Overcoming the scientific generation gap in Africa: an urgent priority

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Based on recently completed studies, this paper attempts to provide a realistic picture of the scientific profession in Africa today. Activities in science and technology (S&T) have gone through a process of institutionalisation and professionalisation in Africa over the last thirty years, but these efforts have not been sufficient to create a sustainable dynamic of scientific production or of regeneration of national scientific communities. The situation today is critical, with S&T systems and the working environments of scientists deteriorating in many countries. While institutional mechanisms such as centres of excellence and S&T diasporas can, under certain conditions, contribute to the regionalisation and internationalisation of African science, they will never substitute for the weaknesses of national research systems. In the battle for sustainable development in Africa, nothing will replace home grown scientific capacities, and it is high time for the conditions for their renewal to be created. The results of empirical studies discussed in this article not only provide a vivid picture of the present day conditions of the scientific profession on the African continent, they also contribute to a diagnosis of the situation as one of political urgency.

With roughly thirteen per cent of the world's population, Africa enjoys only one per cent of the world's wealth. Half of Africa's people are estimated to live in poverty, and two fifths live with inadequate nutrition and hunger. Many historical, political, socioeconomic, and environmental factors help to account for Africa's impoverished state. Yet there is one often forgotten but critical factor that plays a central role in the continent's inability to participate fully in the global economy. That factor is Africa's woeful shortcomings in science and technology (S&T). The fundamental driver of long term economic development is increasingly science based technology. If Africa wants to break its well entrenched logjam of problems and sustain economic growth, it must revitalise and strengthen its own S&T capacities and devise long term problem solving strategies.

The way scientific research is structured and carried out has changed radically over the last thirty years. This is as true for Africa as for the rest of the world.[1] But following two decades of intensive development of scientific institutions, associated with a drastic increase in the academic population and a steady growth in the number of scientists, in most African countries the state of S&T has deteriorated substantially since the end of the 1980s. Recent assessments of African scientific communities have detailed the prevailing dismal conditions time and again.[2] Severe cuts in government spending have pushed institutions of higher education and research centres into steep decline. Buildings are poorly maintained, modern laboratory equipment is rarely available, and faculty and staff go underappreciated and sometimes unpaid. As a consequence, many African academics are today hired on a practically full time consultancy basis by international bodies, or work for NGOs, banks, or industrial companies or at their own business. Through this process of deprofessionalisation, the pool of active people in science has significantly decreased in a decade. Adding to this decade long litany of problems that have fractured Africa's S&T infrastructure is the fact that virtually no recruitment took place throughout the 1990s. In consequence, African universities and research institutes are heading rapidly towards a scientific generation gap. Given such circumstances, it should come as no surprise that the continent's best scientific talent continues to leave in large numbers, creating a chronic brain drain problem. As a result Africa's overall relative capacity to contribute to world science has significantly decreased during the 1990s[3] and will continue to decrease if nothing is done in the very near future to train, recruit, and support a new generation of scientists in Africa.

Against this background, several policy documents have recently been drafted. The most ambitious is the programme on Science and Technology for Africa's Development (STAD) proposed within the framework of the New Partnership for Africa's Development (NEPAD).[4] This programme is a product of wide ranging consultations over the last two years, mainly with senior government officials and African policymakers. It was presented and discussed at the Science Forum held in Johannesburg last year during the World Summit on Sustainable Development and is a

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document with many merits. First, it acknowledges comprehensively the range of problems facing science in Africa today. This is of course just a first step, but a necessary one. Second, it lists a number of generic S&T policy programmes aimed at promoting increased awareness through a broadbased and dynamic African constituency for S&T, at building a better understanding of national systems of innovation, at encouraging the sharing of experience in leveraging funds for S&T activities, and so on. Third, it discusses S&T cooperation among African countries and between Africa and the rest of the world. In this context, it recognises the establishment of networks of centres of excellence as one of the best ways of strengthening the continent's S&T development. The STAD document falls short, however, of discussing one crucial aspect of S&T for Africa's development, namely the continent's capacity to reproduce, sustain, and successfully exploit indigenous national scientific communities.

Similarly, political discourses (for example speeches by African ministers and policymakers at the 2002 World Summit on Sustainable Development) propose that the tens of thousands of African scientists abroad need no longer be a bane but on the contrary could constitute a boon for Africa. The idea is spreading rapidly within and beyond Africa, so much so that a consensus seems to have been reached that what is increasingly referred to as the African S&T diaspora will substitute for the shortcomings and weaknesses of national scientific communities on the continent itself. Again, it is important to stress that such a diaspora cannot substitute for weak or non-existent S&T human resource capacities at home. The S&T diaspora's effectiveness, which still needs to be established, will depend decisively on the internal dynamics of the indigenous scientific communities.

