Mobility, migration and networking of Cubans working in European science and technology: building capacity through Transnational Knowledge Networks

# Mobility, migration and networking of Cubans working in European science and technology: building capacity through Transnational Knowledge Networks

This thesis is submitted in partial of the requirement of the University of West London for the Degree of Doctor of Philosophy

London, June 2016

**Miriam Palacios-Callender**

## DECLARATION

I, Miriam Palacios-Callender, affirm that this thesis submitted to the University of West London is my own work of research. Contributions have been referenced or acknowledged accordingly.

## ABSTRACT

Developing countries are facing the loss of their talents due to high levels of migration towards the developed world. To counter this they are creating mechanisms and policies in science and technology to benefit from those national talents further developed abroad. This study of Cuba explores the value of Cuban scientists and engineers in Europe and reviews their potential for contributing to Cuban science through Transnational Knowledge Networks (TKNs).

This empirical investigation examines two essential conditions for the development of TKNs: first, it provides a demonstration of the scientific capacity in Cuba as a sending country, and second, profiles the Cuban expatriate scientists in Europe as active researchers (CRiE). Both investigations were carried out through bibliometric methods using bibliographic databases such as *PubMed* and *Scopus*. Cuban expatriate scientists were identified through a systematic search in professional social networks such as *LinkedIn*, *ResearchGate* and *Academia.edu* before compiling their scientific records for bibliometric evaluation. Cuban researchers in Cuba (CRiC) were the also evaluated as a cohort group. The empirical investigation covered the period between 1995 and 2014.

The main contribution of this investigation is to support the idea that TKNs are embedded in the global network of international scientific collaboration and this feature would enable expatriates to function as instruments for development of Cuban science.

The primary dataset was created using the scientific publications of expatriate scientists obtained from the *Scopus* database in the period between 1995 and 2014. Records in *Scopus* also include affiliations of all authors in each publication allowing the creation of another dataset of expatriate research links with other institutions. Network analysis using UCINET software was also used to study the degree of connectivity of the expatriate scientists.

Results show the demography, performance and connectivity of a scientific community (Cuban researchers in Europe) and demonstrate their potential to strengthen the networking capacity of the home country.

## ACKNOWLEDGEMENTS

This has been a fascinating and challenging journey and I have enjoyed learning and sharing knowledge all the way with my fellow PhD students and academics, both at the University of West London and elsewhere.

The significant starting point was when I had the opportunity to present a paper on June 8th 2012 at the ‘VISTAS Interdisciplinary Colloquium on Emerging Research in Education, Economy and Communication’. There I met researchers and fellow students of the Graduate School at the University of West London, and this gave my project a 'lift off'.

I am very indebted to Dr Stephen Andrew Roberts and Professor Peter Komisarczuk who initially enabled me to join the research group in the School of Computing and Engineering and set me on my way. I would like to acknowledge the time, energy, dedication and enthusiasm of my leading supervisor Dr Stephen A. Roberts. I have benefited from his mentorship, constructive criticism, advice and support. I would like to thank my second supervisor, Professor Thomas Roth-Berghofer for his support. The student meetings and seminars at the School have also provided a space to improve my knowledge and research technique. I have been supported by the UWL Graduate School in many ways, and wish to mention Maria Pennells and Dr Tony Olden for their support and encouragement.

Absolutely crucial to this research has been the interaction with the community of students and researchers of the network of the Cuba Research Forum at the Centre for Research on Cuba, University of Nottingham. My research has led me to many people and sources of ideas and information in Europe, the US and in Latin America as part of my journey. In this process I wish to acknowledge the support of UWL in enabling us to host a one day networking event at the University of West London, on Friday 28th March 2014: 'Developing research networks in global science and technology'. This event has proven to be pivotal in providing wider momentum for the doctoral research. The event really has helped to create a basis for an emerging TKN for Cuban scientists in the diaspora.

Beyond this immediate group I am indebted to many scholars and researchers in many countries who have exchanged emails, shared documents, engaged in conversations and who have supported and inspired me in countless ways.

I must also mention the contribution of Raul Cristobal Liz for helping me to create the webpage ‘transnational knowledge network-bibliometrics’ and for writing the computer programme to transform part of my data in matrices required in the UCINET software for the network analysis.

And finally, I must give all credit and gratitude to my husband Charles Alexander Callender for all his support, patience, tolerance and understanding as I have made this doctoral journey.

## DEDICATION

To my parents Marta and Juan for teaching me the importance of social justice.

To my children Miriam and Marcelo devoted to their families and careers.

To the ‘*Pinos Nuevos’:* Sara, Emma, Annabel, Camilo and Adrian for foresting the future with their dreams.

## TABLE OF CONTENT

**CHAPTER 4**

**METHODOLOGY AND METHODS**

**CHAPTER 5**

**RESULTS – PART I**

**SCIENTIFIC COLLABORATION IN CUBA**

**CHAPTER 6**

**RESULTS – PART II**

**CUBAN SCIENTISTS AND ENGINEERING IN EUROPE**



**CHAPTER 7:**

**RESULTS - PART III**

**CUBAN SCIENTISTS OF THE REVOLUTION**

**CHAPTER 8**
**DISCUSSION OF FINDINGS**

**CHAPTER 9**

**CONCLUSION**

## List of Figures……………………………………………………..…………xvi

# List of Tables ……………………………………………………………xviii

## List of Charts…………………...……………………….…………………………………...xx

## List of Acronyms, abbreviations and definitions……………………xxi

CITMA: Cuban Ministry of Science, Technology and Environment

CRiE: Cuban researchers in Europe

CRiC: Cuban researchers in Cuba

CRiLA: Cuban researchers in Latin America

CRiUS: Cuban researchers in the US

GERD: Gross Domestic Expenditure on Research and Development

GDP: Gross Domestic Product

GNI: Gross National Income

HDI: Human Development Index

HE: Higher Education

ICT: Information and Communication Technology

**iCRiE**: interviewee Cuban researchers in Europe

**iCRiC**: interviewee Cuban researchers in Cuba

PPP: Purchasing Power Parity

R&D: Research and Development

SME: Small and Medium Enterprises

STIS: Science, Technology and Innovation System

s&e: scientists and engineers

S&E: Science and Engineering

S&T: Science and Technology

TKN: Transnational Knowledge Network

North and South: In this thesis the terms refer to the Brandt's line division adopted in 1980. The line separates the rich countries mainly in the Northerm hemisphere except Japan and Oceania and the poor countries in the Southerm hemisphere. The definition since them is used metaphorically as other parameters such as GNI and HDI and the Internet access are taken into account to classify the degree of development of countries and regions.

## List of Appendices……………………………………………………...xxii

# CHAPTER 1: INTRODUCTION

"*Knowledge belongs to humanity, and thus science knows no country and is the torch that illuminates the world*"

*Louis Pasteur (1844 – 1895)*

## 1.1 INTRODUCTION

The research covered in this thesis intends to build a platform to support further studies in an area in which two important axes converge: one dealing with challenges of the dilemma of how science should better serve societies preserving the openness and freedom of knowledge in its universal goal versus countries and companies' policies to safeguard and profit from their investment in science; and the second axis coming from the shifting paradigm of converting brain drain into brain gain, which is the concern of all countries and regions, but is crucial for emerging and developing economies to compete on the world stage in the knowledge society. The convergent zone will reflect how regions, countries and economies have created a variety of mechanisms to ensure their capacities to harness from their investments in science and technology for their economic growth. To further translate into practice the results of this research, this study takes the case of Cuba as a small developing country with a consistent effort to develop scientific capability for the benefit of the Cuban population.

The convergent zone at the cross roads of science as a global enterprise and the North-South divergent economic growth has multiple avenues to explore, but the present research intends to analyse the role of cooperation within the pathway to overcome the challenges of the advent of the knowledge society for developing countries and how scientific cooperation and collaboration could be enhanced by harnessing the potential of transnational communities working in developed countries through different models of Transnational Knowledge Networks.

## 1.2 KNOWLEDGE SOCIETIES, INFORMATION SOCIETY AND SUSTAINABLE DEVELOPMENT

Knowledge in its most general definition could be defined as the theoretical and practical understanding about a reality acquired through a process involving perception, learning and reasoning. Naim Afgan and Maria Carvalho (2010) argued that, different from information,

> '*Knowledge requires organizational structure of facts with respective attributes reflecting specific properties and processing*'

Developed countries with larger educated populations and better infrastructure are in a stronger position to benefit from the creation of knowledge. For the rest of the world seeking a better life for their societies the urgent beginning so far, has to be improving the education for all: without that, the creation of new knowledge, might convert them into consumers of more sophisticated technology rather than producers of wealth for their economies.

A knowledge-based society, or a knowledge-based economy, is a term used only recently to identify a new period or age in discontinuity with the previous (Industrial Age), which is based on the accelerating speed of knowledge creation and accumulation (and depreciation) with an intense scientific and technological progress (David and Foray, 2002). As early as 1994, Peter Drucker (1994) called this new epoch as the "*Age of Social Transformation*" in which knowledge, not labour or raw material, or capital is the essential resource.

According to the United Nations Educational, Scientific and Cultural Organization (UNESCO, 2005, 5), in the world report "Towards knowledge societies", the current aims should be addressed as:

> '*Knowledge societies should be able to integrate all its members and promote new forms of solidarity involving both present and future generations. Nobody should be excluded from knowledge societies <u>where knowledge is a public good</u>, available to each and every individual*'.

However, the concept of knowledge as a public good has been challenged, implying that it is seen as a rhetorical discourse far from the real world because knowledge encompasses too many assets such as inventions subject to copyright, the functioning of the education system, the scientific research capacity and the practices of know-how, among others. Defining those realities either as commodities or as a public good is not in the scope of this study. However, in the next section “science and scientists”, it will be explained why the concept of scientific knowledge as a global public good and the ethos of scientists are the fundamental elements supporting this study.

## 1.3 SCIENCE AND THE SCIENTISTS

Science is a system of acquiring knowledge using observation and experimentation to describe and explain the natural world, but as defined by the Science Council[1]:

> ‘*Science is the pursuit and application of knowledge and understanding of the natural and social world following a systematic methodology based on evidence’.*

This definition includes the turning points in the history of science from Francis Bacon codifying the scientific method, to Galileo overturning the scholastic philosophy by erecting the art of systematic experimentation and Newton excelling in both processes to new heights (Price, 1961, 45).

Science is conducted by scientists and as a sector of the society they have also evolved with the social changes. From being isolated thinkers they became professionals of science in the mid-eighteenth century as a result of financial support for their scientific activity (Beaver and Rosen, 1979).

Scientists conduct research under principles codified by Robert Merton (1957), which are at the centre of their successful achievements:

---

[1] ***Science Council*** was established by Royal Charter in 2003 with the object of advancing science and its applications for public benefit http://www.sciencecouncil.org/definition

*<u>Communalism</u>: 'Substantive findings in science are a product of social collaboration and are assigned to the community; progress in science comes through cooperation and collaboration between individual scientists and between generations of scientists'*
*<u>Universalism</u>: 'Claims of truth are evaluated in terms of universal or impersonal criteria, and not on the basis of race, gender, religion or nationality. It also implies that scientific results should be analysed objectively and be verifiable or repeatable'*
*<u>Dis-interestedness</u>: 'Scientists are rewarded for acting in way that outwardly appears to be selfless. Scientists should have no emotional or financial attachment to their work. Secrecy is forbidden. Rewards come from their scientific achievements, not through monetary gains'.*
*<u>Organized Scepticism</u>: 'All ideas should be tested and subjected to rigorous, structured community scrutiny. The scientists should wait until all facts are in before a judgement is made about a particular theory or experimental findings'. This description refers to originality or the novelty in the scientific contribution.*

Although the ethos described by Merton has been many times challenged (Crane, 1972, 6), still they are at the centre of the highly functional reward structure in science that encourages scientists to share their discoveries. The reason is that scientific knowledge has characteristics of what economists call a public good (Stephan, 1012, 6): it is non-excludable and non-rivalrous. The scientist cannot exclude others from using his or her research if it is made public through publication and there is no way of appropriating monetary benefits in the process either (non-excludable). Moreover, publishing scientific findings creates a reward system that has proved essential in the production and sharing scientific knowledge (non-rivalrous).

The growing role of scientific knowledge in the global economy has also been accelerated with the advances in information and communication technology. Moreover, the creation of value depends more on a better use of knowledge, regardless the level of country development, the form and origin of knowledge (UNESCO, 2010).

Although science is universal by nature it is still confined to relatively few rich countries and there is a scientific divide by which progress is limited only to small part of the planet. The former Secretary General of the United Nations, Kofi Annan, has clearly deprecated the perpetuation of such scientific asymmetries, saying, "*The idea of two worlds of science is anathema to the scientific spirit"* (UNESCO, 2005, 98).

In the scientific divide there are other factors by which the diffusion and utilization of knowledge could be inefficient and has to do with the way the national systems for research and innovation operate. Places where knowledge is created should be well connected to business, industry and government to facilitate the flow of innovations. Closer links between these stakeholders (academy-government-industry) are typical of advanced economies and not totally functional in less developed countries.

