Paper presented in the IV Globelics Conference at Mexico City, September 22-24 2008

Globelics

Scientific Community, Relationship between Science and Technology and the African Predicament: Who is to Blame and what can be Done?

Diyamett, Bitrina D.[1]

Abstract

As globalization gather momentum and innovation motor increasingly turning technology into science, the concept of "Triple Helix" is gaining currency in many countries, especially the developed ones. Governments are increasingly becoming aware of the importance of the universities as strategic actors in national economic development given their strategic position in new knowledge generations. The concept of Triple Helix is also currently being exported to Africa, and as well gaining popularity. However, the concept presents a serious dilemma for the Scientific Community in Africa. The dilemma largely emanates from the fact that there is a system disconnect at the boundary of science, which is global in character, and technology that is local in nature. Scientific Communities in Africa, and the Universities in particular, seems to have been caught in a dilemma between trying to be at the same level with the rest of the scientific community world wide, and responding to the governments' and donor pressures to be of service to the local productive sector, which is at a much lower level technologically; and where the popular notion of "Science in Society and Science for the Society" does not seem to hold.

This paper is an attempt to bring to the fore these dilema. It discusses the behavior of the scientific community world wide, the convergence between science and technology, especially in developed economies, and the pressure on the African scientists to gear their scientific inquiries to solve local

[1] Bitrina Diyamett, is a Senior Research officer at the Tanzania Commission for Science and Technology (COSTECH), and a National Coordinator, African Technology Studies (ATPS) Network, Tanzania Chapter. She is currently a PhD Student at the University of Dare s Salaam, Tanzania.

problems, at the same time required to publish in international referred journals as basis for professional recognition and promotion. The paper concludes by an attempt to suggest how this dilemma can best be addressed, including changing the way scientific research is currently being funded.

Introduction

In 2000 the University of Dar es Salaam organized a Convocation Symposium on Multi-Dimensional Crisis of Education in Tanzania. I was asked to attend this symposium to represent the Director General (DG) of The Tanzania Commission for Science and technology (COSTECH) who is my employer. The DG of COSTECH was invited to be a discussant of a paper by an eminent scientist from the Faculty of Science, University of Dare s salaam. During his presentation the scientist emphasized the paragraph quoted below:

> …..”*Not long ago the Tanzanian national science awards were being given in appreciation of the “discoveries” of antiquities! How can scientific advances be taken seriously by school children this way? While others in science conscious societies are engaged in advances and inventions of the state of art technologies like satellites, we in Tanzania orchestrate the use of bamboo for water distribution or fabrication of wooden duplicating machines, Indeed these are examples of dubious concept of appropriate technology, that has been used by some external funding agencies to substantiate motive towards scientific underdevelopment of developing countries. It tends to marginalize the conceptual thinking of policy makers and some scientists who may be victims of this concept. Hence relevant science suffers through government and policy makers getting indulged supporting mediocre research that perpetuate what may be termed as traditional ways of doing things that goes down to antiquity. This effectively thwarts prospects for developing science and technology in developing countries.”(Diyamett, 2007 p. 21)*

From the quotation it is clear the scientist was referring to COSTECH’s program on “Tanzania Award for Science and Technology Achievements” (TASTA). The award is given to any body, individual, or, organization who comes out with an invention with potential for contribution to socio-economic development. Most of the past TASTA awardees happened to be individuals who live deep down into the communities in rural areas, trying to come up with solutions to solve their immediate problems. A study of 30 individual inventors, including TASTA awardees, conducted in Tanzania between 1999 and 2002, indicated that about three quarters of the inventors are individuals without institutional affiliation. This is despite the fact that the award policy also involves researchers from higher learning institutions such as the Universities. Among the important inventions and innovations are bamboo water pipes and manually operated duplicating machine (Diyamett, 2007).