The examination of the status of S&T on the African continent that follows is divided into five parts. The first stresses the central role of human resources in science capacity building. The second divides the continent up into three main scientific geographical regions (North Africa, South Africa, and Median Africa) to convey something of the diversity of situations existing in Africa. The third part offers a hierarchy and typology of African countries based on a study of the publication outputs of African scientists. The fourth part reviews recent changes that have contributed to a transformation of the scientific profession. Fifth and last, a discussion is presented of the extent to which centres of excellence and the S&T diaspora may be able to contribute to the regionalisation and internationalisation of science in Africa. A concluding section advocates the necessity of training and supporting a new generation of scientists in Africa as a matter of great political urgency.

Owing to a chronic lack of reliable data, writing about S&T related issues in Africa is not an easy task. This difficulty has however been partially overcome thanks to the results of a recent study on science and scientists in Africa at the end of the twentieth century.[5]

Human resources and science capacity building

The term capacity building is used in a variety of contexts often linked to the debates around sustainable development. It may have different connotations, and these are most often not made explicit. Even if we consider only S&T capacity building, the term is frequently used in the limited sense of for example human, institutional, or national capacity building. In order to be fully effectual, science capacity building must comprehend a multiplicity of resources, actors, and organisational and institutional components interacting in a long term systemic process. Yet, as discussed above, the importance of one of these components tends to be underestimated or even ignored altogether by senior African government officials and science policymakers, namely S&T human resource capacity.

While acknowledging that education, training, and recruitment of scientists should be at the heart of development efforts, it is also essential to go beyond this notion to include other aspects critical to the creation of an infrastructure for scientific and technological capacity building. In 1991, the concept of capacity building was defined in its broadest sense by the United Nations Development Programme, to encompass:

- the creation of an enabling environment with appropriate policy and legal frameworks
- institutional development, including community participation
- human resources development and strengthening of managerial systems
- capacity building as a long term, continuing process, with all stakeholders participating (ministries, local authorities, NGOs, producer and user groups, professional associations, academies, and others).

Although this definition is as relevant and applicable today as it was in 1991, it is important to stress that all stakeholders and sectors of society should be allowed to play a role and participate in the process of capacity building in order to efficiently and successfully engage S&T human capacities for sustainable development. Indeed the activities listed above are required not only to develop but also to sustain and fully utilise human S&T capacities. In addition, certain conditions external to the scientific enterprise are necessary to support S&T capacity building for sustainable development, including some level of economic, social, and political stability. Similarly, peace, equity, and justice are preconditions for S&T human capacities to operate and for sustainable development to take place.[6]

As a result of the rapid development of higher education institutions throughout the developing world particularly during the 1970s and 80s, the proportion of students receiving academic degrees in their home countries has increased significantly. However, data gathered at the International Foundation for Science (IFS)[7] show that Africa remains significantly more dependent than Latin America and Asia on foreign countries (mainly France, the USA, and the UK) for the academic development of its human S&T capacities. What is more, observations gathered from recently submitted applications to IFS by newly graduated African scientists indicate that this dependence on foreign training may have increased in recent years for a number of countries in East and West Africa where the higher education systems went through a severe crisis during the 1990s. This last observation also hints at the fact that Africa cannot be considered as a single entity of concern.

A heterogeneous continent: North, South, and Median Africa

It is indeed important to note that significant differences exist between the countries of North Africa, South Africa, and Median Africa (sub-Saharan Africa excluding South Africa) in such critical areas as scientific infrastructure, budgeting, training, scientific collaboration, and publication output. Moreover, it is important to keep in mind that not even the division of Africa into these three geographical regions conveys the full diversity of experience that can be detected when the situation is closely examined. For example Median Africa, which today is the continent's most troubled region, is in itself far from being homogeneous. The results of a recent Africa wide questionnaire survey[8] illustrate these disparities in relation to several key characteristics, three of which are briefly discussed below: salaries, self-sufficiency in undergraduate and graduate education, and the level and structure of research funding.

While African scientists acknowledge that they enjoy a high degree of job security, they also express strong dissatisfaction – indeed frustration – with their salaries and job benefits. However, scientists in South Africa are much less dissatisfied with their salaries (52·4%) than their colleagues in North Africa (62·2%). Not surprisingly, scientists in Median Africa are the most dissatisfied. A startling 92% of survey respondents from this region said they were displeased with their earnings.

The number of students pursuing an undergraduate or graduate education in African universities has increased significantly over the past three decades. Nevertheless, the higher the degree that is sought and ultimately earned, the more likely it is that a student will pursue his or her studies abroad – in Europe (mainly France or the United Kingdom) or to a lesser extent in the USA or Canada. While South Africa's university system now allows it to be 'quasi self-sufficient' in the awarding of all degrees, the university systems in North Africa and particularly Median Africa continue to depend on foreign institutions to educate and train their scientists.

The structure of research funding also varies from region to region. Although international institutions and foreign nations remain the most important sources of funding for science throughout Africa, Median Africa's scientific community is more dependent on outside donors than South Africa or North Africa. Similarly, South Africa and North Africa enjoy a higher percentage of funding from indigenous institutions than Median Africa.