Moreover, the scientific divide is also due to the failure of leading-decision makers to recognize both the need to invest in research and development and to develop the human capital as a strategic investment for economic growth. More governments of the South are more aware of the importance of science and technology in the process of improving their economies and more resources are being placed in research and development.

If we think of science as a worldwide endeavour and, as Louis Pasteur envisioned, some sort of mechanism should evolve to share at the international level the contribution of the scientists regardless their nationality. After all, science has benefited greatly from foreign-born scientists. International scientific collaboration can be seen as a useful means to leverage scientific capabilities worldwide.

## 1.4 WHY MOBILITY OF SCIENTISTS MATTERS

International mobility is a natural behaviour of researchers dating as a practice from the medieval scholars. Researchers have the need to share ideas as well as allowing colleagues to scrutinise and evaluate their contributions. From international meeting to short visits the international mobility of scientists is the engine behind the creation and diffusion of scientific knowledge. It has been part of the scientific communication by which researchers learn and improve their skills through tacit knowledge. Moreover it is crucial for international scientific collaboration.

Countries of the European Union acknowledge the benefit of the mobility of students and researchers not only for its vital role in the creation of knowledge, but as a mean to ensure competitiveness in the global race for talents (Commission of European Communities, 2001).

The mobility of highly qualified professionals has been considered essential for both the personal improvement of the researcher's career and for the national science, technology and innovation systems of the countries according to the report of the Network for Science and Technology Indicators for Ibero-America and Inter-American countries (RICYT, 2011, 411).

Freedom of movement to access places rich in original knowledge and skills is critical for bridging the scientific divide between the rich and less developed countries. Problems however might arise when other factors intervene disturbing a natural process of learning and exchanging knowledge through international mobility. The lack of resources for research or poor teaching facilities back in the home country, as well as a low standard of living, as well as political and economic instability might be at the bottom of the decision not to return home by those improving their careers abroad. The worse consequence is the increasing concentration of brainpower in places of the North at the expense of the human capital from other places in the South: this is denoted as a brain drain, reinforcing the scientific divide (UNESCO, 2010, 6).

## 1.5 BRAIN DRAIN, BRAIN GAIN OR BRAIN CIRCULATION?

Mobility of scientists becomes brain drain when it reaches asymmetric proportions weakening the scientific capacity of the country from which the scientists have permanently departed. This problem was first observed after the World War II, as evidence showed that between 1949 and 1965 over 97,000 scientists emigrated to the United States from the United Kingdom, Germany and Canada (UNESCO, 2005). Since then, not only has migration and brain drain between the industrialized countries taken place, but the permanent movement from the South to the North of those pursuing careers in science and technology has accelerated. More recently a third wave of brain drain has emerged by which European scientists and engineers are moving to work in the United States (this can be called North-North). However, at the same time scientists and engineers from the South have occupied those places left in Europe. Therefore the net stock of scientists and engineers in the North may not have changed significantly. Instead the new pool of scientists has contributed to enrich qualitatively their newly adopted home by their diversity. Meanwhile the South as a whole has experienced a constant depletion of brains. Although the term of brain drain originally referred to the migration of British scientists of the United Kingdom, the term has turned into a wider and more ambitious description of skilled or highly skilled migrants. The views and claims in the last five decades of research about the consequences of the migration of the best educated in society are still suffering from diverse alignment:

> '*Skilled migration is marked by a number of fundamental dilemmas and trade-offs in terms of conflicting rights to development, education, (e)migration and equality. It also often opposes political principles, ethical and political imperatives (such as global justice and individual freedom, or the control of people's mobility) as well as actors (states, corporations and migrants themselves)' (UNESCO, 2012, 1).*

In the 1990s the approach towards migration of skilled migrants as detrimental to the home countries started changing with new views analysing the possible benefit that those emigrants might represent for the home countries. Within the shifting paradigm, the terminology started changing from *migration* to *mobility* or *circulation* as a more dynamic representation of the problem. Similarly the term *brain drain* evolved towards *brain gain* by not only referring to the physical return of the migrants, but to other assets acquired abroad with direct benefits to the development in the origin country. Under the new perspective the right of the individual to migrate might not be seen in conflict with the interest of the state. Rather the problem might become a solution in which the three parties could win: the migrant and both the sending and the destination countries. Particular interest has been shown in the case of expatriate scientists as transnational knowledge networks or scientific diaspora but as potential rather than immediately active new players to contribute to the home country's development (UNESCO, 2012, 63).

Cuban scholars in international migration share the view that the brain drain continues eroding the effort of the developing world in improving their education and the creation of knowledge, regardless of the intention of international organizations promoting the contribution of the expatriate professionals in the development of their countries of origin. The failure, as Ileana Sorolla Fernández (2012) argues, is the consequence of not tackling the root of the problem. It has also been recognized that in Cuba, the research in highly skilled migration lacks the interdisciplinary and inter-sectorial communication, as well as between knowledge systems and policymakers (Delgado Vázquez, 2012).

## 1.6 RESEARCH BACKGROUND

The research subject is narrowed to the case of the Republic of Cuba, a country located in the Caribbean region where the brain drain has been critically affecting the small islands of the region (Docquier and Rapoport, 2012) with emigration rates for high-skill workers over 40% in 1990 and 2000: Jamaica and Haiti have been the worst affected with emigartion rates for high-skill workers over 80%. This rate is calculated as a percentage of the national high-skill labour force, indicating the intensity of the brain drain for the sending country. In the case of Cuba the stocks of high-skill emigrants was 331 969 in the year 2000, with 28.8% emigration rate. Although the lowest in the Caribbean region Cuba is in the thirteenth place among the thirtieth most affected countries in the world with population over 4 million (Docquier and Rapoport, 2012).

The Cuban socialist government has consistently improved the education of the population since the earliest days of the revolution of 1959 with the eradication of illiteracy through the massive campaign that took place in 1961 and the university reform in 1962 ensuring free access to higher education. The socialist character of the new government generated a wave of migration toward the United States, which in those days represented a sector of the population that had access to education and wealth.

In Cuba in 2010 the tertiary educated represented 69% of the active labour force with more than 3.5 million graduated from higher education and technological colleges out of 5.1 million in the work force (ONE, 2010). The tertiary educated workforce dedicated to S&T in 2010 was 82,540. Scientists, engineers and technicians are employed in 119 R&D institutions in 14 provinces and in another 34 institutions of S&T. However only a small proportion of around 6.8% was dedicated to research (UNESCO, 2010, 125; RICYT, 2011) between 2006 and 2007.

Competitive scientific research requires high state investment, which is difficult to meet for small countries of the developing world. In the case of Cuba the resources the state dedicates to education and public health have to be taken into account, as these have been historically significant. One of the successful investments of the state in science and technology has been in the biotechnology industry, orientated to improve the health of the population and to generate high-tech goods to reach the international market. Between 1995 and 2010 export of biopharmaceutical products increased five- fold, becoming the second largest export earner after nickel (Cardenas O'Farrill, 2014). Besides the advantage of the state as a source of investment for this high-tech industry, it is the competitiveness of the human capital and the collaboration of the researchers from industry, academia and research institutions that has made the project highly successful. The human capital is highly valued and morally rewarded for serving society in recognition to their role in the socio-economic development of the country, therefore their lost is considered as a brain drain (Clark Arxer, 2015).

Beside the above brief description of how science and technology are contributing to the development of Cuba, the living conditions of the population have been critically affected by the collapse of the Soviet Union and socialist countries in Eastern Europe, and worsened by the prolonged embargo of United States against the country.

The position of the Cuban government in relation to the highly skilled migration from the South to the North was expressed by the now President Raul Castro (2009) in the 15th Summit of the Non-Aligned countries Movement[2] (NAM) in Sharm el Sheikh, Egypt:

> *"Non-Aligned Movement has become more active in UNESCO, but there is potential to continue strengthening and consolidating its work in this agency where the efforts of the NAM member countries are crucial to turn into a reality such indispensable objectives as education for all and respect for cultural diversity; the preservation of humanity's cultural heritage and the end of brain drain from our South nations; and, the shrinking of the enormous gap between the rich and poor countries in the areas of information and communication".*

Evaluating opportunities for the future of the Cuban science and technology, Luis Alberto Montero Cabrera, professor of Theoretical Chemistry at the University of Havana and member of the Cuban Academy of Sciences (2012) has mentioned as opportunities[3]:

- *'The Cuban scientific activity is endogenous, mature and competitive in almost all disciplines and scientists and researchers in general are aware of their role in society (social consciousness)'*
- *'The Cuban government has explicitly expressed their commitment to support science and technology, which is in the final documents of the recent VI Congress of the Communist Party'*
- *'The educational attainment achieved through the national educational system has empowered the Cubans to make the best use of the revolution in the information and communication technology, for the benefit of the society and for themselves'*

---

[2] ***Non-Aligned Movement***: The Non-Aligned Movement is a Movement of 115 members representing the interests and priorities of developing countries. The Movement has its origin in the Asia-Africa Conference held in Bandung, Indonesia in 1955. The three basic principles are the right of independent judgement, the struggle against imperialism and neo-colonialism, and the use of moderation in relations with all big powers.

[3] Translation made by Miriam Palacios-Callender for this doctoral thesis.

- *'Cooperation and collaboration is a natural behaviour among Cuban scientists and it is at the centre of the breakthrough in science and technology, especially coming from multidisciplinary collaboration'*
- *'The need to improve the living conditions of the Cuban population might motivate the scientific activity and with it, scientists can retain the social prestige earned from their past commitments'.*

However, as Montero-Cabrera argued, there are threats that should be taken into consideration if science is to continue to be a priority for the country. For the purpose of this research these appear to be relevant:

- *'The critical mass of scientists formed in the last forty years is reducing naturally due to age-related aspects and the domestic cadre formed in the last twenty years is also reducing due to internal socio-economic disadvantages which are generating some migration either to other countries or to other areas of the Cuban economy with better remuneration'*
- *'The information and communication technology has not updated fast enough, neither is it providing access to the enormous amount of information available worldwide. Difficulties in the mobility of personnel nationally and internationally due are hindering the connectivity required for the advance of science'*
- *'The content of the syllabus in primary and secondary education are not fully updated in the subjects of natural sciences and mathematics'*

Interestingly the same year the Director of the journal *Temas*, an academic and social scientist at the Cuban Research Centre of Cuban Culture Juan Marinello, in his 'Letter to a youngster who departs' projects a generational thought in transit (Hernández, 2012). The letter published in the Cuban magazine *La Joven Cuba* [The Young Cuba] can be seen as the account of one generation's historical and philosophical views asking to the next generation for reflection in spite their decision to depart for 'new pastures'. Moreover, the metaphoric prose addressing the departing youngster "*Wake up every-day thinking that this vessel where we are all still rowing will only move if all keep rowing*" epitomises the sense of belonging to the same project [Cuba as a nation] wherever the geographical location of the youngster will be in the new borderless world.

## 1.7 IDENTIFYING THE RESEARCH PROBLEM

The long lasting commitment of the Cuban government to develop science for the benefit of the present and future generations of the country could be jeopardised by economic factors affecting the living standard of the population, driving part of those with education in science and technology away from Cuban science and technology institutions to continue their professional career abroad. This is a worldwide problem but what makes the subject particularly attractive for this investigaton is that maybe in the case of Cuba the problem could be turned into part of the solution. In this problem there are three main components: the scientific environment in both geographic destinations and the nomad Cuban researchers abroad. The counterpart of Cuban researchers abroad, the Cuban researchers in Cuba, is included in the concept of the Cuban scientific environment. Because collaboration is essential in the ethos of scientists and natural to the Cuban formal socialist education (Kapcia, 2005) the ties between those working at home with those working abroad could be optimally developed. Moreover, Cuba excels in applied science addressing problems of the Cuban population with little room for basic research for the obvious economic limitations. However, Cuban scientists abroad have the qualifications to aspire towards top academic institutions where basic research could be excelled. Complementing each other's side offers more benefit than harm to all parts involved, especially now with the state of the art of the information and communication technology facilitating bridges in space and time. Although Cuba's natural destination country is the United States of America this investigation is centred in Europe as a destination region because the model of study based on scientific collaboration could not operate and could not have operated between Cuba and United States in the time frame of the study.

There is a worldwide expectation on the evolution of Transnational Knowledge Networks as an instrument for development especially for developing countries (Tejada, 2012). On the other hand research gauging the contribution of the developed nations or regions to the developing world through international scientific collaboration (Gaillard, 2000; Gaillard and Arvanitis, 2013) has also gained in relevance as evidence indicates that the growth of the global network of scientific collaboration (Wagner, 2001, 2005) has the potential to transform social and economic development around the world. Both approaches offer the ideal theoretical and empirical frameworks to investigate the potential of the Cuban human capital working abroad in institutions of science and technology.

The migration of both experienced and young graduates in science and technology is seen by the Cuban government and probably by the scientific community in Cuba as a net loss for the future of science in the country. Although the drain of talents from the South towards the developed North is universally condoned there is a need to search for alternatives not only to slow down the process but to transform the loss into some sort of gain.

## 1.8 RESEARCH QUESTIONS

In this thesis the research problem will be addressed investigating the following questions:

- Is the Cuban Science Technology and Innovation System ready to use the human capital abroad?