The presentation ended with applause and clear indication that the participants were in support of the argument put forward. Being a representative of COSTECH at the meeting I was requested to make a brief comment on the presentation. I was then fresh from fieldwork where I was examining the plights of individual inventors/innovators, most of whom were TASTA awardees. I stood for about seven minutes; by the time I was sitting down I could see a clear total reversal of the impact the earlier presentation had on the perception of the participants. This was the last paper before coffee break, and it became the major issues of discussion during the break. I did not stop thinking about the event, even many days later. I thought about the possibility of the eminent scientist being right and I being wrong, of both of us being both right and wrong. Above all, I, for the first time thought, very seriously, about the relationship that exists between science and technology, especially as it relates to poor developing countries. This paper is precisely about this. It is an attempt to revisit the relationship that exist between science and technology and situate this relationship in an African context in regard to the contribution of science in socioeconomic development. The rest of the paper is structured as follows: The section that follows (section 2) defines science and discusses the behavior of the scientific community worldwide. Section three is devoted to historical relationship between science and technology, definition of technology and the current convergence of the two, presenting a dilemma for African scientists. Section four is an attempt to proposal modalities of addressing this dilemma.

2.0 Science and the Scientific Community

The English dictionary defines science as a branch of knowledge or study dealing with a body of facts or truths systematically arranged and showing the operation of general laws (Random House, 2006). Science can be divided in two major branches: natural science that deals with the study of natural world, and social science that deals with systematic study of human behaviour and society. The word science is however used in this paper to mean natural science, which represents major branches such as physics, chemistry, biology, earth and space sciences. Unlike social sciences, where two or more theories can co exist, or slightly adjustable to a particular socio economic environment, the truth in natural science is one all over the world-science is universal. That acceleration due to gravity for instance is 9.8 m/sec^2 in Tanzania as well as in the U.S, and where there is slight difference; it is not because of some social or cultural environment, but the position of a country or region on the globe, irrespective of what race happened to inhabit it. The co-existence of more than one postulate to explain a phenomenon in science creates a crisis among scientists, and the scientists won’t rest until the crisis is settled and only one postulate that becomes a theory is passed (Kuhn 1962, cited in Diyamett, 1992). This oneness in science might have led to the sociological concept of ‘scientific community”. The concept in its broadest sense refers to a group of scientists sharing the same attitudes, norms, and values. It is also being used, in a narrower way, to characterize a group of scientists active in a specific field of science. All the scientists active in a country are said to form a "national" scientific community, whereas most scientists claim to belong to the "international" scientific community (Gillard, 1994). Thus, the same concept is used for various levels and with different meanings to describe the international, scientific community and down to small groups of specialists that share the same values universally. Although the concept of scientific community has been challenged and criticized, no appropriate concept has been proposed, and is being used in recent publications and still considered a useful methodological tool in on going research programs (Gillard, 1994).

The oneness of the scientific community is also reflected in the widespread international scientific research collaboration reflected in co-authorship in scientific publications. The table below depicts how widespread research collaboration in science is. The table indicates only the top 10 of the 50 countries identified in international co-authorship in 1995/96 (Glanzel , 2001).

Table 1: National Publication Output and Share of International Co-Publications (All fields combined, 1995/96)

Rank	Country	Number of Papers Produced	International Share in percentage
1	Thailand	1131	64.2
2	Hungary	5213	50.3
3	Portugal	2870	50.1
4	Czech Republic	5587	49.1
5	Switzerland	20872	47.5
6	Poland	12374	45.7
7	Chile	2496	45.4
8	Belgium	14695	45
9	Venezuela	1137	44.9
10	Romania	2069	44.7

Source: Glanzel (2001, Pg.6)

The table above indicates that of the 50 countries studied; only 2 are from Africa, and none from Sub Saharan African countries. The table also indicates that, although the highly developed countries have a much larger share of publications, their share of international co-authorship is much smaller. For instance USA had 403,050 papers, with international share of co-authorship of 18.1%. Others with number of papers and international share in brackets are: UK (110,898, 27.2%), Japan (108,019, 14.4%), Germany (93,683, 33.3%), Sweden (23,698, 39.0%) and Denmark (11,809 (43.33%). This indicates that collaboration between and among scientists within the same territory (country) in developed countries is more pronounced than the one between and among scientists in developing countries.

