Mobility, migration and networking within the Cuban scientific community: developing scientific capital in the digital age

Miriam Palacios-Callender | m.palacios-callender@ucl.ac.uk
Wolfson Institute for Biomedical Research, University College London

Stephen A. Roberts | stephen.roberts@uwl.ac.uk
School of Computing and Technology, University of West London

Since 1959 Cuba has developed a strong base of higher education and has used this as a foundation for an active scientific research sector to support the national economy. Following the global political changes of the early 1990s the country has maintained this trajectory. These influences have impacted on the normal processes of mobility, migration and networking in the scientific community. This paper reports on a programme of investigation which will study the influence of changes in the global scientific community and the impact of emerging digital communication technologies on the development of the Cuban scientific community. The main historical influences and the contemporary context are reviewed, a pilot study using bibliometric analysis is reported and some key propositions examined which will be used to guide future studies and define investigative questions.

Keywords | *Cuba; mobility; migration; networking; brain drain; brain gain; brain networking; science policy; bibliometric studies*

Background and context

The Republic of Cuba is the largest island bordering the Caribbean with a surface area of 109,886 km2 including 4,000 smaller islands and keys and a population of 11.2 million in 2010 (ONE, 2010). Cuba was the last colony of Spain in Hispanic America becoming a Republic in 1902, after 30 years of wars fighting for independence and 4 years occupation by US troops in 1898. The evidence shows that little was achieved in education and health for the general population during the first half of the 20th Century (Truslow,1950) and the science and technology infrastructure was weak despite the existence of an Academy of Sciences founded in 1861.

The year 1959 marked a radical shift in the history of Cuba when a revolutionary group brought an end to the Batista dictatorship (Perez, 1988; Bethell,1993). Since the early days of the revolution, the socialist system favoured the development of equity across society and considered health care and education as rights of the Cuban citizen. Access to services was provided free of charge at all levels. In 1960, the President of the revolutionary government Fidel Castro made the first science policy statement: *"The future of our country has to be necessarily a future of men (and women) of science"…"because that is precisely what we are mostly sowing; what we are sowing are opportunities for intelligence"* (Castro, 1960).

In the process of providing health and education to the Cuban population, and to develop science and technology, the Cuban government sent abroad thousands of students to obtain degrees in higher education (HE) in universities of the Socialist Countries, starting as early as 1961. This was the first kind of mobility of human capital to improve the scientific and technological capabilities of the country. Further flows of individuals rather than groups took place later in order to support centres for research and development and the fast growing university campuses. In this case, personnel were sent either to obtain a post-graduate degree or to continue with further specialization and/ or collaboration in science and technology. In the last decade the mobility of scientists has depended more on the network of scientists with international connections through collaborations of mutual interest. In both cases the mobility is to acquire and develop capabilities inside Cuban centres of research and/or education. There is another kind of mobility, in this case to deliver scientific, educational, technological capabilities towards developing countries, which is part of the ethical nature of the socialist system. In the period from 1963 to 2010, around 135,000 Cuban specialists in healthcare collaborated in 108 countries (Marimon Torres and Martinez Cruz, 2010).

For the purpose of this study mobility is defined as the migratory condition of the students/ scientists / specialists moving back and forward between Cuba and the collaborating countries and migration is defined when students/ scientists/ specialists change residency to a country different than Cuba. Mobility generates migration and in the case of Cuba, migration generally increased after the collapse of Socialist Europe and Soviet Union, aggravated by the American blockade. This particular phenomenon has only received limited study in depth in the Cuban scientific and technological community. Furthermore, there appears to be no evidence indicating that regardless of the number of emigrants in science and technology, this migration has impaired the development and achievement of Cuba in science and technology. The Cuban scientific elite is justifiably protagonist about their scientific achievements, especially in biotechnology (Reid Henry, 2010), infectious diseases (Guzman, 2005) and neuroscience (Becker Barroso, 2009) among others.

The landscape of science in the 21st century has emerged with a great expansion of global networks in which individuals in the same field of research collaborate across different international institutions. In scientific publications, for instance, over one-third of research papers come from authors' addresses from more than one country (Royal Society, 2010). The expansion of the global network of knowledge is a consequence of the proliferation of digital information and communication technology, as well as more affordable ways to travel. Lack of permanent jobs in academia and industry has contributed to mobility of trained specialists among developed countries, where leaders in science move from country to country searching for permanent positions and better funding. However, due to the economic instability of globalization and inequality between regions, the migration of scientists has increased towards countries with better funding and infrastructure, creating a 'brain drain' for countries with lesser resources. New emerging economies are breaking this one-way flow of human capital towards developed countries by attempting to reverse the brain drain into 'brain gain' through re-engagement with those who had left.

Today, there are more than 900,000 university graduates in Cuba (Clark Arxer, 2010) reflecting the government's effort in developing the human capital of a country with limited natural resources. Donella Meadows (the founder of the Institute of Sustainability and adjunct professor of environmental studies at Dartmouth College) when reviewing the achievement of Cuban scientists in sustainable agriculture as the country had to face the economic crisis of the former Socialist countries in Europe (and the American blockade since 1962), pointed out that '*Cuba has only two percent of Latin America's population, but eleven percent of its scientists*' (Meadows, 2000).

It is precisely the worsening of living conditions under the economic crisis of the 1990s that lead to a wave of migration of Cubans from that decade to the present. With Cuba having a significant number of scientists, and with the evidence of scientific migration from other countries of the region, the mobility and migration of Cuban scientists presents a novel area for research. Such a programme of study opens the possibility to transform the disadvantage of losing highly qualified human capital into opportunities for the country of origin to reconnect to this resource by improving communication with Cuban scientists living abroad. Some nations have already made good progress by enabling their scientific diasporas to engage with the home country (Boyle and Kitchin, 2011). Scientific diasporas are defined as 'Self-organized communities of expatriate scientists and engineers working to develop their home country or region, mainly in science, technology, and education' (Barre 2003). But in this realm Cuba has yet to maximize her potential advantages. The first stage in this process is to audit and better understand the dynamic of the Cuban scientific community. Later will come an attempt to develop innovations in communication which have the potential to reinvigorate Cuban scientific capital.