Other characteristics, such as the trends in scientific output discussed below, also show contrasting developments according to region. What such statistics reveal is that there is not one but several Africas, and that the scientifically weakest countries are located in Median Africa. All told, it is estimated that there are about ten thousand full time active researchers in Egypt, and roughly the same number in Maghreb countries (Algeria, Morocco, and Tunisia). Meanwhile, the Republic of South Africa has approximately thirteen thousand full time researchers, which is comparable to the number of full time researchers in the whole of Median Africa (Table 1). Table 1 also lists some of the main scientific indicators for the fifteen most important African countries.

Recent trends in publication output[9]

Assessing the relative scientific capacity of each African country is not an easy task, given the lack of reliable data concerning inputs such as numbers of researchers, S&T budgets, and so on (South Africa being the exception). Here a detailed analysis of numbers of scientific publications in Africa indexed in the PASCAL database (1991–97) and in the ISI database (1987–2001) is used to assess recent trends in African scientific productivity. Despite their limitations, discussed elsewhere,[10] it is considered that these two databases can be used with some degree of confidence to characterise the relative importance of the main scientific producers and also to identify trends.

The first observation that can be made is that S&T capacities in Africa, as in the rest of the world, are concentrated in a few countries. South Africa, with slightly more than three thousand publications during 2001, is the main producer, accounting for a third of the continent's scientific literature indexed in the ISI database. Egypt comes next, with just under two thousand publications. These two countries combined today represent nearly half of African scientific production. They are followed by Morocco (772 papers), Tunisia (515), Kenya (427), Nigeria (417), and Algeria (358). Taken together, these seven top producers (slightly more than a seventh of African countries) account for three quarters of African scientific production.

The second observation is that African production is marginal compared with that of the rest of the world, and that productivity per scientist is low. The PASCAL database shows that in 1991 African scientific production in terms of publications amounted to just four per cent of the publication output of European scientists. In 1997, this figure fell to three per cent. As a whole the African continent lost at least a quarter of its capacity to contribute to world science during the 1990s. At the end of the period covered by the study using the PASCAL database, South Africa had a publication output comparable to that of Greece, and Egypt's output was comparable with Portugal's.

Hierarchy and typology

Not only are scientific capacities unevenly distributed in Africa, they are also not always proportionate to a region's or country's wealth and/or population. Today, five main groupings can be distinguished.

Group 1 consists of two states, the Republic of South Africa and Egypt, which together represent nearly half of the continent's total production. In these two countries of 'complete science', all disciplines are covered. Group 2 consists of five countries which account for a further quarter of Africa's publication output: Morocco, Tunisia, Kenya, Nigeria, and Algeria. While these countries enjoyed well established scientific communities in several fields at the beginning of the period under review, they are among those that have experienced the most turbulent fortunes.

The remaining countries share the remaining quarter of recorded production. They can be divided up as follows. The eight countries in group 3 – Cameroon, Ivory Coast, Ethiopia, Ghana, Senegal, Tanzania, Uganda, and Zimbabwe – regularly produce between seventy and a hundred and eighty papers per year. This output is sustained either by groups or networks of scientists specialising in a few disciplines, or by groups of scientists in a handful of cutting edge institutes often working in collaboration with foreign scientists. Such people and places represent small pockets of research activity achieving modest but sustained levels of accomplishment.

The thirteen countries in group 4 (Benin, Botswana, Burkina Faso, Congo, Gabon, Gambia, Madagascar, Malawi, Mali, Niger, Sudan, Togo, and Zambia) publish between twenty and seventy references on average each year. Production in these countries often depends on a few eminent scientific figures. As a result, the scientific infrastructure remains extremely fragile, highly sensitive to political change, and heavily dependent on external collaborations and sources of funding.

The remainder of the African continent (group 5) is comprised of scientifically small countries whose performance in terms of scientific production is erratic and closely tied to a few authors or visiting scientists. This last group includes countries that have recently experienced fundamental political changes, international isolation, civil war, and/or massive destruction of infrastructure.

Major recent trends

While different databases may provide slightly different perspectives on trends in scientific publication output among African countries over the past decade, they are in agreement that the paths of different countries have diverged enormously. Whereas in the 1970s and 80s the medium sized scientific powers (groups 2 and 3 as already defined) experienced sustained growth and became scientifically established, the 1990s brought abrupt changes of fortune, completely upsetting previous classifications. The main changes are summarised below (see also Figs. 1 and 2).

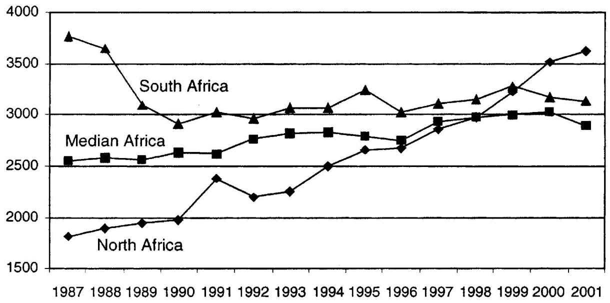
First, the continent's science giant, South Africa, has encountered difficulties in maintaining its level of performance. After a sharp decline at the end of the 1980s, the contribution of South Africa has remained stationary in absolute numbers of publications (see Fig. 1).