The table also compared values for 1995/96 and 1985/86, and indicates that the collaborative research in science is on the increase. This trend is also supported by Narian, 1991, Luukkonen, et, al. 1992, Georghiou, 1998, and Wgner et al., 2004. According to Wagner, at el., 2004, the growth in international collaboration in scientific research may be due to factors internal to science and scientists themselves than policy influence. It appears that scientists at subfield level seems to be linking together for enhanced recognition and reward than to policy related factors (Wagner, et al., 2004)(the "republic of science" seems to be at work here). Further more, the choice of individual scientists to collaborate may be said to be motivated by the reward structure of science where co-authorship, citation, and other forms of professional recognition lead to additional work and funding in a virtuous circle (Wagner, et al., 2004). African scientists, just like others throughout the world, also seek for recognition[2], and therefore collaboration and co-authorship. However, unlike scientists in the developed world who collaborate among themselves as well, most of the scientific collaboration in Africa is more skewed towards collaboration with the developed world, and they compete among themselves for collaborators from more developed world. They seem to be doing so more for access to funding than recognition. For example the existence of special aids development programs between Scandinavian countries and Latin America and Africa countries have led to collaboration between the Scandinavian countries, African and Latin American scientists (Wagner, et al, 2004). Otherwise the scientific community is universal, be it in the US or Africa. The collaboration between scientists is on the increase, and all scientists, irrespective of their countries of origin, strive for professional recognition from peers all over the world. This in itself is not a bad thing as it raises the capabilities of scientists in poor developing countries to generate new knowledge. The challenge is from the fact that science is not supposed to be an end in itself, but means to an end-it has to be brought to the service of human kind through technological innovations. This touches issues on relationships and complementarities between science and technology, which is briefly discussed in the following section.

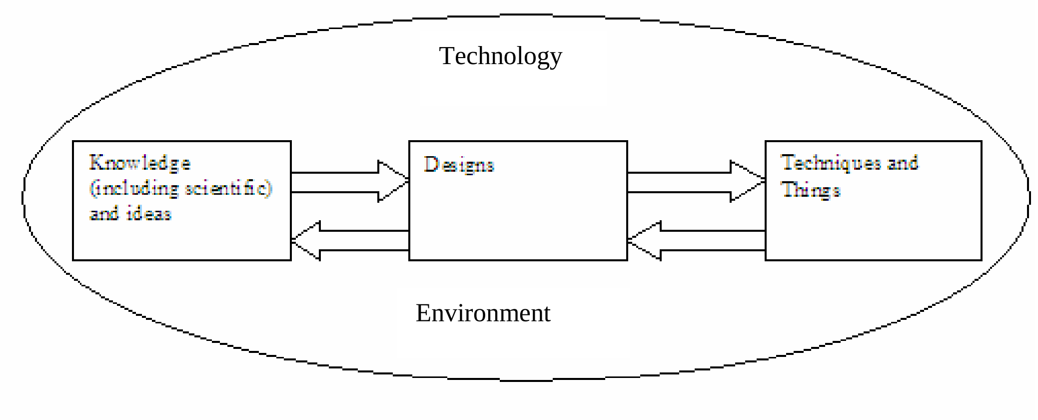
3.0 Relationship between Science and Technology, the Current Convergence of the two, and the Challenges Facing African Countries.