  This question aims to address the characteristics of the Cuban scientific collaboration supporting the thesis that the ethos of Cuban scientists of cooperating between institutions with different resources rather than competition was a key element in Cuban STIS for success overcoming the period of economic restrictions after 1990. In the study there is a particular interest to observe the evolution of Cuban scientific collaboration before and after the collapse of the Soviet Union and the socialist countries of Eastern Europe. Particular attention is observed regarding the adaptation of Cuban scientists to their conditions after 1959, such as “sharing” resources, facilities and knowledge especially in times of restriction. Another feature to evaluate is the scientists’ attitude of including the needs of the society as the end point of their achievements and how the STIS promotes these behaviours.

- What is the nature and state of the Cuban scientific community in Europe?

  The investigation addresses the demography and performance of Cuban researchers in Europe (CRiE), and does this in respect of their counterparts in Cuba (characterised in the empirical studies as CRiC, a subset of the overall national scientific population). For the European group the following is studied: the relevance of the environment in terms of the ranking of the academic or research institutions where they work; the pattern of collaboration; and the network characteristics of their scientific publications with an emphasis on their collaboration with Cuba from their European institutions

- What could be the optimal nexus between both communities?

  This will address the ideas around the interaction between practitioners and policy makers in Cuba and the countries of Cuban scientific diaspora

## 1.9 RESEARCH AIMS AND OBJECTIVES

Taking the previously mentioned views of Cuban academics (Montero-Cabrera, 2012; Hernández, 2012) this investigation aims to evaluate the hypothesis that the risk of losing the Cuban scientific capital working abroad can be analysed as an opportunity for the future of science in the country, providing that the elements ensuring the process of integration are taken by all the stakeholders. The research has the original advantage of being undertaken by a Cuban researcher with experience in biomedical research in Cuba and in Europe.

General objectives are:

- This investigation evaluates the readiness of the Cuban Science and Innovation system to harness the potential of Cuban researchers in Europe (CRiE) through the study of the patterns of the Cuban scientific collaboration as the key-enabling ethos of the contemporary behaviour, which is shared by the international scientific community. Through this investigation relevant bibliometric datasets (inputs and outputs datasets) were created for the present and future studies of science in Cuba

- This investigation evaluates the scientific potential of Cuban researchers working in European institutions of science and technology (CRiE) aiming to demonstrate that one of the objective prerequisites for a Cuban transnational (or Diaspora) knowledge network (C-TKN) does exist. Similarly, additional bibliometric datasets of CRiE and CRiC (inputs and outputs datasets) were created for the present and future studies.

- To explore the social dynamic of the Cuban scientific community through the semi-structured interviews carried out with both CRiC and CRiE focussing on the scientific collaboration as a crucial element to blend researchers willing to contribute to the home country in education and science.

## 1.10 METHODOLOGICAL FRAMEWORKS: MULTIDISCIPLINARY CONTRIBUTIONS

Contributions to the field of highly skilled migration come from diverse disciplines such as anthropology, economics, geography and history. This study takes the migration of scientists in the chosen context as its core of attention and goes on to explore patterns of the mobility and migration in that community. Because the work of scientists can be traced through their publications the paradigm of information science has been a crucial instrument in this study, as much as have recent contributions in geography of science, history of science, sociology of science, science policy and human development. Moreover the recent paradigms of complex systems could support future studies in the dynamics, complexity and evolution of the scientific networks under the challenges of the knowledge and information societies.

The specific methodological issues arising are explored in the relevant chapter below. However, to orientate the reader the empirical basis of the study is first of all summarised here as a prelude to the justification for the approaches and methodologies subsequently chosen. The field of information science and the speciality of bibliometrics is already well established in practice and provides the tools needed to explore these complex systems of scientific activity.

## 1.11 RESEARCH METHODS

### 1.11.1. *Quantitative methods:*

*Triangulation method:*

Different sources of information were combined to estimate the size of the sample of Cuban scientists and engineers working in Europe such as the OECD database of migrants of 25 years and older according to their education attainments (Docquier and Marfouk, 2006), United States of America's National Science Foundation data according to SESTAT-2003 (Kannankutty and Burrelli, 2007) and the brain drain database from the German Institut für Arbeitsmarkt- und Berufsforschung (IAB) (Brücker, 2013).

*Normalization process:*

Institution names and researcher's names were disambiguated from alternative English translations (in the case of institutions) and different combination of names and surnames of the Cuban researchers as a frequent error mistaking the second surname as the first. In some cases, electronic e-mails to the corresponding author were sent to confirm the name and location of the affiliations. Disambiguation of different names or acronyms in Spanish was also performed as well as a manual inspection to eliminate false document.

*Creation of datasets in Excel:*

Primary datasets were created from downloading data as comma separated values (csv) from different sources such as Web of Science, PubMed and Scopus. Working datasets integrating supplemented information with the purpose of processing and analysing the data were created to calculate relevant bibliometric indicators.

*Professional networks:*

Three biographical datasets were created: Bio-CRiC (curriculum vitae of Cuban researchers in Cuba), Bio-CRiE (Curriculum vitae of Cuban researchers in Europe) and Bio-World (Curriculum vitae of Cuban researchers working in worldwide destinations) were created from available public information in *LinkedIn, ResearchGate, and Academia.edu.* These datasets were essential to confirm the Cuban identity of each researcher before accessing Scopus as the data source of choice for their individual set of publications.

*Bibliometric methods*:

Bibliometric indicators were used to evaluate scientific capacity through the study of the Cuban pattern of scientific collaboration focusing on the role of the more advanced institutions in relation to the rest of the STS system of the country. The period of study was from 1990 to 2010 processing data at five-year intervals, and analysing the surveyed period as aggregate data.

Bibliometrics were also used as a valuable tool to study the performance of Cuban researchers in Europe, to trace their demography and mobility, to assess the working environment from the ranking position of the European institutions where they work and characterise their collaboration patterns.

Descriptors (names of authors, publication details and author affiliations) and indicators (productivity, seniority and classification of the type of collaboration) were used in both studies: Patterns of national and international collaboration in Cuban science (RQ 1) and Mobility and migration of Cuban scientists in Europe (RQ 2).

*Social Network Analysis*:

The analysis of network characteristics of the CRiE emerging from their scientific collaboration was carried out at a macro (region: Europe), meso (countries: Belgium, France, Germany, Italy, Spain and Great Britain) and at micro (institutional and examples of high performance and mobile CRiE) levels.

The model created is based on a matrix of type I (initiator) and type II (collaborating) institutions. European institutions from where CRiE generates scientific publications were defined as type I institutions and the worldwide collaborating institutes shown by the co-authors affiliations were defined as a type II institutions. A group of symmetric matrices were obtained per region, country and individual researchers, counting through the researcher publication records, the times (frequency) type I (nodes) institution collaborates (edges) with type II (nodes) institutions using an ad hoc programme. Analysis and visualization was carried out using the software UCINET (Borgatti et al., 2013).

1.11.2. *Qualitative methods:*

*Semi-structured interviews:*

Top Cuban scientists with residency in Cuba or in Europe were selected for semi-structured interviews. The process of interviewing researchers was carried out following University of West London Code of Ethics. An information sheet about the research objectives and a consent form of voluntary participation were provided in both English and Spanish before each interview. All documents were transcribed to English ensuring the anonymity of the interviewed researchers and offered to them for correction.  The purpose of the interview covered three main aspects:

- Part 1: Confirmation of general data about their qualifications, years and places. Questions were formulated addressing the subject of collaboration from their personal accounts

- Part 2a: A set of questions for CRiC to assess the researcher opinion about collaborating with Cuban scientists in Europe, or with other Cubans, not necessary scientists living abroad.

  OR

- Part 2b: A set of questions for CRiE to assess the researcher collaboration with other Cuban researchers in Europe or worldwide

- Part 3: A set of questions for CRiE to assess the researcher collaboration with Cuban scientists in Cuba (CRiC)

*Ethnographic account of Cuban scientists*:

A group of Cuban scientists was interviewed by the investigator, who invited them to reflect on the issues identified in an independent manner. These interview data were gathered and processed. The personal knowledge and experience of the investigator has assisted in the utilization and interpretation of the material gathered. A valuable and consistent feature of this body of evidence is that all interviewees started and pursued their career after the Cuban revolution of 1959.

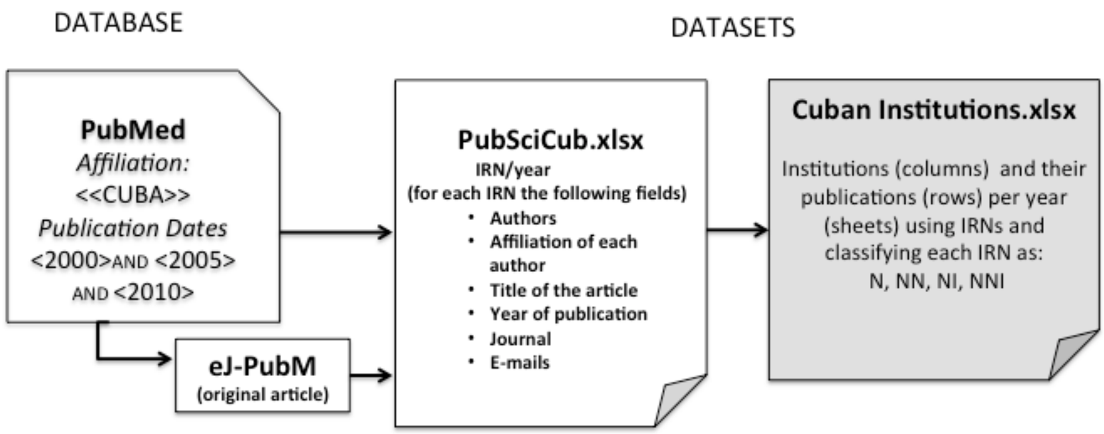
## 1.12 EXPERIMENTAL DESIGNS

### 1.12.1 *Quantitative studies*:

The empirical designs used in different sections of this research are shown in diagrams and further explanation will be in the corresponding chapters:

The study of the pattern of collaboration in Cuban scientific institutions is discussed in chapter five:

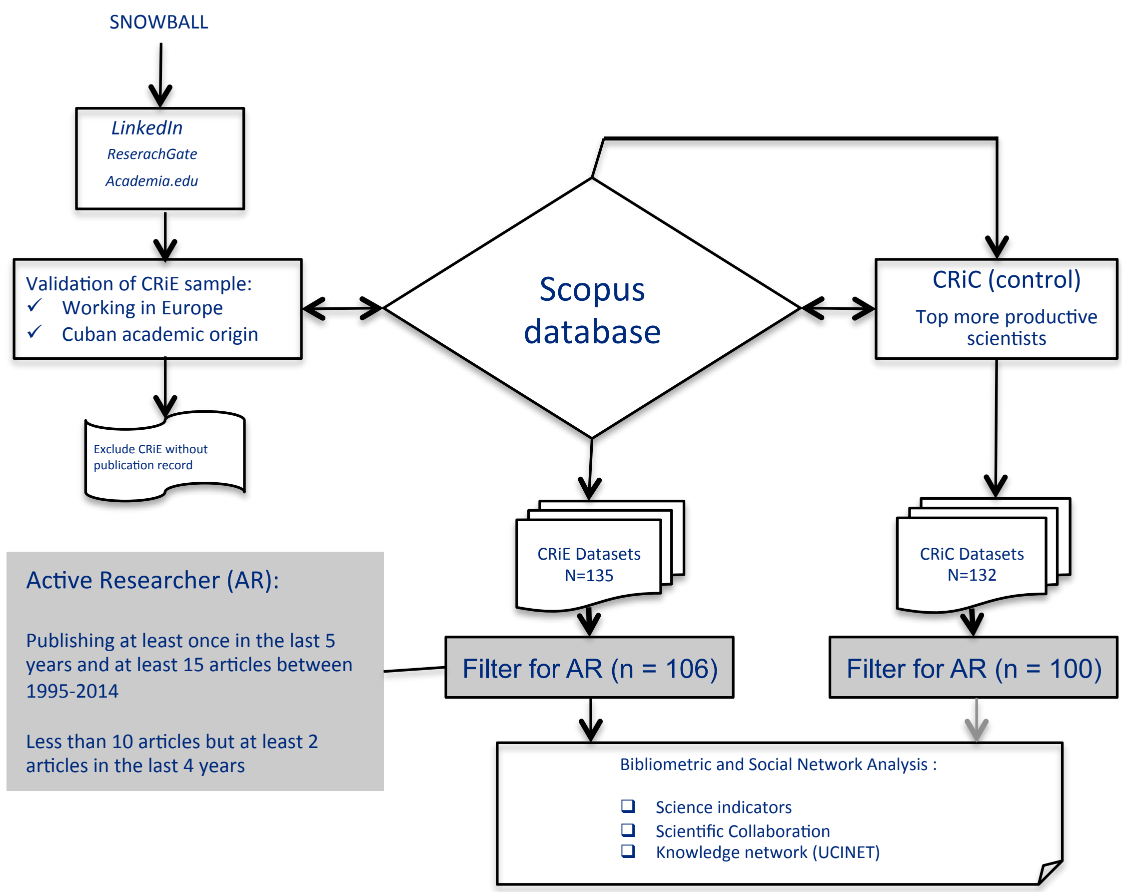
Figure 1.1 Diagram of the experimental design




*PubMed* was the database of choice in this part of the research aiming to study the patterns of scientific collaboration in medicine and biomedical sciences. The research is also supported by previous studies carried out by other researchers especially bibliometricians evaluating the quality of science in Cuba. *PubMed* is the database of the National Library of Medicine in the United States comprising more than twenty four million documents from more than five thousand journals in biomedical literature from *MEDLINE* and the life sciences journals. This is summarized in Figure 1.1 above.