Scientific production, mobility and migration: the Cuban experience

Cuba started the development of science and technology with the creation of the National Centre of Scientific Research (NCSR) in 1965, with excellent infrastructure for the formation of scientists who then went to create or support other institutions of research in specialised fields, like the Centre of Animal Health, and eight specialised institutes of research in the Ministry of Health (MINSAP) in 1966. This was the phase of expansion of research capacity in different fields, more freedom of the scientist to do research as well as more geographically dispersed throughout Cuba. In 1981 a new small Centre of Biological Research near the NCSR experienced a different approach: intensive and focussed research projects with an enterprise mode of operation and directly subordinated to the government. As a result a small multidisciplinary group of scientists produced interferon gamma from human leukocytes in record time to treat the dengue epidemic. Following this model of operation the Centre of Genetic Engineering and Biotechnology (CGEB) created in 1986 embodied new forms of high technology research/development and production but on a much larger scale. It was the first time in which a research institution in Cuba covered all the processes of drug discovery from research to commercialization. The 1980s was the beginning of transformation from the model A (the linear theory) in which pure research, technological development and production and market were growing independently to the model C (Goldemberg,1998) in which the three phases of development were completely superimposed. The success of this strategy prompted the creation of the Scientific Pole (Polo Cientifico) with new installations and expansion of spin off groups of successful research projects/prototypes mainly from NCSR. Among them, the Centre for Immunoassay to produce laboratory instruments for hospital clinical analysis, Centre for the Production of PPG, a policosanol derived from by-products of the sugarcane industry to treat high levels of cholesterol. Projects were integrated through a cycle from Research and Development to Production and Marketing. The flow of communication and cooperation among institutions of the Scientific Pole had a substantial impact in the overall scientific production and creation of knowledge for the rational use of scarce Cuban resources. The Scientific Pole represents another step forward

The investment in human capital to produce a highly qualified workforce allowed Cuba to develop the biotechnology industry in the 1980s (Limonta,1989), the first vaccine against meningitis B in 1985 and subsequently another vaccine against Haemophilus influenza type B, the latter the first human vaccine made from synthetic antigen (Kaiser,2004; Verez-Bencomo et al., 2004) among other innovations. The products coming from this innovative industry have benefited the Cuban population thanks to the efficiency of Cuban Health System (Marquez, 2009) and products like CIMAvax, a vaccine for the immunotherapy of non-small cell lung cancer which even at the trial stage has been well received in the developed world (Randal, 2000; Perez et al., 2011).

In 1994 the Cuban Academy of Sciences (ACC) merged with the National Commission for Environment and Natural Resources, and the Executive Secretariat for Nuclear Affairs to form the new Ministry for Science, Technology and Environment (CITMA). This new structure aimed to harness Cuban scientific and technological knowledge to a more efficient and sustainable form of development. Later in 1996 the Cuban Academy of Sciences was established by law as an official institution of the Cuban State. (Clark Arxer, 2010). Stressed by the economical crisis of the 1990s, Cuban scientists and technicians joined the government programme to develop organic agriculture as the only way out of the precarious consequences of the reduction in availability of pesticides by more than 60 % and fertilizers by 77%. Innovative approaches were put in practice by experimenting with bio-fertilizers, bio-pesticides and the use of fermentation and tissue culture. To strengthen this organic agricultural revolution the country continued investing in knowledge and technology for organic agriculture, ensuring that both are incorporated in the higher education curricula to create a new generation of agronomists. In the Scientific Conference of the Food and Agriculture Organization of United Nation (FAO-UN) Nadia Scialabba (2000) praised the new development in sustainable agriculture that was taking place in Cuba: "Cuba is perhaps the best example of large-scale government support for organic agriculture and is an encouraging model to replicate in other countries". This observation, as it can be noticed in other fields of Science and Technology is a consequence of the priority of the CITMA to encourage and guide research projects towards social needs through sustainable approaches and methods.

Although migration is intrinsically linked to the development of the human race, it is currently a problem for developing nations when it concerns their highly skilled citizens. It was the exodus of British scientists to the United States after World War II that lead to the concerns of the Royal Society about the migration of scientists, which they called at the time 'brain drain' (Balmer et al, 2009). The brain drain often referred to highly skilled workers, the latter defined as those who achieve tertiary education, moving from low-to high- income countries. This definition refers to 'all highly skilled workers' in any sector or discipline and is in general a useful start point. But for the purpose of this study our focus is narrower looking specifically at scientists and engineers. Nevertheless, the general definition provides a good basis to explore the different levels of the problem.

Between 1990 and 2000 the movement of skilled immigrants to OECD countries increased by 64 % from which, 93% were from developing countries. (Docquier et al., 2007). The OECD study (OECD, 2008) found that the net total gain in highly skilled expatriates is 7.8 million for the United States, about 1.4 million for Europe, 1.6 million for Canada and about 700 000 for Australia. Although these values include both developed and developing countries, the brain drain affects small developing countries more. This is the case of Jamaica, Haiti, Trinidad and Tobago, Mauritius and Fiji with the loss of more than 40% of their highly skilled citizens. In 2000 there were 44 countries (41 developing) with emigration rates above 20% for graduates from tertiary education (Hanson, 2010) with African countries like Ghana, Sierra Leone, Gambia and Uganda in the worst situation. In terms of brain gain to the developed receiving countries the contributions are mainly from the new growing economies with large populations like China and India. Between 1993 and 2003 the number of foreign scholars employed by US universities increased by more than 70 % especially in natural sciences (Thorn and Holm-Nielsen, 2006). China lost more than 700,000 professionals who studied abroad between 1978 and 2006 (Royal Society, 2011), Philippines 1,111,000, India 1,035,000 million and Mexico 949,000 and Cuba 332,000 (Docquier and Rapoport, 2011). Interestingly migration of highly skill workers is observed in developed countries as well with United

Kingdom in the top of the list with 1,479,000, Germany 994,000, then United States with 427,000, Italy with 397,000 and France 318,000 respectively.