3.1 Relationship and Convergence between Science and Technology

There has been, and there still is a popular believe that science predated technology, and technology being simply conceived as application of science. However history tells us that technology antedated science by far. When early people were making fire out of friction, no body

[2] Note that the incentive structure at universities is also geared towards this tendency-the promotion policy requires a scientist to publish in peer reviewed international journal.

ever before systematically investigated that friction between two objects can produce heat energy. It has been written many times that it is technology that gave birth to early scientific investigation-It was the working of steam engine as a technology that led to the new field of thermodynamics in science. In chemistry, the science of polymer that emerged in the twentieth century, in large part resulted from research performed inside industrial laboratories to develop materials that could better fulfill the changing requirement of industry. The rise of scientific understanding supporting aircraft design reflects a similar story-a primitive version of the aircraft (technology) came first and the science discipline of aerodynamics followed (Richard, et al., 1993). There are many other written examples that support the fact that technology antedated science, and that the two reinforce each other: innovation in technology produces developments in science and vice-versa. Going by these facts, technology can therefore be defined not as a thing, but a spectrum of events running from knowledge and ideas on the one end, and things and techniques at the other end, with design in the middle. The causality runs from both directions. Diagrammatically it can be represented as follows:



Technology does not exist in a vacuum, but within what can be referred as 'technology environment', which include social, economic, political and cultural environment of a given society. Although the technology environment, to a large extent affect the way science is pursued in a given society, but logic internal to science remains universal.

With the emergency of new technologies the overlapping between processes is more pronounced and the spectrum is blurred-the scientific, design and things and techniques domain are overlapping. Good examples are nanotechnology, biotechnology, information and communication technologies. The biotechnology revolution, for instance, has brought about an unprecedented convergence of science and technology. In fact, the line between the two fields is increasingly hard to define. As frontier of technology rapidly move and competition between industrial firms and nations become fierce, another phenomenon is rapidly appearing: industries are increasingly turning to scientists in the higher learning institutions to keep abreast with the frontiers of knowledge. On the other hand the Universities, especially of the developed world, have turned to the companies for research funds. In regard to the above point, Professor Eric Thomas, Vice Chancellor of the University of Bristol, in his speech to the Bristol society had the following to say:

> *"…Universities have undertaken a new role recently-that of an economic force, firstly by their sheer size and secondly by their knowledge transfer and spin out commercial activities. If I was to give one example that encapsulated the changes I wish to highlight, it is this. I was recently on a trip to Japan that included a meeting with the British ambassador and two members of his staff that represent 'Invest UK', the branch of civil service which is charged with attracting inward investment from foreign companies. During the meeting, the two from 'Invest UK' told us that one of the important points they used in attempting to attract Japanese companies to invest in particular location was the proximity of that location to a higher education cluster because of the potential synergies. As one of them said" we sell higher education now, not subsidized green field sites" "(Thomas, 2002, Pg 5).*