Among Maghreb countries (Fig. 2) there has been an overall rise in scientific output over the last ten years. In this period Morocco nearly tripled its score,

Table 1 Scientific indicators for fifteen most important African countries in S&T terms: HE = higher education, FTE = full time equivalent (from J. GAILLARD, M. HASSAN and R. WAAST: 'Africa', in *World Science Report*; 2002, Paris, UNESCO)

		Full time researchers		FTE researchers			1998 published scientific papers			
Country	Staff in HE	Public sector	Private sector	Theoretical*	Probable*	Researchers per 10^6 inhabitants	Total	Per researcher	Per 10^6 inhabitants	Per $\$10^9$ GNP
Algeria	16 000	1200	700	5000	3000	100	241	0·08	8	5·5
Tunisia	9000	800	400	3000	3000	350	491	0·16	55	26
Morocco	10 000	700	500	3200	3200	120	510	0·16	20	14·5
Egypt	40 000	1500	…	15 000	10 000	230	1313	0·13	20	17
Madagascar	900	260	…	500	300	35	50	0·17	3	13·5
Senegal	1000	435	…	700	600	80	106	0·18	12	21
Burkina Faso	700	200	…	350	350	30	72	0·21	7	26
Ivory Coast	1200	500	…	800	600	55	87	0·15	6	8
Cameroon	1800	300	…	800	800	60	167	0·21	12	18
Nigeria	14 000	1300	…	5000	3000	40	450	0·15	4	14·5
Kenya	1800	600	…	1000	1000	35	506	0·51	17	53
Tanzania	1400	…	…	800	600	70	196	0·33	6	30
Zimbabwe	1100	300	…	600	600	30	176	0·30	16	21
Mozambique	600	…	…	…	…	…	…	…	…	…
South Africa	17 000	8500	5000	13 000	13 000	350	2738	0·21	72	21

*Theoretical numbers before and probable numbers after questionnaire survey.

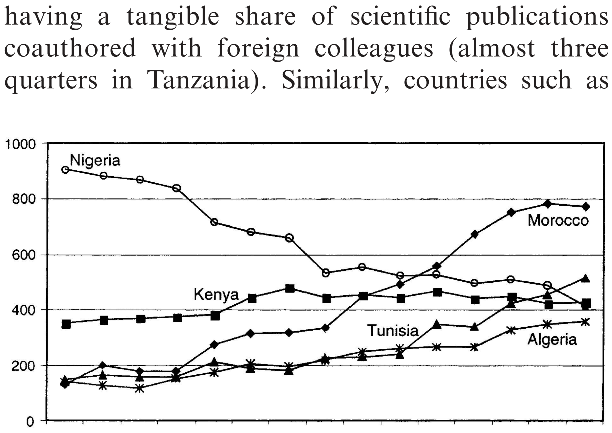


1 Publication output in North Africa, Median Africa, and South Africa, 1987–2001 (source: ISI)

and moved from fifth to third place on the African continent. Tunisia also showed a strong surge in production. Even Algeria managed to improve its performance, despite disruptions caused by civil war and the persecution of its intellectuals. The portion of Africa north of the Sahara (including Egypt) now accounts for more than a third of African publications (catching up with and now even overtaking the output of South Africa).

On the other hand there has been a staggering collapse in Nigeria's scientific ranking (Fig. 2). Over the last ten years Nigeria's scientific community has experienced a fifty per cent decline in published scientific output. In the absence of career prospects and faced with the dilapidation of establishments paralysed by large budgetary shortfalls and with high staff turnovers, many research scientists have emigrated or changed profession. Many, while remaining scientists, also devote themselves to other activities. The government of Nigeria has however recently taken a number of positive initiatives which may revitalise S&T capacities if appropriately implemented and sustained.

Among countries in groups 3 and 4, changes have often been sudden and unpredictable. Thus, despite severe restrictions on operating budgets, poor salaries, and poor working conditions, countries such as Cameroon, Tanzania, and Senegal have experienced an upswing in scientific output. Scientific cooperation (mainly with European colleagues but also with American colleagues in the case of Tanzania) contributed to this surge in production, these three countries having a tangible share of scientific publications coauthored with foreign colleagues (almost three quarters in Tanzania). Similarly, countries such as



2 Publication output in African countries of group 2 (see text), 1987–2001 (source: ISI)

Ghana, Uganda, and Malawi that have been boosted by aid and cooperation seem also to have experienced scientific revivals. The progress achieved by Burkina Faso is also noteworthy, and largely due to sound support from government authorities and the strong commitment of scientists.