Migration in the 21st century continues to drive global demography and development. In the first place its size is significant, with a global population of first generation migrants around 250 million. Secondly, unlike in earlier migrations the new migrant populations have greater possibilities to reconnect with their homeland through the availability of cheap flights and the revolution in communication (Economist, 2011). Although the brain drain is still a concern for sender countries, new forms of engagement of talented scientific diasporas are building new engines for growth and development in their homelands (Solimano, 2006; Seguin et al., 2006; Economist, 2011). The governments of China, India and Nigeria have pioneered different initiatives to articulate in one way or the other the potential for their scientific and technological diasporas to meet their specific needs (Royal Society, 2011). The apparent expectation of transforming the brain drain into brain gain or brain circulation has still an unresolved humanitarian problem: the emigration of health professionals from low- to high- income countries. The dramatic situation faced by countries with fragile health systems has called the attention of the World Health Organization and in 2010 a Global Code of Practice for recruitment of health personnel was approved during the 63rd World Health Assembly. An analysis of the overall loss of returns on investments in the formation of doctors in countries from the sub-Saharan region was estimated as $2.17 billion while the benefits to destination countries are concentrated in the United Kingdom ($2.7bn) and United States ($846m) (Mills et al., 2011).

Exploring the consequences of mobility and migration: a Cuban pilot study

A pilot study has been carried out to help shape a future investigation of the theme. The general hypothesis which informs this pilot study is that currently, there exists a scientific population of Cubans abroad that continues to develop itself professionally. This hypothesis will be tested using bibliometric analysis. If this hypothesis holds true, there is great potential to harness this brain-rich population of Cubans to further develop science and technology in Cuba i.e. brain gain as is occurring in other emerging economies.

In order to explore these emerging ideas an exploratory study was developed to test out the potential and possibilities for a more extended investigation. This study was initially reported at the UWL VISTAS Colloquium under the title of ‘Mobility, Migration and Networking of Cuban working in Science and Technology’ (Palacios-Callender, 2012). The results of this can be summarized as follows.

Methodology for pilot study: A case study of 25 Cuban scientists with residence abroad were analysed using bibliometrics as an attempt to measure the state and development of the group (Laudel, 2005). The publications of these scientists were followed for 25 years beginning in 1986.

Mobility phase was defined as the period of time where the scientists moved back and forward between Cuba and other collaborating countries. All scientists in the group had experienced periods of mobility of variable length, but the exact duration couldn’t be found using bibliometrics. Migration phase was the period when the scientist changed residency to a country different than Cuba. The year of migration as well as places of destination were taken from the publications showing the addresses of the authors. The composition of the sample in terms of generation and gender is shown in table 1 and in terms of regional location where the Higher Education (HE) and post-graduate studies were carried out in table 2. Information in both tables was taken from the professional network LinkedIn and information collected by the author. One scientist was American of Cuban Origin (AOC) who received the education (HE and PhD) in Cuba. The list of publications per scientist/specialist were made by searching through PubMed and Google scholar and a data base per scientist was created with the names of the scientific journals per year, the times each article was cited and impact factor of the scientific journals. The database was then made anonymous before processing the information.

Table 1: Composition of scientists by generation and sex

	female	male
Born between 1946 - 1964	4	1
Born between 1965 - 1980	6	14
total	10	15

Table 2: Distribution of scientists in different countries during their professional formation

Country	High Education	Post-graduate degree
Cuba	16	12* + 2
Spain	1	2
Italy	0	2
Belgium	0	3
Germany (East Germany)	0	1
Hungary	2	0
UK	1	2
Russia	4	0
Canada	0	1

(*) PhD Research partially or totally done abroad (during Mobility phase). Italy, Spain, UK, Germany, Belgium and Czech Republic.

Results of pilot study: Once scientists migrated from Cuba to a new country of residence, they often migrated later on to another country. The distribution of destination countries at the time of the last publication was : 3 in developing countries of the region (Chile and Mexico) and 22 in developed countries (15 in Europe/UK and 7 in North America). Areas where the scientists are currently employed include: research in academia (18), health services and research (3), industry (2) private sector (1) and international agency (1). Distribution of scientists per areas of research regardless of the migratory status is shown in figure 2. Publications per area of research taking into account the migratory status is shown in figure 3, with 188 and 314 scientific papers from scientists with the status of mobility and migration respectively. There is an increase in scientific publications by 67 % coming from scientists that have migrated. This substantial increase is explained by two reasons: first, 80 % of scientists belong to the generation that was born between 1965 and 1980 (see table 1) and therefore during the first 12 years of the present case study they were still at universities as students or recently graduated. Secondly, international publications in the area of the research included in this study, increased more than 30 % in the last 15 years. This can be observed when plotting the number of publications over time (Figure 4) taking into account the migration status. Figure 4 also shows the number of publications as a result of collaboration or networking between scientists with residency abroad (migration) and Cuba (total of 6 papers out of 314). A summary of the research output of the case study is shown in table 3 indicating those articles that have been cited as well as the number of times they were cited and how many of them were published in scientific journals with more than 4 and 9 impact factor (IF). Although the size of the sample is small and we do not know how much it represents the entire population, it seems that the main feature of the migration phase is the achievement of publishing in journals with higher impact factors, with a ratio of 1:7 (mobility phase: migration phase) in the top 70 scientific journals of the field. The relevance of the research measured by the times they were cited per publication showed that it is more relevant in the mobility group (52.5 vs 37.3). However, it is due to one particular paper cited 1,263 times and not to the pattern of the whole group. The number of publications as a result of the collaboration or networking between Cuban scientists abroad and at home is small (6 out 314 papers) and they were mainly between universities.