The above summarizes what is happening through out the world, especially in the more developed countries. Collaboration between the university and companies has become the norm in developed countries and the concept is currently being exported to Africa and gaining wider currency. With governments the third actor in providing conducive environment and incentives for the collaboration, the concept has come to be popularly known as "triple helix". The functioning of this helix has been studied in different context by scholars of technological innovation, and they too, have become the fourth important player in the helix. Good for the developed countries' universities, because science and technology are more or less intertwined-it is where the convergence between science and technology is currently happening. Just like science and technology, there is a symbiotic relationship between basic research and applied research that is more relevant to the needs of the industry. The scientists therefore can still conduct curiosity oriented basic research, while at the same time fulfilling the needs of the industry. In relation to this Granberg and Jacobson, cited in Brundenius et al., 2006, argue that, the believe that 'curiosity-driven' research is a threat to innovation and economic growth is misleading, arguing that the two research orientation are complementary (Brundenius et al., 2006). With Universities accessing funds for research from the industry, it is a perfect win-win situation. But what about the universities in poor countries where technology is at a much lower level such as the Sub Saharan African countries? Where technology, to a large extent is divorced from "big science" which is a dream of any scientist; where funds for research can not adequately be provided by the private sector, neither the governments? Where the Notion "Science in Society and Science for Society" does not seem to hold? Should the level of science be brought down to the level of technology? For sure this is not a desirable scenario-every country should strive for excellence in scientific research if it is to avoid marginalization in an increasingly globalized world. More over, as already argued in this paper, the scientific community is one all over the world, and they prefer to work on current and emerging issues. A most desirable scenario therefore is to bring local technology to the level of the frontiers of science universally; but how feasible is this option, and what would be the modalities? This is an issue I will return to in the last section. For the time being it suffices to note that, even in the socio-economic context of the poor developing countries, the relationship between science and technology is better for those sectors where technology employed is closer to science. A Tanzanian based study conducted between 2001 and 2004 comparing technology transfer from R&D organizations including universities for three sectors, namely industry, agriculture and health, shows that there is a better connection between R&D and health and agricultural sectors compared to the industrial sector (Wangwe et al., forth coming). One of the conclusions of the study in regard to these differences is that technologies used in health and agricultural sectors are more advanced compared to that in the industrial sector. This assertion is corroborated by the recent and novel form of collaboration that seems to be emerging-Some good scientists in Africa seem to be turning to companies in the developed countries for collaboration, where they can conduct their "big science", and at the same time find some application for their work. In regard to this, a group of scientists from the University of Dare s salaam, Faculty of Science is currently negotiating a contract between them and an American Company, where they can transfer and commercialize their inventions (discussion with an eminent scientist from the Faculty of Science, University of Dar es Salaam).

3.2 Some Challenges Facing African Countries

At this juncture, let me return to the quotation in the introduction that I started off with. I am now in a position to understand better the position of the eminent scientists than I was in 2000. However this is not to say that I am now agreeing with what was said then, but to say that perhaps my comments after the presentation by eminent scientists might have been slightly different. That I did not see the dilemma the scientists are in as clearly as I see it now. My argument then, as also expressed in Diyamett (2007) was that for more than two decades the Faculty of Science, University of Dare s salaam has actively been involved in research on the Tanzanian indigenous plants for natural chemicals that have medicinal potential. A number of scientific discoveries have been made from this research, particularly focusing on bio-molecules that have anti malarial properties. Among some of the discoveries are antimalarial and tryponocidal compounds (ability to kill parasites that cause sleeping sickness). However none of these until to date have gone outside the doors of the laboratory. To the contrary, many of the local inventions that scientists consider as useless antiquities are a directly responding to the needs of local problems, which could not be solved by "big science" any way. My argument then was why are the scientists criticizing the local efforts, while they themselves have failed to make their science work for the poor people. I however did not realise that turning science into useful products and processes is not an automatic and easy thing to do- a ripe environment has to be in place. In addition it is not something that can be done by the scientists a lone, and perhaps, as already demonstrated in this work, it is not even their priority. Scientists, who are increasingly asking for the 'Republic of Science', have to be 'tamed' by their governments for the socioeconomic developments of their respective countries. This can be done through appropriate institutional frameworks and incentive structures that are unique to Africa. Hitherto there is growing tendencies to copy the structures that have proved to work in more developed countries, such as the Triple Helix as understood and applied in more developed countries. While policy and academic discourse, and therefore theories on the triple helix in the developed countries rightly 'chased" practice, for the case of African countries practice seems to be "chasing" theories. Worse still, these are theories developed from the empirical observation from developed countries. For instance there is now a huge campaign and the popularization of the concept of the Triple Helix from both governments and the development partners. Universities are forced to justify their existence by collaborating with local producers, most of who are operating with technology that is at a much lower level than scientific research carried out at the universities. Some University Faculties, such as College of Engineering and Technology of the University of Dare s salaam in Tanzania for instance have adhered to the call by including a program on SME in their activities. I have often asked myself whether the researchers get academic satisfaction working with small scale industries that are employing less science intensive technologies; or rather, whether the work is *complementary* in the sense that some “curiosity” oriented basic research at the College arises by working with SMEs. Or is it that the two actors are forced to co-exist? What about the sustainability of the relationship once the donors withdraw the funding? What is it that is done by the university in SMEs program that can not be done by the Industrial R&D organizations put in place by the act of Parliament precisely for the purpose? This is however not to purport that universities should not make themselves useful to the society in which they exist, but rather, the role of universities, which I consider centers of excellence in their countries, has to be carefuly and clearly thought of. It is wrong to replicate the institutional arrangements of the developed countries. It must be understood that the direct universities involvement or rather partnership with the industry, even in developed countries is a recent phenomena, and has been necessitated by the requirement of the changing economic system. In the developed world, there has always been, to a large extent, a co-evolution of economic system and science and technology system since industrial revolution. Even today, some countries do assign universities only the R&D intensive programs of the industry. In German for instance, the collaboration between industry and the university is limited to knowledge intensive high technology areas, while for relatively lower technology SME, the appropriate partners has been found to be the *Fraunhofer Institutes*, whose research programs are oriented towards more applied research (Schmoc, 2006).