In contrast, the production of Ivory Coast, Gabon, Niger, and Mozambique, sustained not long ago by vigorous external support programmes, has recently begun to stagnate or shrink. The Republic of Congo, which in the 1980s was showing great promise, has slumped since 1994. The neighbouring Democratic Republic of Congo (formerly Zaire) slips further into the depths of scientific obscurity, whereas thirty years ago the prowess of its universities would not have augured such a sad fate. It is indeed hardly necessary to mention how insignificant the scientific outputs have become of those countries ravaged by civil wars, or confronted with famine, population exoduses, or obscurantism, for example Angola, Burundi, Liberia, Rwanda, and Somalia. Sudan, which at one time occupied a significant position, is now in a state of incessant decline.

Overall, however, if we stick to the division of Africa into the three scientific geographical regions proposed above – namely North Africa, Median Africa, and South Africa – we can see that in absolute terms the scientific production of Median Africa, despite the collapse of Nigeria, has increased over the last ten years from some two and a half thousand publications annually to some three thousand publications, nearly catching up with South Africa. In the same time, North Africa has clearly overtaken the position of South Africa (see Fig. 1).

The scientific profession in Africa

What is the reality of being a scientist in Africa today, and how do African scientists perceive their own profession? The questionnaire survey, country case studies conducted in some fourteen countries, and interviews show that the conditions under which scientists work have deteriorated globally during the last decade, principally in Median Africa.

Deterioration of working conditions

Because of current conditions, the professionalisation and institutionalisation that marked African research in the 1970s and 80s has greatly deteriorated.[11] The results of the questionnaire survey, interviews, and case studies indicate that Median Africa went through a sharp break at the end of the 1980s, caused initially by the withdrawal of the state (because of financial obligations that weighed down state budgets). In most of the countries in Median Africa, the state budgets managed at best to pay the deflated salaries of scientists. Not only were salaries frozen, but galloping inflation caused huge drops in people's purchasing power. During the 1990s in Cameroon, scientists' purchasing power dropped by a half. In Nigeria, teachers' wages sunk to a seventh of their former level between 1980 and 2000. Earlier entitlements in kind (housing, transport, healthcare) were also lost. Some more or less marginal increases have been granted since that time, but even these are cancelled when state budgets cannot pay.

The questionnaire gives evidence of this evolution but does not show its magnitude (when addressed to experienced scientists who are still doing research). It was during interviews that the real effects of the situation, i.e. deprofessionalisation of scientific activities, became apparent, since many scientists have had to change profession or leave the country because of low salaries and poor working conditions.

Inadequate wages and extraprofessional activities

In interviews, scientists across the board expressed dismay at the salaries and social benefits attached to their jobs (as mentioned above, dissatisfaction was almost unanimous in Median Africa). Although scientists on average earn nine times the minimum wage, their salaries are not high enough to cover their living expenses, and half have second jobs which pay, on average, four times more than their main salary. An estimated 37% are employed as consultants or work for a private company, 20% teach, especially in private universities, a further 20% run consultancies or personal companies, and 13% work in agriculture.

These results were confirmed by interviews and case studies carried out in various countries. A study carried out at Ahmadu Bello University in Nigeria showed, for example, that three quarters of staff had a second job which took most of their time and generated most of their income: 40% on a farm, 20% in trade, 15% overtime (this was the case for more junior staff). Of the remaining quarter, half, who were senior staff members in the university or worked for the government, said they did not have a second occupation. The remainder drew their livelihood from consultancy or participation in research commissioned from abroad.[12] In universities closer to the capital or other industrial cities, a larger percentage of scientists supplement their income by working as consultants (close to a fifth in Lagos or Ibadan).

Deprofessionalisation and exodus

The low salaries and poor working conditions mentioned above (which an interviewee in Cameroon described as making scientists ‘hellbound’) lead not only to changes within countries, but also to emigration, particularly for scientists from the worst stricken countries. The Nigerian example is the most overwhelming. The best known scientists, who are well ensconced in the global networks for disciplines in which Nigeria could be competitive, find jobs mainly in the USA and the UK. As this path grows more difficult, emigrants also leave for other countries in Africa (these days even for French speaking countries such as Senegal).

Since there are no reliable data, outward movement within the continent (which sometimes turns into circular movement) is impossible to quantify. Interviews confirm that nearly all scientists are tempted, sooner or later, by a project that takes them to ‘greener pastures’, as the Tanzanian scientists like to say. Surveys in institutions confirm very high staff turnovers, especially in the research institutes. In many universities, positions for research scientists and teachers remain vacant. Certain disciplines (e.g. in the social and physical sciences) at the University of Ibadan, for instance, are administered by interim heads of department, and a third of teaching positions are at present unfilled. These situations have an impact on the quality of research and on the training of the upcoming generation of African scientists, at the very time when a lack of job prospects persuades large numbers to go into law, economics, or information technology rather than science.

In many countries, expatriation is temporary (Egyptians and Sudanese go to the Gulf States) or is limited to a nearby region (Tanzanians and Kenyans tend to go to southern Africa), thus abiding by a logic based on circular movement rather than definitive departure and, thus, net loss. Some Tanzanian scientists often temporarily, and depending on the wage differential, work in newly created universities in the region (Botswana, Namibia) or in older universities in South Africa.[13]

The questionnaire partly confirms the logic of this circular movement. A fifth of interviewees had been offered a job abroad at one time or another in their scientific career, and while more than half the offers came from countries of the North, i.e. the USA and certain European countries (especially France and the UK), offers also came from countries of the South (e.g. Kenya, Saudi Arabia, South Africa, and Botswana). The vast majority of job offers abroad were accepted, but in most cases expatriation was temporary. Thus on the whole this situation entails circular movement rather than a brain drain.