Figure 2: Number of scientists per area of research

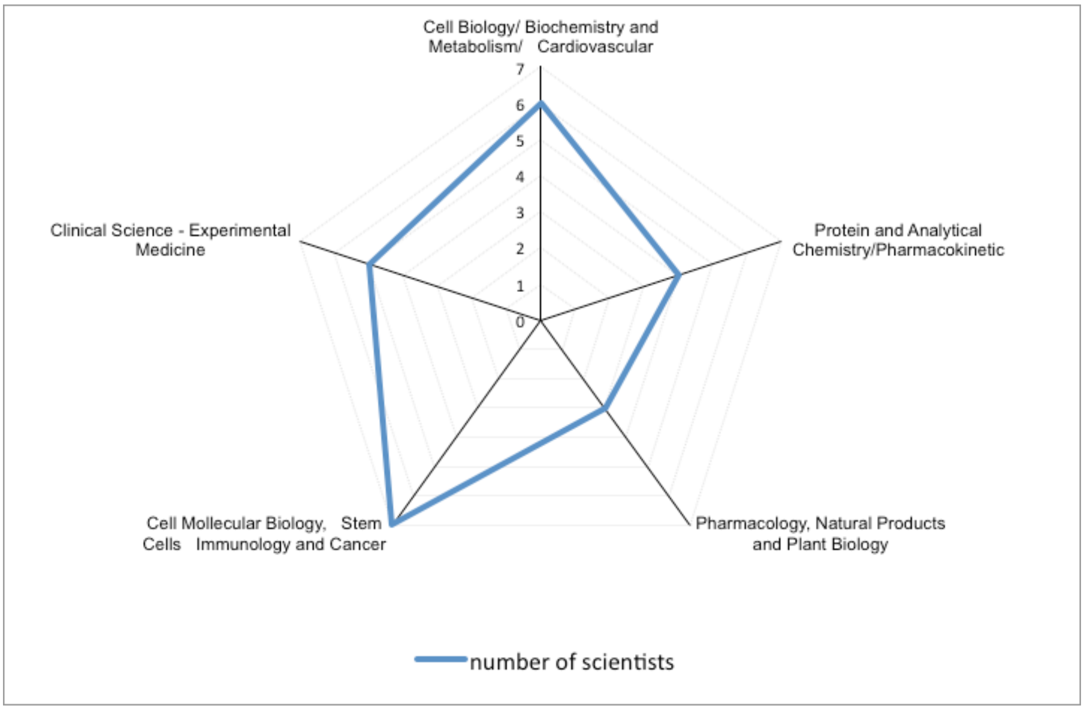

Figure 3: Publications per area of research

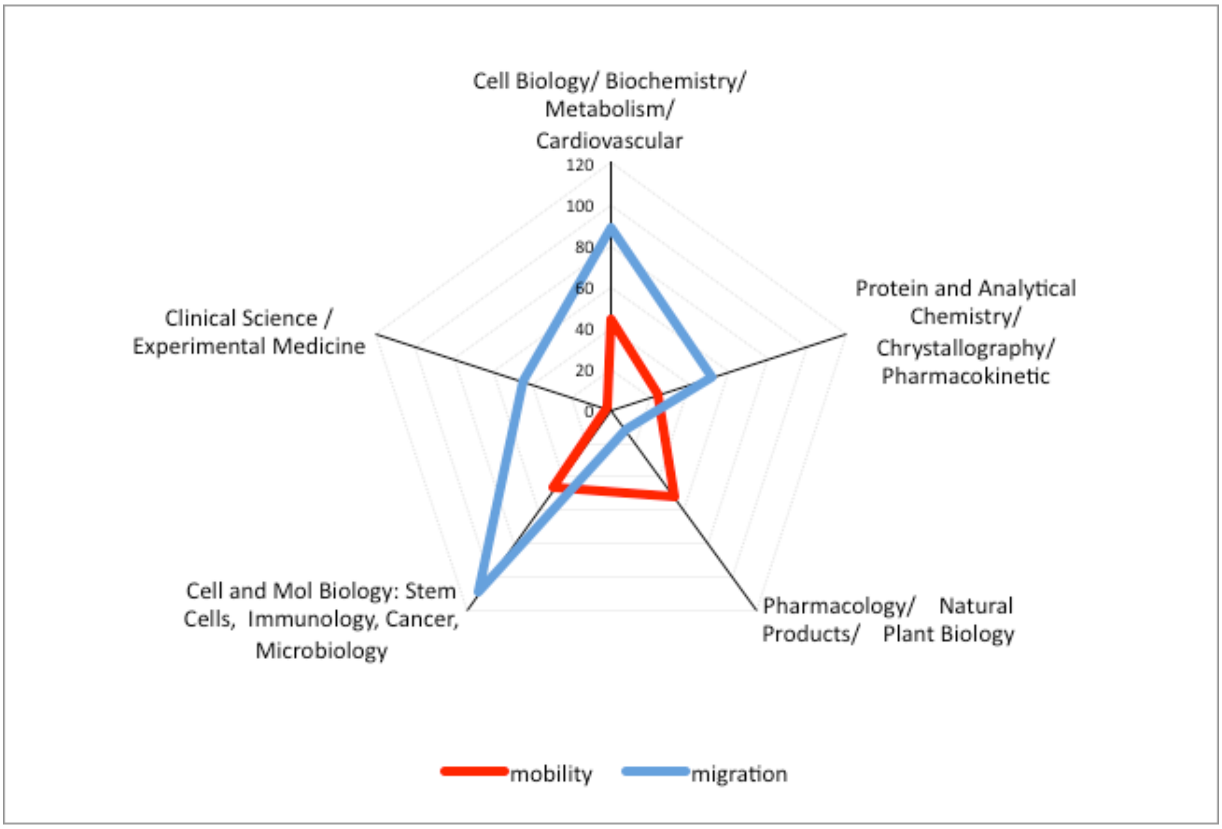

Figure 4: Publications in 25 years (1986 – 2011)