The major challenge for countries with low level of technology such as Tanzania is how to conduct a meaningful “big science”, while at the same time responding to the needs of the enterprises employing technology that is at a much lower level than the frontiers of science in these countries. It appears that there has to be, for some time, a coexistence of two sub-systems of innovation, especially for the industrial sector. First is the one that belongs to firms, including both formal and informal, that make use of technology that is not science intensive, where innovation is incremental and happen through learning by doing. The second subsystem that is yet to emerge in most poor SSA countries is the system that utilizes the frontiers of science in these countries for commercial exploitation. This must include collaboration between universities and entrepreneurial cadre that is yet to emerge. The cadre that is committed to invest in new innovative industries emanating from the commercialization of research outputs from the universities. Otherwise the concept of university industry collaboration, or more appropriately, the concept of triple helix as applied in developed countries seems to be an imposition that is difficult to work for Africa.

4.0 Coping with Dichotomy between Science and Technology in Poor Developing Countries: A Need for Institutional Reform.

In the previous sections we have argued that scientific community is basically universal and collaboration between and among scientist is being driven, to a large extent, by logic internal to science. In addition, science is increasingly converging with technology, presenting an ample opportunity for the scientist in the developed world to work with the industry. The picture is different for poor developing countries-there is large dichotomy between science that is universal and technology that is local and at a much lower level compared to science that is global, making a coexistence of two different subsystems of innovation in such countries: the one that is existing and utilizing low technology in the production systems; and the one that is yet to emerge by commercializing state of the art scientific research results.

The challenge that is facing innovation policy making in such countries is to make the two sub-systems to co-evolve until they meet in some point in time. This section is an attempt to describe how best to make this happen. First is to re-examine the relationship between the universities, the R&Ds and productive sector, especially the small scale low tech sectors. This can be in terms of further research, with major question being to what extent there are complementarities between university science and innovation in these sectors. Within the relationship, the role of the university must clearly be identified. How can the relationship between the university, R&Ds and SMEs be better organized? The argument here is that the university is supposed to be a center of excellence in knowledge generation, and therefore its role must be to expand frontiers of knowledge appropriate to local condition. Other intermediate and low level of knowledge generation must be left to the R&D organizations. The contribution of university can be in terms of producing manpower for the R&Ds and the productive sectors; and to collaborate with the R&D in solving firm's technical problems that is beyond the ability of the R&Ds. To this end therefore, there has to be a clear national innovation policy that guides the activities of the universities and that of the R&D organization. Hitherto, for instance in Tanzania, the activities of the R&Ds, to a large extent overlap with the activities of the universities.