The study of the Cuban researchers in Europe including the cohort group of Cuban researchers in Cuba, discussed in the chapter six, and is summarized in Figure 1.2 below.

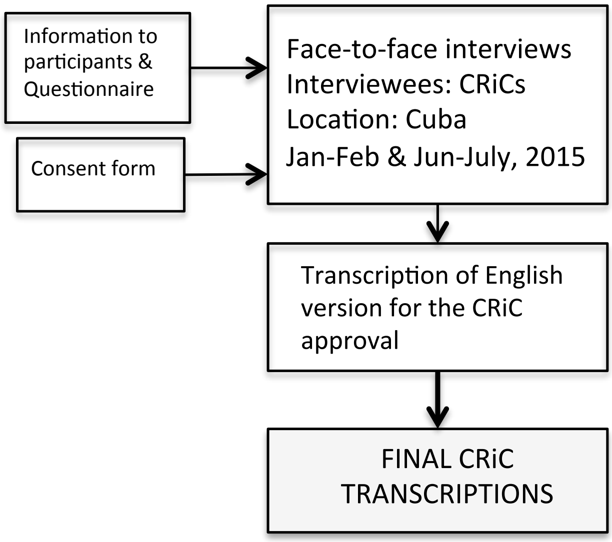
Figure 1.2. Diagram of the experimental design of Cuban researchers in Europe:

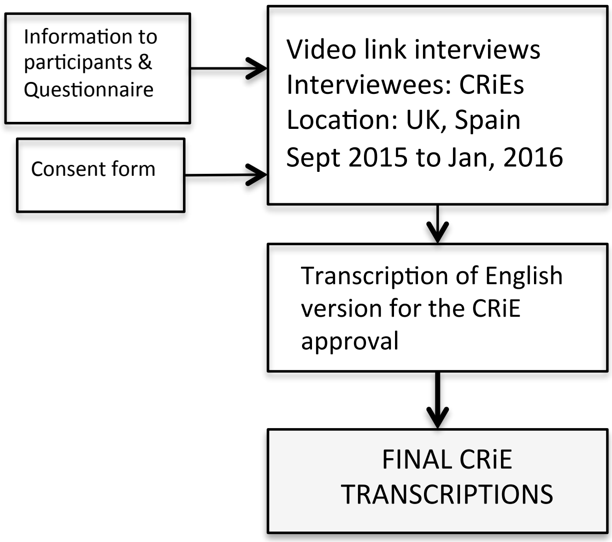



1.12.2 *Qualitative study:*

This section of the study was developed through the ethnographic account of motivations, perceptions and experiences of Cuban researchers about scientific collaboration in general and within the Cuban scientific community carried out through semi-structured interviews in Cuba and Europe as indicated in the diagram shown in Figure 1.3.

Figure 1.3 Fieldwork diagram of qualitative study of Cuban scientific community




## 1.13 SCOPE AND COVERAGE

The scope of this investigation refers to the Cuban scientists and engineers working in European science and technology institutes who by their patterns of publication can be considered active researchers. Although the United States is the main destination of Cuban emigration the current relationship between both countries interferes with the potential outcome of the present study. Because the main objective is examining their possibilities for further integration in a form of network platform into the Cuban Science, Technology and Innovation Systems the scope also refers to the evaluation of the Cuban scientific capability measured essentially through the pattern of scientific collaboration shown by Cuban institutions through the analysis of empirical data and from literature.

The evaluation of the performance of the scientists in space and time was carried out through the analysis of bibliometric indicators such as productivity, seniority and scientific collaboration.

Scientific collaboration defined as co-authorship publication in peer-review journals is used in this study to explore the ability of cooperation in the samples of Cuban scientists selected (CRiE and CRiC). Other forms of cooperation will not be evaluated in this study. By choosing scientific collaboration as the model to assess "communalism" as one essential ethos in our samples of scientists, this study provides an instrument to evaluate a functional characteristic of a scientific network.

Other activities non-related to the exercise of publishing in scientific journals are qualitatively explored through interviews of two groups of eleven and twelve scientists respectively in each sample (CRiE and CRiC). These activities include academic and professional tasks such as teaching, capacity in organizing international meetings, leadership at research institutions and in academia, and their experience in the nexus academia-government-industry.

The timeframe of the study spans 20 years. When studying Cuban STIS the period covers from 1990 to 2010 and when following scientists performance (CRiE and CRiC) from 1995 to 2014. This research started in 2012 analysing Cuban scientific capacity and therefore the logic suggested to evaluate twenty years starting from the post- 1990 period. The five years shift is due to the characteristics of the migration of Cuban scientists to Europe reflected in the collective pattern of scientific publication: only around 12% of the sample of CRiE has been publishing during the whole period, while more than 50% were publishing for the first time in the last 10 years.

## 1.14 LIMITATIONS OF THE STUDY

The study as a first approximation of the problem does not evaluate content or cognitive gains coming from the exchanges of knowledge in the network of Cuban researchers in Europe. Instead it provides the first account of those points of contacts on the networks between institutions in Europe and institutions in Cuba from which other studies will follow.

There is another aspect of the transfer of scientific knowledge into economic value in the form of intellectual property that has not been included in this research. Intellectual property plays an important role in the economic growth and developed countries have dominated this process of capitalizing on the information and/ or innovation associated to specific knowledge almost exclusively, with a world share of number of patents over 90% (UNESCO, 2010, 13). The number of patents is frequently included in the output of the national science, technology and innovation systems together with the number of scientific publications. The reason of excluding the analysis of patents, as another output for science and technology is due to its definition of knowledge (or innovation) as a commodity, and therefore will not be of interest to evaluate under the premise of sharing knowledge among members of the scientific community (CRiE and CRiC) that work in different countries or regions.

Cuban medical doctors working in Europe are not investigated in the study, first because there is a consensus for the adoption of the World Health Organization Global Code of Practice for the international recruitment of Health Personnel (WHO, 2010); secondly Cuba is perhaps one of the few countries in the world not suffering from shortage of health care professionals. Instead Cuba brings the service to countries with expatriation rates of doctors above 50% (meaning that there are as many doctors born in these countries working in OECD countries as there are working in the home country).

The study covers the European region only but findings and pitfalls of the research will have great impact in the study of other regions where Cuban scientists and engineers are moving to advance their professional careers and their life chances and quality of life.

## 1.15 IMPLICATIONS OF THE STUDY

This study assessing the possibilities and realities of a network platform of collaboration within the Cuban scientific community opens new avenues and areas for discussion among practitioners and policymakers towards the optimal use of the Cuban human capital in science. The retrieved and processed documentation represents a valuable start point for Cuban policymakers and professionals of science and engineering in Cuban Higher Education (and working abroad) concerning future network structures with the potential to strengthen the Cuban scientific capabilities. Countries of the Latin America and the Caribbean region are designing strategies to harness the human capital dispersed in top scientific institutions in the developed world (Meyer et al., 2015) and the present study might contribute to document the situation in the case of Cuba.

Transnational Knowledge Networks might have an additional pivotal role in the current integration of Latin American countries in areas of internationalization of the higher education, economic agreements and cultural exchanges. Cuban scientists abroad by progressing successfully in their careers could be seen as a net result of Cuban quality in higher education for all, which turns out to play a diplomatic card if they continue to be part of the country in terms of recognition. Interestingly, Cuban scientists working abroad are often recognised for their human values acquired in the socialist education. The human capital abroad does not have to be excluded from the possibility of contributing to the home country. The first step was mentioned by a Cuban academic regarding this type of natural connexion with the home country *'the door must be left open'* (Hernández, 2012). It also should mean 'they (Cuban residents and Cubans abroad) can cook a meal together, can create a great ballet together, or a summer course of advanced science, or a fantastic new design in engineering'.

## 1.16 STRUCTURE OF THE THESIS

The introduction to the field of research covered in Chapter 1 starts with concepts and recommendations mainly from international and regional bodies such as the United Nations Educational, Scientific and Cultural Organization (UNESCO, 2005, 2010 and 2012), the Network for Science and Technology Indicators for Ibero-America and Inter-American countries (RICYT, 2010) or the Cuban official statement regarding the drain of talents in the South at the 16$^{th}$ Summit of Non-Aligned Movement (NAM, 2009).

Chapter 2 covers the background of related subjects to give wider information and context at the global and national level. Special attention is given to the loss of talents from the perspective of the countries in the South and the emerging transnational knowledge networks. Particular attention is given to the history of science in Cuba and finally to the Cuban migration.

The literature review in Chapter 3 focuses on the analysis of previous contributions to the fields of mobility of scientists and scientific collaboration using bibliometric methods, regardless of the disciplines or fields to which those articles were contributing to.

Chapter 4 is the review and discussion of the theories underpinning the assumptions of the research problem that were mainly developed under the paradigm of information science and sociology of science based on the theoretical contribution of Derek de Solla Price (1961, 1963, 1976, 1990), Robert Merton (1957) and Donald Beaver (1979, 2001). Graph theory is discussed to support the analysis of the social network of Cuban researchers in Europe based on the contribution of Stephen Borgatti and collaborators to the network research (Borgatti et al., 2013).

Chapters 5, 6 and 7 present the results of the three component parts of this study coming from the three research questions: Collaboration in the Cuban Science Technology and Innovation System; Demography, performance and collaboration in Cuban expatriates working in institutions of Science and Technology in Europe; and finally the qualitative assessment of the nexus aiming to connect the scientific network of Cuban scientists and engineers. The integral discussion of these results is in the chapter 8.

Chapter 9 summarises the preliminary accounts of those cornerstones supporting the rationale behind the research subject of emerging of transnational knowledge networking and its possible role in strengthening the scientific capacity in the country of origin.

## 1.17 SUMMARY

This chapter describes concepts, points of views and recommendations regarding the essential parts of the thesis with the purpose of giving the general framework in which the research is conducted. To ensure neutrality and consensus around points of big discrepancy from a North-South perspective some definitions are taken from international organizations in which both North and South are represented. Additionally basic indicators regarding education and science in Cuba are also provided from international, regional and national sources. Some key references were chosen to take into consideration the views of the country represented by the government and individual academics. All together this chapter represent the basic canvas where the meaning of a Transnational Knowledge Network for Cuba could be depicted.

From the above consideration the following themes will be supporting the rationale behind the research questions:

- We are living today in a society in which economic growth depends more than ever before on the creation of new knowledge and on the availability of the fast moving information and communication technology

- Higher education in general and STEM careers in particular are crucial for the growth of the high-tech industry with products of high added value

- In spite of the great advances in science, technology and innovation the digital divide and knowledge divide are realities of the North and South divergent economies disturbing both sustainability of the progress and peace at local and global levels

- Mobility and migration of highly skilled workers grows with the globalization of the world economy creating asymmetric flows with poles of concentration of talents in developed countries and depletion of them in developing countries, with the small countries in particular most affected

- Options to diffuse such tensions might come from different sources, and the emergent Transnational Knowledge Networks seem to be an alternative with the capacity to evolve towards more efficient forms of social organization

- Transnational Knowledge Networks cannot operate efficiently if the country of origin does not have in place a science technology and innovation system

- Scientific collaboration and networks connecting research teams between North and South and South-South including those through TKNs could be important elements for development and to facilitate relations and operations between North and South and South-South (Science Diplomacy)

- By exploring the TKN concept in this specific case we hope to reinforce the view that such networks can encourage open and transparent conditions in knowledge application which reflect the best characteristics of open scientific communities.... so-called 'republic of science'[4].

[4] ***Republic of science***. Term used referring to the self-governed community of scientists. Contributions to the concept were made by John Simon and Michael Polanyi (*The republic of science: its political and economic theory*, 1962) and the concept is an accepted term in the discourse.

# CHAPTER 2: A REVIEW OF CUBAN SCIENCE IN THE GLOBAL CONTEXT

*"The future of our country has to be necessarily a future of men of science"*

Fidel Castro Ruz (1960)

## 2.1 INTRODUCTION

This chapter aims to provide the research background supporting and showing the way in which Cuba is in the global enterprise. It focuses on how science has become a global enterprise in which more countries are increasingly playing a role on the world stage. There is evidence that some characteristics of this process involve the mobility of scientists towards poles of development, producing brain circulation within the developed countries while depleting the human capital in the developing world in a way known as the brain drain. This problem is closely examined through the evaluation of the human capital involved in this process, such as post-graduate students, doctorate holders and researchers in those places where new knowledge is mainly created: the institutions of Higher Education[5]. Emerging economies with significant human capital abroad began to put in place mechanisms within the last two decades for the return of their highly qualified workforce in an effort to reverse the brain drain. Simultaneously some scientific diaspora began to interact with their countries of origin through specific platforms or channels mediated by the governments in the home country. Other developing countries and regions were following similar trends and in this chapter we briefly review the research carried out in Latin America regarding brain drain, brain gain and brain circulation.