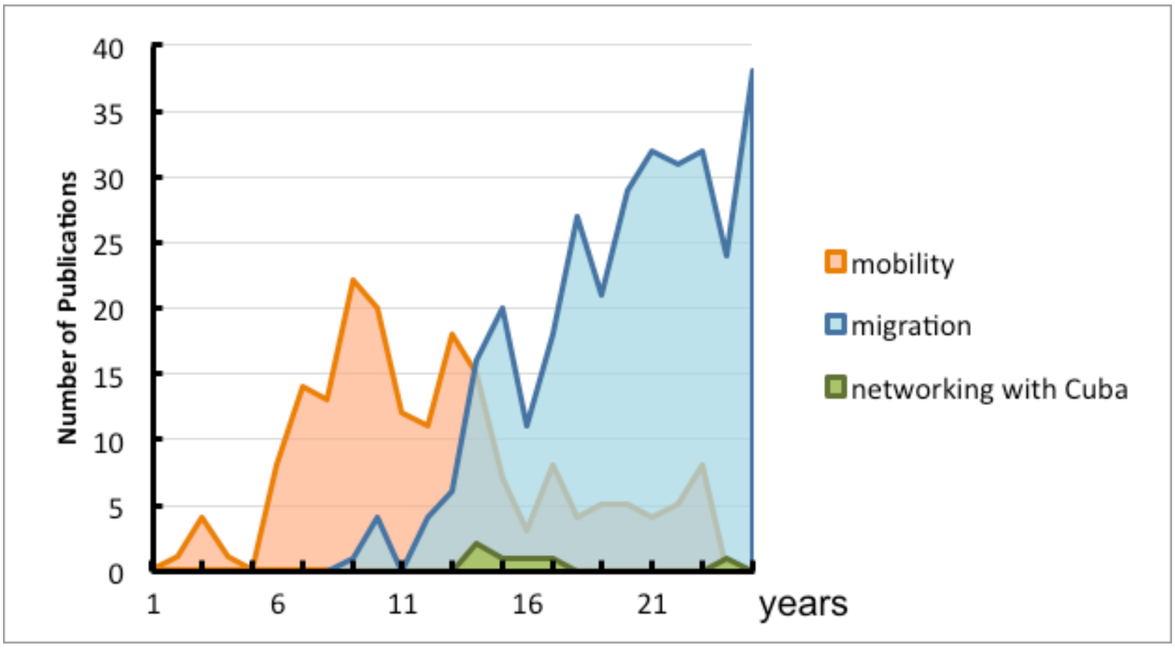

Table 3: Summary of bibliometric findings

Phase	Total publications	Number of cited publi-cations	Total times of cited articles	Average citation per paper	Number of publications in scientific journals with Impact Factor (IF)		
					>4	>9	Top 70 journals by IF
Mobility	188	141	7401	52.5	40	3	1
Migration	314	281	10,467	37,3	153	27	7
Networking	6	5	61	-	1	1	0
Total	502	422	17,891	42,4	192	30	8

Some findings from the pilot study: By looking only at publications, the power of innovation of the group was not measured and therefore an important contributor to the development of science and technology was not taken into account but this will be included in the extended study proposed. Interestingly, the migration of Cuban scientists to the US represents only 20% (5/25) when the total migration of Cubans to US is about 81% (Martinez-Fernandez, 2006). The international trend however shows that the US is the first choice for international migration of scholars and scientists. Although the size of the sample is too small to support any conclusion, it suggests that the almost non-existence of scientific exchange between Cuba and the US, and therefore lack of direct contact between scientific institutions of both countries, are at least the partial explanation and should be further investigated. The number of publications in collaboration between Cuban scientists at home and abroad is very small, but it might not reflect other types of collaborations or networking, which should also be taken into account in further studies.

There is no doubt that Cuban social achievements stem from investing consistently in the development of its human capital, which is epitomised in the words of Clark Arxer: "*By harnessing [Science and Technology] to social needs over the past 40 years, Cuba has managed to eradicate illiteracy, extreme poverty, hunger and infant deaths due to preventive diseases*" (Clark Arxer, 2010). International organizations have acknowledged the effectiveness of Cuban policies improving the human indicators for which these institutions work, in relation to health, education and human development (WHO, 2008;WHO,2010; UNDP, 2011; WWF, 2006). Thus, WHO, UNDP and WWF have recognized the increased effectiveness of Cuban policies to improve human indicators.

Despite those achievements, Cuba might benefit from its scientific and technological population abroad in a world where the global network of knowledge is becoming an asset for those countries and organizations which master its use. One advantage to countries that incorporate networking with their scientific diaspora is that these very individuals can help advance science and technology while possessing a deep understanding of the national culture and ideology. Cuban scientists are part of global science and those working abroad might search for opportunities to benefit their country of origin, like identifying sources of funds, access to new technology and infrastructure to be used in collaboration with their institutes, local knowledge relevant to translational science, etc. Expectations of the new Migration Act (Gaceta Oficial de Cuba, 2011) have to meet reality in the coming years if there is any real interest to find a role for the scientific and technological migration (Global Commission, 2005; Florida International University, 2011).

The present case study, although limited by the size of the sample, illustrates how Cuban scientific migration has the potential to be part of Cuban development in science and technology. Bibliometrics was an essential tool in this study to identify the number of scientists in active positions, but requires further improvement especially if the number of scientists in the sample increases. Qualitative research methods will be required to assess the potential contribution of this scientific population to the development of a network project. To transform this possibility in reality both Cuban authorities and the scientific and technological community abroad must work together towards the creation of an effective network system.

Studying mobility and migration: underpinning propositions

The themes of history of science and social studies of scientific activity are already well established specialities. The theme of mobility, migration and networking in the Cuban scientific community forms part of this wider area which it is planned to explore through a combination of study methods including scientific production and productivity (using bibliometric and scientometric methods), modes of communication and the use of the emerging digital technologies. To this can be added the study of the institutional and organizational apparatus of scientific development.

There is a very small number of UK based specialists studying the Cuban scientific community (one such is Dr Simon Reid Henry at Queen Mary University of London) but many more looking at the wider issues of scientific communities in the developing world (Alboroz et al., 2010; Holmgrem and Schnitzer, 2004; RICYT, 2011) . Thus the work proposed has scope to make an original contribution to knowledge and to serve as a contribution to an important pool of specialist literature with wider ramifications for policymaking. The use of the ICTs and web based platforms is a growing field of interest and an experimental test bed is envisaged as part of the project and its application potential. The academic study will lead on to action research and development.

There are eight main linked themes which have been identified in the study area and after a general exposition, each of these can be considered in the contemporary Cuban context.

1.Science is an enterprise based on knowledge and communication: Scientific endeavour is an institutionalised activity which has developed to allow the discovery and creation of new knowledge. It has become ever more collaborative in its modes of operation because this ensures the exposure and transparency of findings as a necessary means to attest to the validity of new knowledge claims. The established paradigm of scientific method has evolved and is respected because it provides a consistent means of maintaining this process. Not only is original inquiry subject to scientific method (whether through rigorous and systematic description and/or by experiment, testing and replication) but its validation and acceptance is best ensured through formal communication and variety of social exchanges. Science has developed its activity and integrity by developing normative social behaviours in which communication plays a key part. Thus the preliminary phases of publication and later the primary archival phase of publication have developed normatively to establish a solid foundation for successive phases of activity. Communication has been (and still is) at the heart of a cumulative process of science which extends the boundaries of knowledge and which protects that body from false claims.

Mobility, migration and networking are natural allies of this normative process in the scientific enterprise. The so called 'republic of science' does exist but may indeed clash with the needs and constraints engendered by national political, economic and social realities.