These observations have been confirmed by three studies, conducted in Tanzania, Cameroon, and Morocco in 1999 and 2000, on the career paths of African scientists who have been IFS grantees. Out of a population of 262 scientists who had received IFS grants over the last thirty years, only four moved permanently to Europe or the USA. The large majority are still exercising their professions in their home countries. These figures show that well targeted personal support at the beginning of a career can play a decisive role in allowing young scientists to get established and stay within their own national scientific community, or in encouraging them to return to their home country after a stay abroad.

Internationalisation of S&T

Scientific advances and technological progress are the results of a learning process that is increasingly achieved through cooperation and collaboration. Today, no country can truly take part in the knowledge society without interacting with peers and colleagues at regional and international levels. As stated already, there is a clear recognition by senior African government officials, policymakers, and scientists of the importance of regional and international collaboration in S&T, and yet many African countries and scientists continue to work in relative isolation, and many regional and subregional treaties promoting S&T cooperation within Africa and between Africa and the rest of the world have failed to translate vision into concrete activities, programmes, and institutions. There is a long tradition of international scientific collaboration, which is today made easier by relatively cheap air travel and high speed communication systems. But digital communication relies on technology which is much less accessible and much more expensive in Africa today that in the rest of the world. In fact, even the telephone is still a luxury in many departments in African universities.[14] Similarly, it is cheaper to travel between most European capitals and Africa than within Africa itself, thus reducing possibilities for regional cooperation. Visa regulation is also an additional handicap: the former Secretary General of the African Association of Universities recently revealed that he needed to get a visa to visit every African country except for Mozambique, his own!

A number of models and approaches can be used to promote regional and international cooperation, including peer collaborations within 'invisible colleges', institutionalised S&T networks, advanced research centres or centres of excellence, North–South and South–South partnership programmes, and S&T diasporas. I propose to discuss two of these below, centres of excellence and S&T diasporas, to the extent that they have been recognised and promoted as the most promising means of strengthening the continent's S&T development in recent African forums.[15]

Regional centres of excellence

Based on the recognition that most African countries taken separately are too small to develop a comprehensive national research system, it has been proposed that they should pool resources to establish regional centres of excellence, or networks of centres of excellence. It is also argued that many African countries do not have the human or financial resources to develop and sustain national centres of excellence in the latest research areas such as biotechnology, new materials, and information technology, which are at the same time essential for participation in the knowledge society. A number of additional arguments speak in favour of regional centres of excellence: the increasing cost of much scientific equipment, the importance of fostering interdisciplinary collaboration, and the importance of critical mass (especially when a multidisciplinary approach is needed). These arguments are particularly valid from the perspectives of small and scientifically weak countries.

Regional centres of excellence have many advocates in the scientific and policymaking communities and have long been supported by donors as well. A number of successful regional or international advanced research centres do exist in the northern hemisphere. In many cases they were formed by pulling together resources and developing a specific field of expertise within a national institution or university before opening up to regional or international collaboration. Several advanced research centres were also created in Europe initially to compete with the United States. Thus CERN (the European – now effectively World – Centre for Nuclear Research) was conceived in the late 1940s by a coalition of European physicists and farsighted diplomats and scientific administrators who realised that no single European country had the resources to compete with the Americans in constructing large accelerators, and that joint facilities would therefore be essential. A secondary objective was to create a joint European laboratory as a contribution to rebuilding bridges between nations that had recently been at war. Today CERN, involving some six and a half thousand scientists from universities and research institutes in over fifty countries, is the world's largest collaborative scientific enterprise.[16]

A number of regional centres of excellence already exist in Africa, and initiatives are under way to create further centres or networks of centres of excellence. Countries of the former East African Community (Kenya, Tanzania, Uganda) are in the process of reestablishing regional institutions. The government of South Africa (through the Department of Science and Technology) is spearheading an initiative to create an African laser centre. With the support of the Doyle Foundation, the International Livestock Research Institute (ILRI) is exploring ways of consolidating and establishing a world class bioscience facility in eastern Africa. These efforts are welcome and should be promoted to the extent that they can provide larger, well endowed, and accessible research facilities for participating African countries in these regions.

Yet centres of excellence so far established in Africa have experienced three main shortcomings: they tend to drain national institutions of their best talents, thus undermining the capacity of the countries they are supposed to serve; they tend to work on developing and adapting world class technologies rather than on issues directly related to regional sustainable development goals and needs; and they tend to fail to mobilise on a long term basis political and economic support from the participating countries to assure sustained funding of their activities. In fact most of the international or regional centres in Africa depend almost entirely on foreign (non-African) funding, and find it extremely difficult to survive when all or part of this external funding dries up.