Secondly, there has to be a deliberate effort to make commercial investment in relevant high technology or science intensive areas. Example is investment in pharmaceuticals. Hitherto, as already explained in this work, there exist a huge relevant research output undertaken by the Faculty of Science, especially in medicinal plants. However this has not been translated into useful products because of lack of local capabilities in pharmaceuticals. There are two major issues here: lack of visionary and committed entrepreneurs, and venture capital. Suggestion here is for University to include entrepreneurship training in their curricula and cultivate the idea of spin-off companies led by University professors themselves. This is not something new; it is widely being practiced by the professors in more developed countries' Universities. The practice takes shape in different ways. One which seems to be most appropriate for Tanzania environment, as a result of lack of highly trained entrepreneurs, is *the integrated academic-entrepreneur* where university professors take active part in the operation of the firms that they have founded based on their current research interest (Brundenius et al., 2006). As earlier pointed out, there is another major problem regarding this approach-venture capital. Where will it come from? Especially given that commercialization of the research idea is much more expensive than carrying out research itself. The suggestion here would be that donor funding should supplement governments' effort in providing venture capital. This imply that there has to be a radical change in the way development partners is supporting research in poor developing countries, to go beyond support of research parse, and include support in commercializing the ideas emanating from research they have funded. The development partners can for instance support the preliminary work towards the commercialization of research outputs, such as work on the commercial concept confirmation.

References

Brundenius, C., Gorranson, B. and Angren, J.(2006), "The Role of Academic Institutions in the National Systems of Innovation and the Debate in Sweden". Paper presented at "UNIVERSIDAD 2006". 5th International Congress on Higher Education, Cuba, 13-17th February, 2006.

Diyamett, B. (forth coming) "from Inventors to Innovators: An Empirical Investigation into Individual investors in Tanzania". ATPS, Nairobi

Diyamett, B. (2004), "The Concept of Technological Innovation: Theoretical Overview and Some Practical Implication for Africa" .In Mwamila B. L. M., Trojer L., Diyamett, B. and Temu, A. (eds.) (2004), *Innovation Systems and Innovative Clusters in Africa, Proceedings of the Regional Conference.* Bagamoyo, Tanzania.

Diyamett, B. (1992), "Book Review-Structure of Scientific Revolutions by Thomas Kuhn (1962). Research Policy Institute, Lund University.

Narian, F. (1991), "Globalization of Research, Scholarly Information and Patent- ten years trend". Proceedings of the North America Serials Interest Group (NASIF), 6th Annual Conference.

Luukkonen,T. and Person, O.(1992)." Understanding Patterns of International Scientific Collaboration". In *Science Technology and Human values, 17(1), Pg. 101-126*

Georghiou, L. (1998), "Global Cooperation in Research". In *Research Policy, 27, Pg. 611-626*

Glanzel, W. (2001), "National Characteristics in International Scientific Co-authorship Relations". In *Scientrometrics 5(1), 69-115*

Gaillard, J. (1994), “The Behavior of Scientists and Scientific Communities. In Solomon, J., Sagasti, R., and Jeanlet, C., (1994) eds, *The Uncertain Quest: Science, Technology and Development.*

Jeanlet, C., (1994) eds, *The Uncertain Quest: Science, Technology and Development.*

Nelson, R. and Rosenberg, N (1993), “Technical Innovations and National Systems”. In Nelson R. eds (1993), N*ational Innovation Systems: A Comparative Analysis*. Oxford University Press.

Schmoc, U., (2006), “The Role of Universities in Economic Growth- The German Situation”. Paper presented at “UNIVERSIDAD 2006”. 5th International Congress on Higher Education, Cuba, 13-17th February, 2006.

Wagner, C., and Leydesdorf, L. (2004), “Self organization and the Growth of International Collaboration in science. ASCoR, University of Amsterdam

Wangwe, S., Diyamett, B. and Komba, A. (forth coming), “Trends in R&D Activities in Tanzania: Funding Sources, Institutional Arrangements and Relevance”. IDRC