For a country like Cuba that has invested so much in their human capital at the expense of social comfort it is not surprising to manifest its concerns when it comes to lose this human capital. Cuba has implemented a controlled system to allow high mobility of academics, scientists and engineers to international institutions and organizations. The mobility of highly qualified personnel has supported not only the development of science and technology in the country but it has contributed to improve the visibility and credibility of this critical mass at international level. Through mobility Cuban scientists, engineers and academics have access to expensive physical resources that allow them to speed up their projects, to exchange knowledge and ideas to boost processes of discoveries and innovation back in Cuba. These are universal reasons behind the engagement of Cuban scientists, engineers and academics with international collaborative activities (Wagner, 2006). The contribution of academic travel as a key factor in the geography of knowledge, science and higher education has been well documented (Jones, 2005; Jones, 2009) as well as its role in the formation of centres of knowledge. It seems that the mobility of Cuban scientists and academics has been mainly to developed countries (different from medical doctors as mentioned earlier), and more recently to developing countries of the region. The movement of Cuban scientists and academics and the formation of transnational knowledge networks have not been fully studied and it might be relevant to the network of emerging developing countries of the periphery.

Cuban science is in its essentials identical to that of other countries. However, the situation of the country for various reasons has suffered some disadvantages in term of volume and quality of scientific communication. A significant concentration of the world publishing capacity in science is in the US, and therefore Cuban scientists have great limitations during the process of publishing their results (an American scientist is not allowed to use part of his/her time in helping with the editing of papers from Cuban institutions). Cuban scientists living abroad can help colleagues from the homeland to overcome the restrictions of the US blockade, at least at the present time. The new digital environment does provide many opportunities and advantages that will overcome these traditional impediments to scientific progress in particular the open access archives or information repositories (Arencibia-Jorge, 2004).

Cuban science in the 21st century has to master all the possible methods and media for scientific publishing in order to let the international scientific community know about Cuban findings. The open access initiatives are essential and important policies, especially when the blockade imposed by the United States on Cuba intends to prevent the publication of Cuban authors' papers in the main journals of the United States. In spite of the gap in digital development, from which Cuba cannot yet escape, we count on two essential resources: the human resources and the political will of making Cuban science a borderless science.

2. The scientific enterprise is a matter for national interest and concern: The ideal of science and the model of scientific enterprise has become universal. But universal, nevertheless, in a real world of nation states. Taking the idea of scientific endeavour as institutional scientific enterprise makes the activity a focus of national science policy, and thus typically a matter of economic and strategic concern. Thus each nation has evolved an organizational context for its scientific enterprise which it tries to ensure is appropriate to its needs. The 'republic of science' may have recourse to national (and international) institutions which are real, formal and physical or ones which are apparent, informal and increasingly virtual. The notion of the 'scientific academy' is real and tangible in whatever form it takes and thus forms part of the infrastructure which leads to science having its intrinsic value as well as its economic value.

Mobility, migration and networking thus have a significance and value in the national construction of science activity and enterprise. They are all components of what can be considered as 'a market space 'of science. Mobility is enriching for scientists as the gains are often returned to the home country in the short term (a brain gain). Migration may imply a longer or even permanent absence and therefore loss to the home country (brain drain). Networking may have a mobility component, but in the digitally and interconnected world it offers the possibilities of extensive gains and collaboration without physical movement or as an alternative or supplement to movement. A case from Romania illustrates this well by following up the concept of brain networking, where digital mobility substitutes for physical mobility (Ciumasu, 2010)

This paper has already noted the significant production of medical doctors and the mobility to a range of countries especially in the developing world. In addition since the early 1990s Cuba established a very strong biotechnology sector. In agriculture and veterinary sciences the same story can be told.

3.The political, economic and geopolitical dimensions of science are closely connected: The links between science and development are absolutely clear. The developed countries (largely of the global north) have realized this link now for well over one hundred years. They realize that their history, creativity and productivity has become an asset, indeed a source of scientific and intellectual capital. Global development (as characterised by the Millenium Development Goals) views science and knowledge as not only the key to growth and redistribution but also to global sustainability and survival in the context of climate change, energy deficit and population growth.

Despite more than 50 years of focussed international development and aid the overall situation sometimes appears stationary or at best extremely slow moving. Wide disparities exist yet there is much room for optimism even so. The emerging economies of Asia, Africa and Latin America provide some stories of relative success and Brazil, Russia, India and China are the leaders in a reshaping global economy. All four nations have invested heavily in scientific endeavour and enterprise. How their experiences have been and are being shaped at the moment will provide new insights for mobility, migration and networking. There are many more examples (like Cuba and Mexico) in this intermediate and emerging group where science policy needs to be shaped by and react to the trends which can be observed in both the 'republic of science' and the 'market space of science'.

In a study to evaluate the impact of biotechnology in seven countries they found that in all cases the governments have developed specific policies for the development of the field. Reviewing the case study of Cuba they highlighted the following characteristics: ensure long-term governmental vision and policy coherence, promote domestic integration to spur innovation, tap into national pride and capitalize on international linkages (Thorsteinsdóttir et al., 2004). By making the society part of the success and therefore its pride, the government promotes moral sentiment of nationalism that reinforces the engagement of scientists and engineers with the nation. On the other hand, Cuba has also has up-dated a Migratory Act (Gaceta Oficial de Cuba, 2012) to prevent the brain drain.

,

4.Economies need scientific activity - how can it best be mobilized for economic purposes?: Every national economy (and indeed supranational economy) has to develop scientific endeavour and enterprise as a foundation for growth. In the past much attention was focused on the question of pure/basic versus applied science or between science and technology. National reputations have been characterised (or stereotyped) by such notions. The UK had a reputation for basic science but a poor record on transfer and application; Germany excelled in pure science and technology; Russia was strong on theoretical work and strategic technology, but not good on mass consumer production. Such generalizations often fail on closer examination but do contain a grain of useful truth if only to motivate political debates about 'how to do science'. Cuba has a very strong awareness of this fact and immediately after 1991 and the special period (periodo especial) recognized the consequences and what it had to do.

But less science will be done in the national economy if the balance between mobility, migration and networking is not aligned with needs. Investment in science is one thing, but once made it cannot be allowed to decline or to depreciate without the consequences being felt.