To be entirely successful, African centres of excellence will need (i) to interact closely with national scientific communities in the region and contribute to strengthening of their S&T capacities, (ii) to define together with all stakeholders (ministries, local authorities, NGOs, producer and user groups, professional associations, academies, and others) clear objectives and priority research areas serving basic African needs (e.g. food security, improved livelihood and environment), and (iii) to develop sustainable, adequate, and realistic funding systems, taking into account economic constraints on participating governments and the ebb and flow of external donors. While they should look for additional sources of funding (e.g. from the private sector and NGOs), their long term development and survival will depend ultimately on sustained government support and contributions from participating countries.

S&T diasporas

The idea of the 'S&T diaspora' is based on the remote mobilisation of African scientists and technologists around the world to derive a number of benefits for their home country, including access to scientific information and expertise through extended social, technical, and professional networks, increased training opportunities, and the development of collaborative projects between expatriate and home based scientists.

The S&T diaspora model is appealing to African politicians and policymakers because it appears to present a low cost, self-managing, efficient, and straightforward way to take advantage of the presence of African scientists abroad. The option is also appealing to African expatriates who feel motivated by this opportunity to contribute to the development of their country of origin while remaining abroad and without feeling guilty. During the 1990s, an increasing number of countries took initiatives to create databases of expatriate scientists, to mobilise, organise, and reconnect their scientists abroad with the scientific community back home. Yet their sustainability and effectiveness remain to be established. Back in the early 1990s, a Franco-Colombian research team studied the development of a very promising attempt to network the Colombian scientific community with the diaspora of expatriate Colombian scientists, the 'red-Caldas' (Colombian Network of Scientists and Engineers Abroad). At its peak, it was estimated that the Colombian S&T diaspora numbered two thousand people in forty-three countries. The diaspora was organised into some twenty-one local groups (the network's nodes) connected amongst themselves and with the Colombian scientific community by worldwide electronic communication.[17] In contrast to the initial ambitions, very few joint projects between the diaspora and Colombia were ever developed to completion. Today, some ten years after its inception and following the withdrawal of Colciencias (the Colombian National Research Council) which had been instrumental in its emergence and development, red-Caldas has become very sluggish. Even where nodes survive as friendship networks between Colombian expatriates, it no longer constitutes an S&T diaspora.

The ups and downs of red-Caldas remind us that however simple and enticing they may seem, S&T diasporas are not easy to engage. For them to succeed, a number of difficult steps need to be taken: an inventory of highly qualified nationals abroad must be made and kept up to date in a database; the members of the diaspora will have to be mobilised, organised, and reconnected with the scientific, economic, and industrial communities at home; something must be done to capitalise on their work and networks; interaction must be created between them and the home S&T community through exchanges and common projects. All these steps require important investments in terms of time and energy. They require a sizeable and sustainable budget that cannot be based entirely on voluntarily participation and contributions. Funding must be secured from the home country, as well as sustained political support and a minimum administrative capacity to manage the network. Finally, long term efforts will be necessary to guarantee prolonged survival of the diaspora, since its population will be very mobile, unsettled, and not always focused on the national S&T interests of the home country.

Another limit to the S&T diaspora model may stem from the fact that it is based on a double postulate with an internal contradiction: the (international) universality of science, versus the expatriate scientist's feeling of (localised) allegiance. Observations show that the more researchers see themselves as true scientists, the more they tend to want to use the diaspora as an international scientific network. They tend to prefer contacts with their professional peers rather than with colleagues from different disciplines, even if they are fellow citizens, because science knows no borders. And, vice versa, the more 'national' members of the diaspora feel, the more they give into the temptation to convert the diaspora into a network of national exchange and mutual assistance, thereby weakening its strictly S&T potential.[18]

Yet another limitation relates to the relative size of the home scientific community and the consequent scale of possible connections with the diaspora. In the case of the red-Caldas, the size of the S&T diaspora, slightly less than half that of the Colombian scientific community at home, was far from insignificant. However given the extreme dispersion in fields of expertise, potential scientific exchanges and collaborative work (even virtual) were hampered by cognitive distances between potential partners. Clearly, the success of an S&T diaspora will be directly dependent on the relative size and collective S&T expertise of the diaspora on the one hand and of the home scientific community on the other.

A distinction needs to be introduced here between emerging or newly industrialised countries (NICs), intermediate countries, and scientifically lagging countries of relatively small size. Most African countries fall into the third category. In these countries, local S&T systems are most often insufficiently developed to offer even a minimal level of interaction between the highly qualified expatriates and the national S&T communities. Whereas China, a country belonging to the NICs, has taken (and is increasingly taking) advantage of its S&T diaspora to develop its national S&T as well as industrial capacities, very few countries in Africa can follow suit today. South Africa (which has developed SANSA, the South African Network of Skill Abroad), Egypt, Nigeria, and Morocco are among the very few exceptions. A regional S&T diaspora may however partly compensate for the small size of the individual countries in a given region, assuming that the region corresponds to a political and economic entity sharing common interests and problems. The reviving East African Community, in which regional institutions are now reemerging, may constitute such a realistic regional entity. Similarly, Africa wide and discipline based S&T diasporas may turn out to be useful capacity strengthening tools, again assuming that the conditions briefly sketched above can be fulfilled.