Half of the chapter is dedicated to a brief history of science in Cuba especially after the socialist revolution, how it has been organized in different periods of its development and the paradoxical achievement in the biotechnology industry at the time of economic crisis after the collapse of Soviet Union and socialist countries of Eastern Europe, worsened by the United States embargo (Cubans call the Blockade: '*el Bloqueo*'). Finally the contribution of Cuban researchers in the social

[5] ***Higher Education*** is also referred as academia or universities

sciences about international migration is also reviewed as well as those developments concerning the relationship of Cuban government with her diaspora. Before developing the topics above mentioned it will be challenging to bring some thoughts from Derek de Solla Price in his 1962 Pegram Lecture at Brookhaven National Laboratory. His lectures were dealing with history and sociology of science applying scientific methods to demonstrate the exponential growth of science, the logistic decay and the distribution functions, the challenging role of scientific publications and the evolution of scientific organizations to produce a masterpiece of work known as *Little science, big science*:

> *'The scientist is accepted by society [in the Big Science] and must shoulder his responsibility to it in a new way. The rather selfish, free expansion by exponentially increasing private property of scientific discoveries must be moderated when one is in the logistic state. Racing to get there before the next man might well be, in the long run, an impossible irresponsible action.*
> *It must surely be averred as a matter of principle that the country that has arrived at a full logistic maturity, saturated with science, must try to behave with maturity and wisdom; must give some guidance to the younger countries that are growing up around and gradually outstripping it in scientific superiority' (Price, 1963, 113).*

## 2.2. GLOBAL SCIENCE AND KNOWLEDGE FLOWS IN THE TWENTY FIRST CENTURY

### 2.2.1 *Mobility of scientists towards centres of knowledge*

The mobility of scientists around the world has an enormous impact in the dynamic of almost every area of research, as Bruno Latour (1987) revealed in his book *Science in action* when analysing the circular process of 'going away'. This process allows, as he argued, to mobilise new and unexpected resources for knowledge production, to test the newly constructed truth originated in different settings and to disseminate arguments and facts in time and space. This movement of researchers in the process of creating and exchanging knowledge is at the centre of the formation of networks in science. In this movement are students, post-graduates, postdoctorates, elites of specific fields in science and technology visiting research institutions around the world building the bases of networks and international collaboration. However, beyond the idea that any contribution from science is for the benefit of humankind, there are questions to address regarding where and who benefits more from those networks of knowledge.

Some studies from the geography of science, looking at how geographical movement of academics contributed to the generation of knowledge, pointed out that the process of disseminating ideas, facts and the creation of knowledge centres emerged from strong geopolitical influences (McLeod, 1993) as happened during the transition from the British Empire to the Commonwealth partners. Thus, the pattern of academic travel of Cambridge University between 1885 and 1954 also contributed to the development of an Anglo-American academic hegemony in the twentieth-century (Jöns, 2008), as well as the intensification of the academic networks and the creation of regional clusters of travel destinations. Another expression of this phenomenon was the emergence of the American foundations in the 20$^{th}$ century: the Carnegie, Rockefeller and Ford foundations, which helped to consolidate the United States (US) hegemony after 1945 (Parmar, 2002) by fostering pro-US values, methods in scientific research and the creation of research institutions all over the world. The founders were scientist-philanthropists who believed in education of human beings as the main source of human capital and that the problems of society might rest on the leadership of people with talent. In other words they believed in a pragmatic and utilitarian philosophy of putting knowledge to work and the founders were seen as liberal internationalists. Through the 20$^{th}$ century these foundations were investing in individuals, universities and policy research institutions and programmes as well as building up networks of key universities, by connecting them through fellowships and scholarships for advanced research and training, and thus benefiting the growth of domestic science and consolidating the Anglo-American hegemony (Fisher, 1978). However it also fosters a common language in science which is often seen by some as the language of scientific communication and reputation (Swinburne,

1983) but to others as an impediment (Forattini, 1997), arguing the limitation of non- English speaking countries to benefit from those advances in science.

The geography of international centres of knowledge can be drawn from the number of publications per institution, which is an indicator of their scientific activity, as well as the *h*-index[6] and institution ranking. Centres of knowledge are clusters of institutions mainly in big cities, where the resources and infrastructures are more concentrated, becoming for some emerging economies a strategy to optimise their resources. Moscow accounts for more than 50% of Russian scientific articles, Tehran, Prague, Budapest and Buenos Aires each 40% of national outputs, and London, Paris and Sao Paolo generate each around 20% of national publications (The Royal Society, 2011, 37). Prestige and leadership of those institutions, reflected in their outcome in publications and patents, are the result of their pool of talents (highly awarded scientists), their international collaboration, and their innovation and technology capacities, often generating start-up small enterprises. Worldwide, 96 of the top 100 research institutions are in seventeen countries: 56 of them are in North America, 26 in Europe, 14 in Asia and 4 belong to multinational institutes (global institutions, consortiums or companies) of research, according to institution rankings produced by *SCIMAGO*[7] for 2010. Interestingly, seventy-three of those centres of excellence (76%) belong to institutions of Higher Education.

The mobility also refers to international students pursuing further education in the developed world, (Bhandari and Blumenthal, 2011) adding to the current concept that generation of knowledge is a borderless enterprise (Van Noorden, 2012). In this work conducted by the magazine *Nature*, Van Noorden found that those who had just obtained their PhDs in a foreign country were more likely to remain outside their country of origin compared to those who had a more senior position in their home country and only visited the foreign institution during a short period of collaboration. In another study including 17,000 researchers in four fields of natural

[6] ***h-index****:* It was suggested by the physicist J.E. Hirsch in 2005 to measure both productivity and citation impact of the publications of a scholar. A scholar with an index ***h*** has ***h*** papers each of which has been cited in other papers at least ***h*** times

[1] ***SCImago*** (www.scimago.es) is a research group from the Consejo Superior de Investigaciones Científicas (CSIC), University of Granada, Extremadura, Carlos III (Madrid) and Alcalá de Henares, dedicated to information analysis, representation and retrieval by means of visualisation techniques.

science working in 16 countries the authors explored the links between migration of scientists and the establishment of international research networks (Franzoni et al., 2012). Interestingly this study showed that more than 40% of foreign-born scientists kept links with their country of origin, an indication, according to the authors, of '*a significant knowledge spill over between source and destination countries*'.

### 2.2.2 *Scientific collaboration: networks of scientists, institutions and organizations conducting science around the world*

Perhaps one of the first theories of scientific collaboration was developed by Donald Beaver and Richard Rosen in 1978 (Beaver and Rosen, 1978). Defining scientific collaboration as the collaborative scientific research acknowledged by co-authorships, Beaver and Rosen concluded that collaboration emerged as a result of the professionalism of science, first observed in France in the middle of the eighteenth century, and also found in other countries as the result of financial support for scientific activities (Beaver and Rosen, 1979). Scientific collaboration, Price argued (Price, 1963, 89), was increasingly steady since 1900 and that mass movement of collaborative work was '*a natural extension of the growth created by constant shift of the Pareto distribution of scientific distribution'*. Indeed, as he proved, this new way of producing science, that he called '*invisible college'*, was one of the consequences in the transition from '*Little science to big science'*.

Jones and collaborators (2008) demonstrated that teamwork in all fields of science, engineering and social science increasingly spanned university boundaries and elite universities predominantly led that dramatic shift in knowledge production. Processing 4.2 million scientific articles generated during three decades from 1975 to 2005 by universities in United States, they found that the multi-university collaboration was the fastest growing type of co-authorship structure, generating the highest impact papers of those including top-tier universities and that they were increasingly stratified by in-group university rank.

In the twenty-first century science has been largely influenced by globalisation: more places worldwide contribute more than ever before and scientists are more interconnected. One important feature of this century is that the high mobility of scientists and engineers has been possible through more affordable ways of travelling, allowing the exchange of ideas, sharing methods and material and the physical encounter of researchers further strengthens the networks already in place. The second, but equally important, was the advent of the internet as a global system interconnecting computers and networks, which its exponential development by the end of last century allowed easy communication between scientists, sharing databases online and even operating equipment online.

The impact on the scientific productivity viewed as a global enterprise by these two features of science, technology and innovation in the twenty-first century depends on the countries' resources and socio-economic development and therefore will be discussed when analysing how science, technology and innovation has evolved in Cuba.

There is no consensus about whether the Internet has improved the scientific productivity either of individuals or institutions and how much it has facilitated scientific collaboration. Correlating different ways of using Internet and self-reported numbers of all type of publications, Barjak (2006) found that communication [Internet] correlates strongly with publications in a study involving five academic disciplines in seven European countries. Different studies carried out in the U.S. indicated that computer-mediated communication [Internet] facilitate the organization of work and '*providing, the glue for the virtual college*' (Walsh and Bayma, 1996); but the authors mentioned the need to make broader studies including scientists in developing countries. In the study previously discussed from Jones and collaborators (Jones et al., 2008) they also referred to an unusual jump of 3.4% in the rate of increase in science and engineering collaboration around 1998, which they suggested could be related to the period in which the use of internet and other communication technologies were spreading. However this single jump is characteristic only of the articles in science and engineering and not in those in social science, which did not modify the rate. After 1998 the production of collaborative papers continued steadily at 0.3% as it was before 1998.

Less research has been done looking at the role of the Internet assisting and improving scientific productivity in developing countries. Duque and colleagues (Duque et al., 2005), in a study carried out in developing regions of Africa and Asia, described the situation as:

> *'The very condition that makes the relationship between collaboration and productivity problematic in developing areas, also undermines the collaborative benefit of a new information and communication technology'.*

Taking together both results it is obvious that the socio-economic development of any particular region, or country, must be taken into account when analysing how the emerging global science and knowledge flow contribute to their societies.

2.2.3 *International collaboration and 'the new invisible college'*

Scientific outputs showing international collaboration through the co-authorship from more than one country has doubled since 1990 (Wagner and Leydesdorff, 2005). This increase in collaboration among scientists from distant geographical locations, is called the *new invisible college* and according to Caroline Wagner (2008, 4) is the result of the recent shift in the structure of science. Characteristics defining the new invisible college, as Wagner argued, are driven by networks, emergence, circulation, stickiness and distribution. Those *networks* forming the invisible college are forged through meetings and common interests spanning scientists from institutions regardless of their geographical distance. By '*emergence*', the author means the capacity of response of those networks to new information, communication and opportunities in which new ideas emerge from combination and recombination of people and knowledge. *Circulation* refers to the free movement of researchers to places where they can maximise their access to resources and best contribute with their talents to the pool of scientific knowledge. In this way circulation of the invisible college can advance knowledge more efficiently beyond the national borders. However discussing the *stickiness*, the author give importance to the clustering as an essential feature of the knowledge system, in which those long established clusters or centres of knowledge still retain the attraction of researchers, some because by nature they are internationally founded, otherwise difficult to be assumed by one country, for example as the CERN project; others because their particular field of research which is geographically determined, such as ecosystems. Finally and perhaps the characteristic offering more opportunities for wider participants (which might include scientists from developing countries) is *distribution* by which participant scientists of the invisible college share tasks, expertise, data and resources to advance knowledge.

Those invisible colleges show plasticity as well: they form and dissolve as the project advances in new discoveries; such an example is, the *'protein trafficking and the association between Alzheimer's disease and gene variations in people with different ethnic background'*, in which forty one researchers working at fourteen different countries co-authored a publication in *Nature Genetics* (Rogaeva et al., 2007).

International collaboration seems to increase the visibility of the research, as described earlier in the case of collaboration between U.S. universities. The research group of Felix de Moya-Anegón analysing the scientific impact derived from international collaboration found that the more countries there are involved in the collaboration, the greater the impact of the publication (Guerrero Bote et al., 2013) and unexpectedly, they also found a small benefit as a result of collaborating with the United States regardless of its high impact. Wagner (2001) on the other hand, included the number of students from any particular country in U.S. universities (adjusted for those who chose not to return to the home country at the end of the studies) to characterise the country's contact with external knowledge when establishing an index of Science and Technology capacity per country, on the base of the recognition that the U.S. is one of the strongest hubs for science.

The question for developing countries, which needs closer analysis, is: are they going to be part of and thus benefit from the invisible college? Having alluded to the value of TKNs (as part of the new invisible college), the application of principles of open and transparent conditions can help to establish any necessary equilibrium. Some will contribute more (ideas and resources) and others less, but the scientific republican principle of equality and fairness will balance costs and benefits and the tacit and implicit values of knowledge as public good. Of course to maximise the benefits of this process will require investment in science (over the longer period) to translate scientific knowledge into economic and social value.

Wagner and colleagues in a report to the World Bank reached to the following conclusion:

> *'(International) scientific collaboration is having a positive impact on the ability of developing countries to participate in world science'*

However, they insisted that other enabling conditions should be in place to harness the potential of the scientific collaboration for the benefits to their economic growth and social welfare (Wagner et al., 2001, 61).

International collaboration itself does not define a net benefit to participating countries if other elements for development are not in place. Among them an appropriate science- technology and innovation system should be in place ensuring an efficient conversion of knowledge into economic growth (Inter-American Development Bank, 2010).