5.Sustainable scientific culture is going to be increasingly important: A brain drain represents a depreciation in national scientific capability and such loss puts at risk the sustainability of the scientific enterprise. Simply put, the initial investment creates the assets which then go on to help create scientific capital in terms of knowledge gained and economic innovation realized. The question of sustainability becomes more deeply related to needs and requirements. What is the scientific population and resource a country and economy needs? Whilst science can be seen as an ideal and a good in itself one might believe the requirement is always larger than can be achieved. How the requirements are fulfilled depends on many conditions: the demography of the country; the nature and state of its education systems; the ability to absorb and use scientific production and scientists; the esteem in which science and scientists are held, as well as the political and policy goals of the society. It is said that the UK does not produce enough mathematics, physics or engineering graduates and yet UK science still remains internationally buoyant and has prestige. But this position is sustained by 'draining brains' from wherever they can be attracted. The UK freely exploits the supply of Indian software talent to meet the needs of the UK IT industry. The UK could satisfy its need for mathematicians by sourcing them from China. Or nearer to home, the UK could import German technologists by taking advantage of the European single market in much the same way that Polish builders and plumbers found a market in the UK in recent years.

.

6.Migration and the brain drain are well documented phenomena: These are two themes which have received much academic attention since the 1960s by both scientists and social commentators alike. More recently, the themes of migration and the 'geography of knowledge' have attracted the attentions of geographers and this is consistent with the contemporary interest in the ideas of the knowledge economy, globalization and a digitally connected world.

Historically the idea of migration carried with it the sense of 'no return' seeing migration as a largely irreversible process and a feature of the historical world as was and is. The idea that we may be experiencing the 'end of history' (Fukuyama,1992) could be transient, but new means of digital communication and the creation of virtual worlds might at least help to overcome some consequences of ' irreversible' at least amongst scientific communities. The development of electronic and digital publication and the new levels of information provision and service that have already been created are beneficial for science. Now it may be the turn for social and virtual media to not only enhance communication but also to create communities which have some power to counterbalance the irreversibility of migration. This theme is the primary goal of the research study being carried out by the authors.

7.Developing communications and networking can help counteract the deficits created by migration and brain drain. In the ideal world freedom of movement and people is as valuable as the other significant freedoms of expression, belief and worship. In the wider world the internet, WWW and the digital social media are already acting at the general level to sustain these ideals and show how they might be used in the more specialized communities of science which are affected by migration and the brain drain. The mobility of the scientist is both physical and intellectual. Intellectual mobility can exist without movement and above all it is dedicated to creative and expressive liberty. Physical mobility requires economic resources (a potential inequality) as well as opportunity and freedom of choice. The mobile scientist usually returns or possibly continues a journey (the wandering scholar) but has the choice to return to the starting point. Migration may lead to rupture but science has inherent properties which can often mitigate the impact of migration so it may not be final at least in the medium to long term. But, there are times when migration (with its finality) is the result of lack of opportunity and becomes a case of economic necessity. Whatever the causes of migration, networking and communication have some powers to compensate for the deleterious effects.

8.ICT, Web and digital technologies are now vital and are shaping all scientific communities: The last five years, let alone the last ten years, has seen the mass dissemination of the new and mobile digital technologies, not only in the developed world but increasingly in the developing areas of Asia, Africa and Latin America. These digital technologies are not only the basis of organizational communication but of significant personal use. In fact, they are breaking the boundaries of these two major domains. It is a fact that the Internet originated in the scientific community but its intensification has taken place in the worlds of commerce, business and markets. Now is the moment to appreciate that it is opening many new opportunities again in science and its applications, and this realization is a motive force for a programme of investigation now commencing and for the reasons argued in this paper.

Looking forward

The area of the proposed study is significantly novel: there has been no major empirical academic study carried out of mobility, migration and networking of Cuban scientists, and specifically no study carried out by a Cuban scientist with personal experience of working in both environments and cultures.

The results will contribute to the pool of studies on mobility and migration of scientists in and from Cuba by adding empirical knowledge and by enhancing both theoretical perspectives and potentially informing policy and practice.

As part of the data gathering and as a practical exploratory development the ICT and web based technologies will be deployed as experimental and action-orientated research. This phase of the study (and potential post-study) will be innovative. An analysis, reflection and critique of this part of the process will use and test socio-technical theories in the wider study of contemporary and developing science communication.

References

Albornoz, M., Matos Macedo,M. and Alfaraz, C. (2010) Latin America In *UNESCO science report 2010: the current status of science around the World*, p. 77-101. Paris: UNESCO Publishing.

Arencibia-Jorge, R., Araújo Ruiz, J.A. and Torricella-Morales R.G. (2004) Cuban science and the open access alternative. *HEP Libraries Webzine* (Issue 10). http://testing-library.web.cern.ch/testing-library/Webzine/10/papers/4/

Balmer, B., Godwin, M. and Gregory, J (2009) The Royal Society and the "brain drain": natural scientists meet social science. *Notes and Records of the Royal Society*, 63, p.339-353.

Barre, B., Hernandez, V., Meyer, J. B. and Vinck, D. (2003) *Scientific diasporas: how can developing countries benefit from their expatriate scientists and engineers?* Paris: Institut de Recherche pour le Développement.

Becker Barroso, E. For neurologists in Cuba, hope is not embargoed. *The Lancet Neurology*, 8, p.1088-1089.

Bethell, L. ed. (1993) *Cuba: a short history.* Cambridge: Cambridge University Press.

Boyle, M and Kitchin, R. (2011) *Towards a new generation of diaspora centred development: current practice and emerging priorities.* Paper presented to: Conference - Diaspora and Development: Prospects and Implications for Nation States, September 7th and 8th 2011, School of Extension and Development Studies and School of Interdisciplinary and Trans-disciplinary Studies, Indira Gandhi National Open University, New Delhi.

Castro, F. (1960) Speech at the National Agrarian Reform Institute (INRA), Havana, Cuba.

Ciumasu, I.M. (2010) Turning brain drain into brain networking. *Science and Public Policy,* 37(2), p.135-146.

Clark Arxer, I. (2010) Cuba In *UNESCO science report 2010: the current status of science around the World.* p. 123 – 131. Paris: UNESCO Publishing.

Docquier, F., Lobest, O. and Marfouk, A. (2007) Brain drain in developing countries. In *The World Bank Economic Review,* 21, p. 193-218. Oxford: Oxford University Press on the behalf of the International Bank for Reconstruction and Development.

Docquier, F. and Rapoport, H. (2011) *Globalization,brain drain and development.* Forschungsinstitute zur Zukunft der Arbeit (IZA) DP No. 5590 [Institute for the Study of Labour].

Economist (2011) Briefing: Migration and business. Weaving the world together. The magic of diasporas. How migrant business networks are reshaping the world. *The Economist*, September 19th-25th, p.76 – 78. [Editorial].