The S&T diaspora will never be a low cost, easy, or self-sufficient strategy for growing science in Africa. Its effectiveness depends on the internal dynamics of the indigenous scientific communities. A network of expatriates is at best an extension of a national scientific community rather than a substitute. To be successful, S&T diasporas should therefore be intrinsically tied to the internal dynamics of dense and well developed national S&T communities. In most African countries, indigenous S&T capacities need first and foremost to be strengthened and the next generation of scientists needs to be trained and recruited, before S&T diasporas can become effective.

Conclusions and future prospects

Although the development of Africa does not depend exclusively on its scientists, sustainable science based development will not occur without indigenous scientists. Regardless of the mechanisms designed to regionalise or internationalise such S&T capacity, in time they will only be effective (i.e. contribute to national development) if they are connected to sufficiently populated, dynamic African national scientific communities. That is why, considering the situation briefly described in this paper, training and supporting a new generation of scientists in Africa should more than ever be an urgent priority.

Is national science on its way out?

Over the last twenty years, the organisation of scientific output has radically altered. In the industrialised and industrialising countries, concerns for competitiveness on the global scale in fields where the technological stakes are high (biotechnology, new materials, information technology, and so on) have led to reforms in scientific institutions which henceforth prefer international collaboration involving the public and private sectors in increasingly globalised consortia. This has substantially affected the role and modus operandi of public research institutions, and the professional working conditions of scientists.

In Africa (particularly Median Africa), given the very weak industrial environment, the withdrawal of the state has forced science out of institutions and 'deprofessionalised' it by encouraging the available scientists to work in a free market as experts and consultants. This trend has contributed to the increasingly fragile nature of national S&T capacities. Low salaries and poor working conditions have also led to large scale emigration of scientists from the hardest stricken countries to other countries and professions. Is this an evolutionary change that marks the end of national science in Africa? Consideration of the merits and limits of models of regional and international cooperation shows that neither regional centres of excellence nor S&T diasporas can substitute effectively for the inherent weaknesses of national scientific communities. On the contrary, to become fully efficient and operational, they need to be linked to a strong, qualified S&T home base. It also seems highly unlikely that a free market for science, depending mainly on funding from the North, can survive in Africa without some type of public science underpinned by national scientific communities whose systems of institutionalisation and professionalisation will have to change.

The limits of the market

There are also limits to the free market for expertise and consultancy. Since this work is practised outside universities or the research institutes, it contributes to the disintegration of these institutions and so further jeopardises the emergence of national scientific communities. Dependence on sporadic and unsustainable external funding inhibits the development of national science, which should instead be constructed around autonomous programmes. Likewise, expertise and consultancy divert academic institutions from contributing to national scientific objectives and renewing national S&T capacities. The less time scientists spend on research and on tutoring their undergraduate and graduate students, the less chance there is of a smooth intergenerational takeover. Less public outlay, no jobs, fewer students in the sciences (because jobs are not economically attractive) – this scenario has all the makings of 'planned deinstitutionalisation' of research.

Support for a new generation of African scientists

There is an urgent need to preserve and strengthen the scientific capacity currently available in Africa. But thought must also be given to the future and to the need to create the right conditions for scientific continuity and renewal. Young scientists are becoming so scarce that it is increasingly difficult to find a scientist below the age of forty in Africa today. The situation is not much better in South Africa, where half of all scientific publications are produced by scientists over the age of fifty. Likewise a number of key South African research institutions are staffed predominantly by scientists who will very soon reach retirement age. It is with these concerns in mind that the South African

Department of Science and Technology is organising a National Science, Engineering and Technology Week in May 2003.

Considering the scantiness of African public sector budgets, external cooperation will be required. Contributions from abroad could serve to back up the national research grant schemes that are being implemented in most African countries. This would provide the direct assistance that the emerging national communities need for their survival. Such support is also needed to strengthen teaching capacity at both undergraduate and graduate levels, and thus secure this function in African universities. Foreign cooperation could also be used to enhance efforts at the continental level to strengthen intra-African cooperation and support, or even contribute to the strengthening or creation of regional centres of excellence and to bolstering national research systems.

During this same period, the African countries should reinvest in their national research and higher education systems. Renewed capacity for national research can only be sustainably developed in Africa if it is supported by national political determination that translates into adequate and long term national investment. Scientists alone will not save Africa, but Africa without renewed and strengthened national scientific communities cannot be saved at all.

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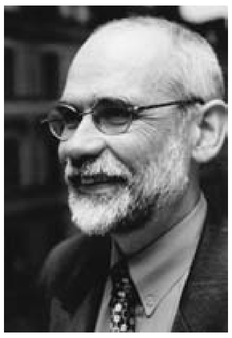

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