### 2.2.4 *Interdisciplinary research and multi-sectoral teams: how to evaluate the benefit to society?*

The generation of knowledge in the current landscape of science has been advanced by the increase in national and international collaboration as it has been shown previously. However there is still another question to address concerning how to translate those advances in science to the progress and sustainability of the modern society. This question is of paramount importance not because it is concerned about how to make the best of science for society, but because in our case it will explain the connexion between scientific advances and countries capabilities for development.

Interestingly some ideas developed almost twenty years ago (Nowotny et al., 1996) have been recently revisited. The authors offered a heuristic approach to understand and explain the trends observed in modern science. They explained that before the World War II science behaved in a way they called Mode 1, in which the cognitive and social norms that should be followed in the production, legitimization and diffusion of knowledge determined the sort of valid problem to investigate and what was a good science. Moreover, those norms and practices adhering to these rules were by definition scientific; likewise those that violated them were not (Gibbons et al., 1994, 17). Then they pointed to the new characteristics emerging after the war, which they called Mode 2. They observed that in this new mode, knowledge was created in broader trans-disciplinary social and economic contexts, and differently to the Mode 1, which only referred to scientists and scientific institutions (including academia). The Mode 2 incorporates other practitioners as well as other types of institutions or sectors to insure that the knowledge is produced in the context of application. Because the objective in Mode 2 is the translation of knowledge, or the improvement of the application through innovation, discoveries or invention here had to be socially accountable. This mode of producing knowledge was found in private industries or sectors and therefore the new knowledge was protected by intellectual property ensuring benefits to the investors (Gibbons, 1999).

Another approach came from those working in the emerging information and knowledge economies, suggesting the Triple Helix model for the study of the knowledge-based innovation system. The elements of this ecosystem were University, or academia where the knowledge was created; Industry as a producer of wealth and Government as the normative control and the model should take into account the balance between differentiation and integration (Leydesdorff and Etzkowitz, 1998).

Both theories aim to provide the means to study new trends in how the generation of knowledge is transformed into wealth for the benefit of the society, and in a way how science has become an enterprise. However, as mentioned in chapter 1, this specific character of knowledge is not included in our empirical study.

For the developing world these theories offer little help since they are made describing or modelling the evolution of knowledge-based innovation in developed countries. Some researchers in the South even doubted if they are a contribution or even an imposition to their natural development (Tuiran, 2009)

2.2.5 *Science, globalisation and conflicting views of the outcome*

Globalisation has opposite outcomes depending on the development of a given country; thus the analysis of how science is influenced by globalisation and *vice versa*, reflects conflicting views. Economists assessing the magnitude, intensity and determinants of the brain drain showed that migration of the high-skilled is the dominant pattern of international migration and the major aspect of globalization (Docquier and Rapoport, 2012). For Freeman (2010) who embodied a U.S. point of view, globalisation of science and engineering has proceeded in five ways: expansion of mass education worldwide, growth in number of international students, immigration of scientists and engineers, non-immigrant trips (academics visits and conferences) and greater international co-authorship and co-patenting. He argued (Freeman, 2006; Freeman, 2010) that accelerating the process of technological changes and implementing best practices around the world will benefit both advanced and developing countries, but citizens of more advanced countries might have comparatively less access to the highest quality of university education and less job opportunities. In his view, the increase of scientists and engineers from highly populous low income countries such as China and India might be a threat to the traditional North-South trade pattern, in which advanced countries dominate high technology industry while developing countries contribute to less skilled manufacturing (Freeman, 2006). Obviously the above views are more concerned about an overcrowded society with foreign talents and the diffusion of knowledge outside the U.S. disturbing the dominant position of its science and engineering associated industries, but lack an assessment of the implication of globalisation and science for the developing countries. On the other hand, Paula Stephan in her book *How economics shapes science* projects different views: '*Knowledge, by its very nature, is not depleted by use'* (Stephan, 2012, 204). She argues in favour of the government (United States) supporting research in science and engineering. Research institutions, mainly universities in the case of the U.S. are funded by the government (approximately 55 billion USD per year) and they harbour a milieu of researchers including foreign- born scientists and engineers involved in the process of teaching and creation of knowledge. The foreign-born workforce seems to be highly productive and some evidence indicates that their contribution to research is significant (Stephan and Lewin, 2001; Stephan 2012, 183). Because on average, foreign-born scientists are younger, it is expected that in the future, they will be in the position to assume leadership roles in U.S. science.

An opposite perception of the subject of globalization and science is drawn from academics in Latin America and the Caribbean countries, analysing the increasing outflows of students and academics towards developed countries (Didou Aupetit, 2008). There is a consensus that the increase of the mobility (migration) of academics and students towards advanced economies impedes the socio-economic development of countries in Latin America and the Caribbean (LAC). The approach supported by governments, civil societies and scientists of the region has evolved around brain drain, gain of knowledge and scientific networks as elements and players that might compensate for the losses. During the preparation of the regional participation in the World Conference for Higher Education (WCHE) organized by UNESCO in 2009, specialists in the subject identified the divergent economic growth between North and South as a direct consequence of globalization, the recognition of the knowledge society in the regional growth and the knowledge as a public asset for collective use (Didou Aupetit, 2009). This last concept was enunciated in the UNESCO report *Towards knowledge societies* in 2005:

> '*Knowledge cannot be considered an ordinary saleable commodity. The current trend towards the privatization of the Higher Education systems and their internationalization deserves attention from policy makers and should be examined in the framework of the public debate on the national, regional and international levels*' (UNESCO, 2005, 23).

Since the 1990s the region has been developing new forms of networking in those social, economic and political subjects, including those related to Science, Technology and Innovation with the creation of *Centro de Redes* in the Inter-American Development Bank with the participation of more than 350 research institutions of the Latin American and the Caribbean countries. The objectives of this Network of Centres are to leverage the research capabilities, to improve the quality of research performed in the region, and to contribute to the development policy agenda in Latin America and the Caribbean. Brain drain in Latin American and the Caribbean countries has been documented and identified as a problem hindering the development of the region (Bassarsky, 2007; De Los Ríos and Ruedas, 2005 and Jiménez et al., 2010).

In the case concerning this research it is important to point out that Cuba is excluded from the benefit of being part of the Network of Centres, since this organization belongs to and is financed by the Inter-American Bank of Development, in which Cuba is not admitted as a member. However, Cuba is an active member of the IESALC[8] and as such Cuban academics have actively participated and are fully integrated in the regional working plan before and after the World Conferences of Higher Education in 1998 and 2009. Cuba also participates in the RICYT (Red de indicadores de Ciencia y Técnica) in which all countries of America are part, including Canada, United States, Spain and Portugal[9]

Since the collapse of socialism in Eastern Europe and the USSR, Cuba has increased its collaboration with Latin American and the Caribbean countries in science, technology and innovation and with it, the incorporation of Cuban scientists to the epistemic communities of the region both in research institutes and in the Higher Education institutions.

These particular situations illustrated above show how different are the concerns from the current landscape of science in a globalized world. Governments in the

---

[8] Note from http://www.iesalc.unesco.org.ve. This documents the decision adopted by the 29th. General Conference of transforming the Regional Centre for Higher Education in Latin America and the Caribbean (CRESALC) into UNESCO International Institute for Higher Education in Latin America and the Caribbean (IESALC). During the transitional period 1998-1999, the IESALC focused its activities on the strengthening of its organizational infrastructure and on the beginning of several projects within the frame of the Action Plan for the Transformation of the Higher Education in Latin America and the Caribbean (Havana, Cuba, November, 1996). There were carried out likewise several activities related to the '*I World Conference in Higher Education*' (Paris, October, 1998).

[9] RICYT (http://www.ricyt.org/) was created in 1995 and supported by the Iberoamerican States Organization and the Centre of Studies of Higher Education (Organizacion de Estados Iberoamericanos, OEI; Centro de Altos Estudios Universitarios, CAEU)

global North are concerned how important is science and technology for the growth of their economies. Thus, maintaining a high percentage of their GDP for research and development (GERD) as well as stimulating the private sector to invest in research, they ensure keeping their best and brightest scientists and engineers. The majority of the scientific workforce, as in many other sectors, does not have permanent positions; on the other hand they have acquired enough well recognised international skills to opt for any job wherever they can continue developing their expertise and career progression. The poles of attraction are those centres of excellence in science and technology, which also have larger budgets for research. The majority of those top institutions are in the U.S. as shown in the university and institutions rankings. Although countries of the global North are not uniform, they are not depleted of talents, while countries in the global South, exposed to the same trend, suffer the consequences in different scales.

Therefore, each country of the global South has to identify how to overcome such a challenge hindering their economic growth. Investing in their human capital by fostering the studies of their brightest abroad in such centres of knowledge can lead to double losses unless they find the strategy to deal with such problems.

### *2.2.6 Internationalization of higher education*

Internationalization of higher education (HE) emerged as a consequence of globalization that has created demands for highly qualified workforces while preserving national identity and culture. The process of internationalization requires the integration of dimensions such as the international and intercultural into teaching, research and services of the institution to society (Quang, 2003). Moreover the author recognized that it is also the means by which universities increase their income from recruiting international students to support the high cost of modern education. The author reviews different implementations of the internationalization of HE such as activity, competency, ethos and process approaches. The activity approach, characteristic of the 70s and 80s, was concerned about curriculum, student/ faculty exchange, technical assistance and international students. The competency approach is concerned in how to develop skills, knowledge, attitude and values in students, faculties and general staff enabling them with the competences of international knowledge and inter cultural skills. The ethos approach emphasises creating an environment that values and supports international and inter-cultural values perspectives and initiatives. Finally the process approach, which is more concerned towards the sustainability of the process of integrating international / inter-cultural dimensions and initiatives, focuses on programme and organizational aspects such as policies and procedures.

All these approaches are the result of a process of adaptation or evolution of the higher education to the changing world in a landscape of diversity of ethnicity and religions, local communities, environmental interdependence, economic competitiveness and on the other hand to pursue universal goals for peace among nations improving international relations, reducing poverty, hunger and food security, tackling the climate changes and gender inequality (Quang, 2003).

At the same time, internationalization of education is viewed as another area of national income. In the United Kingdom, for instance in 2012 revenues from international tuition fees accounted for £3.8 billion paid by EU and non EU students (Kelly et al., 2014) in a sector that contributes 2.8% of the United Kingdom GDP. The capacity to attract such sources of income depends on the quality of the academic institutions involved, as 38 of those institutions were in the top 500 Academic World University Ranking (2012), accounting for 20% of those in Europe.

Attracting international students can work against the country of origin and promotes the brain drain, as the United Kingdom is also home for 1.2 million tertiary educated migrants.

### 2.2.7 *Brain circulation in countries of the OECD*

Advanced economies pay particular interest to ensure brain circulation or mobility of talents, convinced that exchanges of ideas, methods and procedures strengthen the creation and use of knowledge and therefore their economies. Policies and regulations are in place to facilitate mobility: in Europe the Erasmus (pre-graduate students) and Marie Curie (post-graduate fellows) fellowships; the circulation of the highly qualified scientists and engineers inside the European Union with access to work opportunities; recognition of higher education certificates for citizens of the European Union; and funding multinational research projects to optimize transnational co-operation. In 2012, the Ministers responsible for higher education in the 47 Bologna states agreed on working towards strategies to promote the internationalization of higher education and related research institutions in which each state should develop and implement their own internationalization and mobility specific targets (EHEA, 2012). It is expected that by 2020, at least 20% of graduates in the higher education area should have gained international experience in degree-related visits abroad.

The OECD (Organization for Economic Co-operation and Development) has a similar approach with a wider geographical scope, but limited to selected economies or nations which are members of the organization. Indeed, in the race for the best and the brightest, strong economies like Canada, Australia, United States and others have adopted regulations to attract selectively highly skilled migrants depleting in this way, the human capital of weaker economies.

Since 73% of top research institutions in the world (*SCImago*'s institute ranking) belong to institutions of higher education, it might be interesting to analyse the presence of foreign-born students in institutions of higher education in a particular country of those advanced economies. The international composition of students of higher education in Germany might reflect indirectly the mobility of potential scientists and engineers towards centres of knowledge. In 2013, 11.3% of students in higher education were foreigners: 282,201 out of 2,217,208 German students, had obtained their degrees of higher education either in Germany or abroad, but came to Germany for further studies. The latter, called *Bildungsauslaender,* represents 72.5% of the foreign-born students in German institutions of higher education (DAAD, 2014). Fifty per cent (50.5%) of *Bildungsauslaender* students were in science and engineering (S&E) and according to their place of birth, 35.4% were from Asia; 27.4% from Eastern Europe; 27.4% from Western Europe, 18.9% from America; 8.1% from Africa; 9.8% from Australia and 0.3% from Oceania. On the other hand, the international mobility of German students is also part of the internationalization and mobility strategies of Germany, which includes young researchers, teachers and other staff in HE institutions (Joint Science Conference, 2013). However the proportion of German students abroad is less, representing only 6.3% of German students. The mobility is mainly inside European countries representing the 77.6%, while the proportion of those students in the U.S. and China was 7% and 4.1% respectively.

