations*, Economic and Social Research Foundation. http://www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/SC/pdf/sc_ST_Research-Policy_linkages_Tanzania.pdf

UNESCO, 2011d. *Assessment of women scientists' participation in science, engineering and technological industries in Tanzania* (prepared by M.K. Kasembe and S. Mashauri). http://www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/SC/pdf/sc_Assessment_of_Women_in_SET_Industries_in_Tanzania.pdf

Wagner, C. S. and Leydesdorff, L., 2005b. Mapping the network of global science: comparing international co-authorships from 1990 to 2000*, International Journal of Technology and Globalisation*, 1(2), 185-208.