Florida International University (2011) *The Cuban diaspora in the 21st century.* Miami: Florida International University. Cuban Research Institute.

Fukuyama, F. (1992) *The end of history and the last man.* New York and Toronto: Free Press and Maxwell Macmillan Canada.

Gaceta Oficial de Cuba (2012) Ministerio de Justicia. Decreto Ley 302 sobre Migracion.

Global Commission on International Migration (2005). *Migration in an interconnected world: new directions for action.* Geneva: Global Commission on International Migration .

Goldemberg, J (1998). What is the role of science in developing countries? *Science,* 279, p.1140-1141.

Guzman, M.G. (2005) Global voices of science: deciphering dengue: the Cuban experience. *Science,* 309, p.1495-1497.

Hanson, G.H. (2010) International migration and the developing world. In D. Rodrik and M. Rosenzweig, eds. *Handbook of development economics,* Volume 5, p. 4363-4414. Amsterdam: Elzevier - North-Holland.

Holmgrem, M. and Schnitzer, S.A. (2004). Science on the rise in developing countries. *PLoS Biology,* 2 (1),11 -14 [e1. doi:10.1371/journal.pbio.0020001].

Jones, H. (2005), Academic travel from Cambridge University and the formation of centres of knowledge, 1885 – 1954. *Journal of Historical Geography,* 34 (2), p.338 -363.

Jones, H. (2009). Brain circulation and transnational knowledge network: studying long term effect of academic mobility to Germany. *Global Network,* 9, p.315 -338

Kaiser, J. (2004) Synthetic vaccine is a sweet victory for Cuban science. *Science,* 305, p.460.

Laudel, G. (2005) Studying the brain drain: can bibliometrics help? *Scientometrics,* 57, p.215-237

Limonta, M. (1989) Biotechnology and the third world: development strategies in Cuba. *Annals of the New York Academy of Sciences.* 569: p.325-334.

Marimon Torres, N. and Martinez Cruz, E. (2010) Evolution of the Cuban medical co-operation during one hundred years of existence of the Ministry of Public Health. *Revista Cubana de Salud Pública,* 36, p.254-262.

Marquez, M. (2009) Health-workforce development in the Cuban health system. *Lancet,* 374 (9701) p.1574.

Martin-Fernandez, C. (2006) Cuban international migration: family and society. Paper presented to: British Society for Population Studies, Annual Conference Southampton, UK: 18-20 September 2006. Available at: http://www.ccsr.ac.uk/cuba/documents/ConsueloMartin-BSPS06.pdf

Meadows, D. (2000) *Cut off from global markets, Cuba invents a new agriculture.* The Donella Meadows Archive. Hanover (NH): Dartmouth College.

Nature (2009) Cuba's biotech boom. The United States would do well to end restrictions on collaborations with the island nation's scientists. *Nature*, 457 p. 130 [Editorial]

OECD (2008) *A profile of immigrant populations in the 21st century: data from OECD countries.* Paris: Organization for Economic Co-operation and Development.

Palacios-Callender, M. *Mobility, migration and networking of Cubans working in science and technology.* Paper presented to the VISTAS Colloquium, University of West London, Friday 8th June, 2012.

ONE (2010) *Oficina Nacional de Estadística. Anuario estadístico de Cuba 2010. Edición 2011* http://www.one.cu/aec2010/esp/20080618_tabla_cuadro.htm

Perez, L.A. (1988) *Cuba: between reform and revolution.* New York and Oxford: Oxford University Press.

Perez, C.A., Santos, E.S. and Raez, L.E. (2011) Active immunotherapy for non-small-cell lung cancer: moving toward a reality. *Expert Reviews in Anticancer Therapy,* 11(10), p.1599-1605.

Randal, J. (2000) Cuban vaccine tested in Canadian trial. *Journal of the National Cancer Institute,* 92 (13), p.1037 [Editorial].

Reid - Henry, S. M. (2010) *The Cuban cure: reason and resistance in global science.* Chicago: University of Chicago Press.

RICYT (2011) *El estado de la Ciencia.* Buenos Aires: RICYT(Red de Indicadores de Ciencia y Tecnologia Iberoamericano e Interamericano) and Organización de Estados Iberoamericanos.

Royal Society (2011) *Knowledge, networks and nations: global science collaboration in the 21st century*. London, Royal Society of London. Report 03/11 DES2096 March 2011.

Seguin, B., Singer, P.A. and Daar, A.S. (2006) Scientific diasporas. *Science,* 312, p.1602-1603.

Scialabba, N. (2000) *Factors influencing organic agriculture policies with a focus on developing countries.* Report presented to the IFOAM 2000 Scientific Conference, Basel, Switzerland, 28-31 August 2000.

Solimano, A. (2006) *Mobilizing talent for global development.* Helsinki: UN – WIDER. United Nations University, Policy Brief, Number 7.

Thorn, K. and Holm-Nielsen, L.B. (2008) *International mobility of researchers and scientists: policy options for turning a drain to a gain.* Helsinki: UNU-WIDER.

Thorsteinsdóttir, H., Quach,U., Daar, A.S. and Singer, P.A.(2004). Conclusions:promoting biotechnology innovation in developing countries. *Nature Biotechnology,* 22, DC p.49-52.

Truslow, F. A. (1951) *Report 10764 on CUBA: findings and recommendations of an economic and technical mission organized by the International Bank for Reconstruction and Development in collaboration with the Government of Cuba in 1950.* Washington (DC): International Bank for Reconstruction and Development.

UNDP (2011) Human development report 2011. *Sustainabilty and equity: a better future for all*. New York: Palgrave Macmillan for the United Nations Development Programme.

WWF (2006) *Living planet report.* Gland (CH): World Wildlife Fund for Nature.

Verez-Bencomo, V. et al. (2004) A synthetic conjúgate polysaccharide vaccine against haemophilus influenza type b. *Science,* 305 (5683), p.522-525 [DOI: 10.1126/science.1095209].

Wagner, C.S. (2006) International collaboration in science and technology: promises and pitfalls. In Box, L. and Engelhard, R. eds *Science and technology policy for development: dialogues at the interface*. London: Anthem Press.

WHO (2008) *The world healthcare report 2008: Primary health care: now more than ever.* Chapter 4, p. 64 -78. Geneva: World Health Organization.

WHO (2010) *Global code of practice on the international recruitment of health personnel. Sixty-third World Health Assembly - WHA63.16.* Geneva: World Health Organization.