The dataset of migration of the OECD countries based on gender and educational attainment (Docquier and Marfouk, 2006) is a valuable source to analyse the stocks of migrants with tertiary education, at least as a starting point. Countries with high outflow in terms of absolute values, like the United Kingdom (1.48 million) and Germany (0.94million) compensate their talents with high inflow of tertiary educated migrants from different countries (1.2 and 1.04 million in the United Kingdom and Germany respectively). In this case there is no brain drain, but circulation of knowledge, enriched by different culture and background. However, the source of this dataset comes from national censuses in 2000 or 2001 and does not account for the type of work those skilled migrants perform and therefore any evidence of brain waste is missed in the analysis. In a similar way it is possible to identify from this source those countries suffering from brain drain, with high emigration rate (Docquier and Rapoport, 2012). Another limitation of this dataset is that it only includes countries of the OECD as destination countries, therefore movement of talents South-South, where new poles of development are emerging are not visible.

## 2.3 DEVELOPING COUNTRIES FORMING OR LOSING THEIR HUMAN CAPITAL

### 2.3.1 *Latin American concerns*

Latin American countries, when debating the views and approaches in internationalization of HE, recognized in their perspectives the work to defend the ideas of education as a public good, in which the cooperation and solidarity between peers should prevail and the subsequent condemnation of neo-colonial approaches (Didou-Aupetit and Jaramillo de Escobar, 2014). However some countries showed specifications such as Brazil and Argentina, in which internationalization of education is linked to economic relations in the region (MERCOSUR) and with less emphasis, Mexico and the North America Free Trade Agreement (NAFTA). Contributions to the field of research in Latin America are not fully integrated and each country seems to provide evidence from different disciplines. The report from Mexico refers to demographic analysis of brain circulation, academic mobility and migration and the value of the place where the titles were obtained. Argentina promoted the good practices in the management of internationalization and cooperative agreements to facilitate post-graduate studies in the region with the consequent increase in student mobility in which networks of accreditation ensure international standards and agreements. Optimal use of Information and communication technology was considered crucial in higher education to reach wider areas beyond the country. The participants (including Cuba (Hernández Pérez, 2005)) recognized that a better system for collecting and integrating the research in the area of internationalization of higher education and science should be achieved and that the observatory for mobility of academics and scientists in Latin America and the Caribbean could be used for mapping the evolution of the research.

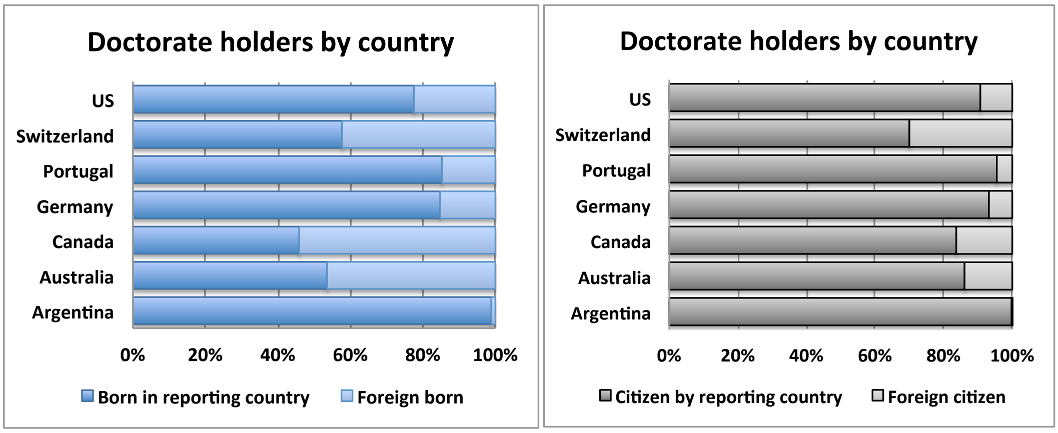
However other views coming from a Latin American living abroad are also shaping the research in this area. An interesting example refers to the study of highly skilled Mexicans in Switzerland and the evaluation of their potential for the country of origin through the circulation of knowledge (Tejada Guerrero, 2007). Another view from a Cuban based in Florida refers to the remittances of knowledge as an emerging mechanism within diaspora for development (Blanco Gil, 2013).

### 2.3.2 *PhD students and Post-Docs as a highly qualified work force: migration policy and globalisation*

A study of the labour market and the international mobility of doctorate holders from seven countries of the OECD (Auriol, 2007) found that Australia, Canada and Switzerland are destination countries for pursuing doctoral studies. Figure 2.1 suggests that a process of naturalization also occurs increasing the probability of those doctorate holders to remain in the country where they obtained the degree.

The study also reveals the absolute numbers of doctorate holders per country in which the United States (2003) is the country that attracts more foreign students with 368,800 foreign born students of which 200,300 were naturalized, followed by Germany with 106,700 foreign born doctorate holders in 2004.

Figure 2.1 Mobility of doctorate holders in seven countries of the OECD




The main hub of international mobility of scientists and engineers is the United States. According to the National Science Foundation of the United States, 3.36 million out of 21.6 million scientists and engineers (15.5%) were immigrants in 2003 (Kannankutty and Burrelli, 2007) working in science and engineering or related occupations in the United States. The demographic profile for foreign-born scientists and engineers indicated that 56% came from Asia, 19% from Europe and 15% from Latin American and the Caribbean countries. Mexico with 2.8% and Cuba with1.9% of foreign-born scientists and engineers are the larger groups of the region working in United States.

Universities in the United States are well recognised by their excellence, as their representation in the Academic Ranking of World Universities indicates, with thirty-eight U.S. universities in the top fifty (76%) [10], and in the SCImago institutions rankings, with forty-two U.S. universities out of seventy-three institutions in higher education included in the top 100 research institutions.

[10] Academic Ranking of World Universities (Shanghai Ranking) 2012. www.arwu.org

This earned prestige of the U.S. universities among international students is the main attraction for those hoping to become top scientists and engineers in the global work market. However there are other reasons manifested by the foreign-born scientists and engineers themselves as Van Noorden (2012), Kannankutty and Burrelli (2007), and Franzoni and collaborators (2012) have shown in their research questionnaires.

By 2008 the PhDs awarded by United States institutions to foreign-born students with temporary visas (Stephan, 2012, 183) increased up to 44% and if those students with green cards are included, it reached approximately 48% per cent[11]. Most of the foreign-born postdoctoral fellows in the U.S. are with temporary visas, but in a process to continue their scientific career they also pursue naturalisation. The entry of foreign-born students to the U.S for the purpose of furthering their education in universities has been facilitated since 2001. Although granting visas to PhD students depends on their ability to support themselves while studying, the Twenty-First Century Act facilitated the recruitment of foreign-born talents for faculty positions by which universities, government and non-profit institutes no longer needed to compete with private firms for a limited number of H-1B visas. The presence of foreign-born teaching positions at U.S. universities and colleges has increased from 11.7% in 1979 to 21.8% in 2006 (Stephan, 2010, 186).

Although it is difficult to gather all the information required for assessing how sending countries might be losing their human capital when studying abroad, an insight could be inferred from available data. The OECD report on doctorate holders showed the distribution of foreign-born doctorate holders in the United States by regions. The following table 2.1 illustrates the situation:

[11] Stephan, P (2012) Data source National Science Foundation of United States 2011

Table 2.1 Foreign-born doctorate holders in the U.S. by region

| Regions | 1993 | 2003 | increase (%) |
|---|---|---|---|
| Africa | 16400 | 34600 | 111.0 |
| North America | 36700 | 51700 | 40.9 |
| South America | 13300 | 31000 | 133.1 |
| Asia | 143700 | 229000 | 59.4 |
| Europe | 89100 | 155200 | 74.2 |
| Oceania | 6100 | 8100 | 32.8 |

Moreover, 30% to 37% of those doctorates were granted citizenship in the U.S., except for Oceania in which the per cent increased from 44% in 1993 to 53% in 2003. The region that had the biggest increase was South America, even when Mexico was counted in the North America region. In absolute numbers, Asia and Europe were the regions with most doctorate holders.

A research carried out by Empirica to evaluate the international collaboration In Europe found that 43% of postdocs researchers in life sciences teams were foreign-born (Empirica, 2005, 46), and 18% if only including non-European countries. Although these figures are representative of 359 Universities from 10 countries in Europe they indicated the degree of brain circulation within the region and the input of non-European researchers in life sciences in the region.

### 2.3.3 *Countries more affected by brain drain: limitations of studies measuring brain drain*

The empirical evaluation of brain drain, brain waste, brain gain and circulation still encounters problems in terms of methodologies and also an integral approach to measure how those flows of human capital are part of the global nature of science, or a modern expression of science in the global market place.

Economists design their research using macro-data from different regions and countries, looking for determinants, which might indicate, or not a degree of correlation between different variables. One of the most cited papers studying brain drain in developing countries was contributed by Docquier and collaborators (Docquier et al., 2007), in which one of the conclusion is that small countries close to major OECD regions are the most affected by brain drain. More recently, their work focussed on the link between brain drain and development, indicating that the highly skilled migration is becoming the dominant pattern of international migration and a major aspect of globalization (Docquier and Rapoport, 2012), in which public policy might play a role determining whether a country or region can gain or lose in the process. The loss of talents, as they pointed out is not only a problem of developing economies, as the exodus of European scientists to the United States is a typical case. However, the problem acquires another level of magnitude in the case of brain drain of Africa's medical doctors (Mills et al., 2011).

### 2.3.4 *Developing countries and the race for brain gain*

The dilemma of developing countries in knowing how to retain their talents is hindered by the intrinsic limitation of their economic growth. It is well known that developed countries not only allocate a higher proportion of their gross domestic (GDP) product to research and development (GERD), but their GDP is by far greater than all developing countries combined, thus, sharing only 19% of the world population they hold 64% of the world GDP (UNESCO, 2010, 3).

The magnitude of the problem can be illustrated analysing Mexico, which is not in the worst position in the region of Latin American and the Caribbean. In terms of drain of human capital 811,000 Mexicans resident in the U.S. have taken university studies without finishing them, 278,000 have finished tertiary education, 442, 000 Mexican residents holding a university degree and 110,000 holding doctorate degree (Tuiran, 2009). The author, who at the time was sub-secretary of Higher Education in Mexico emphasises that the higher the education attained by the migrant, the relatively worse is the drain: in other words for every 15 Mexicans with university degrees, one is in the U.S. But for every five masters and three doctorates there is one in the U.S. According to the statistics there is a net loss of 20,000 nationals with tertiary education moving to the neighbour country every year in the last decade. The highly skilled flows involved different occupations from management to technology, independent professional, enterprise, and many others. However, as Tuiran argues, these flows are of a different nature in terms of time: some are permanent and others temporary or circular involving transient projects. The complexity of these flows represent a challenge to turn the brain drain into opportunities created by globalization.

In terms of new policies for Latin America, Tuiran explains how policies should aim for a broader scope, that it is not enough to address the retention of professionals or their integration to the country workforce when they return, but to reach those already working successfully abroad to engage in networks, especially those working in science and technology.

The above summary of the vision of one academic representing Mexico in the International Seminar organized by EISLAC-UNESCO in the region represents how the research in brain drain, brain gain and circulation demands more research from the academics and policy makers of the region. As Sylvia Didou Aupetit (2009) pointed out, the field still deserves improvement in measuring the magnitude of the problem and its nature in depth. The perception of the brain drain is also changing: the emigrant is not labelled as a defector any more; neither do they leave their home country for political or religious persecutions. Instead the movement of professionals depends more on the balance between risk and opportunities both in the destination and origin countries of the professionals involved.

## 2.4 TRANSNATIONAL KNOWLEDGE NETWORKS FOR THE SOUTH

By the end of the 1990s, emerging research was focusing on communities of highly skilled expatriates working in developed countries, who were interested in helping their homeland in S&T and education. On the other hand, there were some indications that these sort of transnational networks between researchers of countries linked to centres of knowledge were generating international scientific collaboration.

### 2.4.1 *Transnational Knowledge Networks. The North: links between mobility and international collaboration.*

One of the questions discussed in the last decades is how mobility of scientists might be linked to the increase of international collaboration. Mentioned earlier was the formation of centres of knowledge and the international appeal of students and researchers to be part of those research teams. Early evidence on how brain circulation is related to international collaboration is the work of Heike Jöns (2009) studying academic mobility in Germany between 1954 and 2000. In her work Jöns studied the researchers visiting Germany through the following exchange programs: Max Planck Society (founded in 1948), German Academic Exchange Service (since 1958), German Research Council (since 1951), Goethe Institute (since 1952) and Alexander Humboldt (since 1953). For example, the Humboldt supported 116,699 visiting academics from 131 countries. She argues that as a result of accumulative processes of academic mobility the international collaboration measured by co-authorship has placed Germany in the third place after Canada and United Kingdom in co-authoring papers with the United States. The evidence showed that the amount of scientific articles grew almost exponentially as: 5,800 between 1981 and 1985; 11,500 between 1991 and 1995; and 43,921 between 2000 and 2005.

### 2.4.2 *The rise of the Transnational Knowledge Networks (TKNs)*

These communities were empowered by advancements in digital communication making virtual networks possible regardless of geographical distance. They were called intellectual diaspora networks (Brown, 2002), scientific diasporas (Meyer et al., 1999; Barre et al., 2003, 121); scientific, technological and economic diasporas; knowledge networks abroad (Kuznetsov, 2005), and Diaspora Knowledge Network (DKN) by the International Committee for Social Science Information and Documentation (Turner, 2005). It is important to differentiate at this point what is called Transnational Development Networks (TDN), defined as a form of association involving development agents and agencies across nations, as a relationship between individuals and between organizations (Henry et al., 2004). Likewise, Global Knowledge Networks (GKN) refer to those associations of epistemic communities which their primary mission is knowledge creation and dissemination, unlike other network types that are directly political and policy orientated (Stone, 2003).

The paradigm of diaspora as a *nation-in-exile* has continuously evolved as social progress (technology) demands new forms of relations, but some characteristics remain essential to their sustainability. They are of ethnic or national origin, with capabilities to contribute to the development of their homeland, which could only be materialised with their willingness and readiness to do so (Weinar, 2009). The economic outcome from the relationship between the country of origin and the diaspora, he suggested, was of greater importance than symbolic or political ties.

Expatriate Chinese scientists have successfully collaborated in trans-national research with their homeland colleagues with the outcome of joint international scientific publications, which is a symbolic capital reward. Examples of such successful DKN are the Society of Chinese Bioscientists in America, the Chinese Life Scientists in the UK and the Chinese Network of Life-sciences in the Netherlands (Jonkers, 2010).

The evolution of terminology and concepts noted here demonstrates the motivation to consider models of engendering collaboration in various domains. In this study of Cuban scientists in Europe, the choice has been to use TKN as the preferred term, which embodies the characteristics of diaspora communities in general already explored in this narrative.

In Latin America, the brain drain towards OECD countries increased from 10.4% to 14.3% between 1990 and 2000, with Mexico (from 17.9% to 21.7%) and Colombia (18.2% to 21.5%) at the top of the list (Didou Aupetit, 2009). The critical situation prompted different governments of the region to create programmes either for repatriation (Guatemala, Jamaica, Mexico, Panama and Peru) or activating the formation of TKN (Argentina, Chile, Colombia, Salvador, Mexico, Uruguay, Venezuela) through the National Institutes of Science and Technology, Academies of Science, and High Education Ministries.

Interestingly, social researchers in the North discovered those TKNs in the earlier 90s by the means of socio-technical systems (Meyer and Wattiaux, 2006) and in 1999 seven networks out of twenty-nine were identified in Latin America (Meyer and Brown, 1999). Moreover those TKNs were not only domains of developing countries, since France, Japan and Norway were also represented. Table 2.2 shows TKNs in LAC by 1999. Therefore this new *social device* might not be exclusively of the South, but as Meyer reflected on and referring to Thomas Kuhn's paradigms, '*an expression of socio-cognitive communities, not only social or institutional ones*'

Table 2.2 Transnational Knowledge Networks in Latin America in 1999 (Source: Meyer and Brown, 1999)

| Country | Name of Network | Type of Network |
|---|---|---|
| **Argentina** | Programa para la Vinculacion con Cientificos y Tecnicos Argentinos en el Exterior (Program for the Linkage of Argentine Scientists and Technologists Abroad) (PROCITEXT) | Developing Intell/Scien Diaspora Network |
| **Colombia** | The Colombian Network of Researchers and Engineers Abroad (Red Caldas) | Intell/Scien Diaspora Network |
| **El Salvador** | Conectandonos al Futuro de El Salvador (Connecting to El Salvodor s Future) | Developing Intell/Scien Diaspora Network |
| **Latin America** | Asociation I.attino-americaine de Scientifiques (Latin American Association of Scientists) (ALAS) | Intell/Scien Diaspora Network |
| **Peru** | Red Cientifica Peruana (Peruvian Scientific Network) | Developing Intell/Scien Diaspora Network |
| **Uruguay** | Red Academica Uruguaya (Uruguayan Academic Network) | Developing Intell/Scien Diaspora Network |
| **Venezuela** | In Contact with Venezuela | Developing Intell/Scien Diaspora Networks |
| | El Programa Talento Venezolano en el Extrior (Program of Venezuelan Talents Abroad) (TALVEN) | |

.

Among the TKNs in Latin America and the Caribbean are: Red CALDAS from Colombia (Chaparro et al., 2004); RAICES from Argentina, Chile Global, from Chile and Red de Talentos Mexicanos, from Mexico among others (Meyer and Brown, 1999). The achievements of the above mentioned TKNs have been inconsistent, with periods of silence between periods of activity, while some of the TKNs have a temporary life with specific short-term aims. Evidently, it seems to be a gap between promises and deliveries (Meyer, 2007). There is a crucial need in

Latin America and the Caribbean, as it was pointed out earlier for methodological improvements to assess the loss of human capital in S&T and to evaluate the contribution of TKNs (Didou Aupetit, 2009) in the development of the region.

Literature describing other Transnational Knowledge Networks (TKNs) from developing countries included Romania (Ciumasu, 2010), Bosnia Herzegovina (Nikolic et al., 2010) as well as regions in Asia (Agunias and Newland, 2012).

### 2.4.3 *Recognition of transnational knowledge networks in the international migration and development nexus*

Boyle and Kitchin (2011) mentioned some key functions of the three actors (stakeholders) involved in diaspora-centred development. The first actor - the expatriate members of the diaspora, must capitalise on their contributions and enhance their own agendas by consolidating rather than threatening their links with home and host. The second actor - the sender countries, must work towards the process of "nation building", the development of ICT infrastructure and the creation of new citizenship rules. The third actor - the destination countries in the Global North, must promote and secure as opposed to frustrate and undermine the reach of diaspora back to homelands, and contribute to the emerging global dialogue on diaspora strategies and policy initiatives.

Just last year Jean Baptiste Meyer (2015) from the Institute for Research and Development (IRD), Marseille, has explained that still today an integral evaluation both empirical and theoretical of the TKN is necessary to assess their contribution to development. Many countries are searching for new policies, management and governance, he argued, because there is a sense of the importance they might represent for the future of their countries, and he mentioned how for Argentina, they called *Province 29*, and for Uruguay, the *Department 20*. However he insisted, it might represent a negation of the extraterritorial nature of the diaspora.

## 2.5 CUBA AND CUBAN SCIENCE. GENERAL OVERVIEW

The Republic of Cuba is the largest island bordering the Caribbean with a surface area of 109, 886 km$^2$ including 4,000 smaller islands 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 U.S. troops in 1898 - 1902.

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 (Pérez, 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.

Chronologically three important events have marked the rapid increase of the human capital in Cuba necessary for the scientific and technological development of the country: the University Reform in 1962, the long lasting system of sending students abroad to increase the initial capability of the country in higher education since 1961 and the creation of the National Centre for Scientific Research in 1965. This institution generated a critical mass of scientists, leading generations of researchers and helping to create new research institutes.

With the collapse of the socialist countries in Eastern Europe and Russia in 1989-1991, Cuba faced the isolation from these countries and the hostility of the U.S. economic, financial and commercial embargo against Cuba.

Consequently, the economy of Cuba suffered the loss of more than 85% of the export market and in 1991, a state of emergency was declared by President Fidel Castro as the Special Period in Time of Peace (*Período Especial*), in which national measures were taken to safeguard health and education. Ten years later in a report to the World Bank, Lavinia Gasperini (2000) pointed out,

> ‘*Cuba’s schools are the equals of schools in OECD countries, despite the fact that Cuba’s economy is that of a developing country’*

Explaining the reasons behind the paradox, the author argued that Cuba's education system preserved its education strategies, sustained high level of investment in education and a comprehensive and carefully structured system even under severe resource constraints of the last decade.

Years of investment in education as well as in science and technology provided Cuba with the ability to find opportunities, which would contribute to the economy and sustained the progress of the country throughout this state of emergency. Latin American countries entered a new era of co-operation and collaboration with Cuba. In higher education, the co-operation with Latin America and the Caribbean increased from 12% in 1989 up to 72% in 2001 (Hernández Pérez, 2005, 222).

The Cuban population was 11.2 million in 2010 (Oficina Nacional de Estadística, 2010) with 0.9 million graduates from higher education (Clark Arxer, 2010). In 2002, it was estimated that approximately 1.6 scientists and engineers per 1,000 citizens (Wagner et al., 2001) were working in 119 institutions of Research and Development and in 34 institutions of Science and Technology. These statistics reflect the consistent commitment of the Cuban government to develop human capital (Sáenz and García-Capote, 1993; López Mola et al., 2006) to achieve scientific, social and economic progress.

The Cuban Health System has benefited as well from the strategy of the Cuban government to invest in science and technology, in this case creating specialised national research institutes within the health system. The development of science and technology contributed to the improvement of the National Health System, achieving in this way, the world recognition for the high standards in national health (World Health Organization, 2008). Some experts pointed out the contribution of this investment to Cuba's strength to overcome the economic crisis of the 1990s without a detrimental impact on the health system (De Vos et al., 2012).

The Cuban policy in higher education and science and technology ensured high international mobility of Cuban researchers to maintain excellence and competitiveness within centres of research. However, a side effect of this high mobility might be the resulting migration of highly skilled Cuban personnel to other countries during the economic crisis.

The effect of this migration of human capital in science and technology has not been evaluated. Also, this population of Cuban expatriates has not been considered as a resource to participate in the national innovation system (NIS) of Cuba.

### 2.5.1 *Formation of human capital and strategy for development*

After decades of neglect in education, science, and technology (Truslow, 1951), the new revolutionary government that came into power in 1959 declared education and health as social rights. The new government identified that investing in science and technology (S&T) was crucial to reduce poverty and to develop the country towards its economic independence (Castro Ruz, 1960).

Cuba's declaration of economic independence and socialism resulted in geopolitical conflicts with the U.S. and as a result Cuba was isolated from Latin American countries that were nucleated around the U.S. at that time. Cuba aligned with the socialist system of Eastern Europe and Soviet Union, and by 1962, Cuba was expelled from the Organization of American States (OAS).

Two important events, according to Emilio García Capote (2012), in education defined the future of the country in terms of using knowledge for the development of the society. First in 1961 the Literacy Campaign mobilising mainly students from the capital towards rural places declaring the country free of illiteracy by the end of the year. The second was the University Reform in 1962, which included among other aspects, free access to study, ensuring that reaching higher education was a right to all citizens and not the privilege of the few. Opening the access to knowledge to the masses without any type of discrimination ensured the success in later developments regarding the formation of human capital. Those events provided thousands of fellowships to young students from rural and low-income backgrounds for their secondary and tertiary education in the capital city.

As early as 1961, thousands of students from Cuba were sent to universities of socialist countries, mainly the USSR, to complete their tertiary education for the expansion of the new educational system in Cuba, indicating that formation of human capital was a priority of the new government.

### 2.5.2 *Cuban science: academic period (1861-1901)*

This period started with the creation of the Institute of Research in Chemistry in 1848, the Observatory of Meteorology and Physics in 1856 and the Royal Academy of Medical, Physics and Natural Sciences in 1861, as an effort from the academics of that time to promote science in the country. Tomás Romay was one of the main figures in science. In this period the country was involved in struggles for the independence from the Spanish colonial rule. Contributions to science in this period came mainly from personal interests and efforts to develop new knowledge. One of the best known in the Cuban history of science is Carlos J. Finlay, who discovered the transmission of yellow fever in 1881 (López Sánchez, 1987). At this time the only university of the country had already changed its name (1842) from The Royal and Pontifical University of Saint Jerome of Havana, to the Royal and Literary University of Havana, but like in the rest of the world, higher studies were only for the few with economic means.

### 2.5.3 *Cuban science: republican period (1902-1958)*

Evidence indicates that during this period little was achieved in Cuban science, mainly as the consequence of lack of interest from the governments between 1902 and 1958. The infrastructure for science and technology was non-existent. The number of scientists and engineers was not adequate; neither were the number of institutions dedicated to research. Two institutions were created at the beginning of this period: the Experimental Station of Agronomy and the Botanic Garden in 1904. Towards the end, in 1955 the government created the Cuban Institute for Technological Research but its contribution was not significant probably due to its short existence. The illiteracy in the population was high and there was low capacity for the formation of qualified specialists in secondary and tertiary education (Escobar Rodríguez, 2007). In this period the university of the capital changed the name to National University of Havana, and another two universities were founded: the University of Oriente (University of the East) in 1947 and the University of Villa Clara in 1952. Some institutes belonged to the universities, for instance, the Institute of Tropical Medicine founded by Dr Pedro Kourí in 1937, which changed to the Ministry of Health in 1964 (Beldarraín Chaple, 2005). During these years, also called neo-colonial period some Cuban scientists achived international recognition (Prune Goodgall, 2014, 138) and became the founders of the science in Cuba.

2.5.4 *Cuban science: period of directed promotion (1959-1975)*

This period extends from the victory of the Cuban Revolution in 1959 to 1975 when the thesis about science policy was approved in the first congress of the Cuban Communist Party. The international context for this period provided the country with a framework for action, one side coming from the Council for Mutual Economic Assistance (COMECON in English) and the other the intention of the United Nations to work for the co-operation in the application of science and technology to economic and social development (United Nations, 1964).

The priority as it was earlier pointed out, was the formation of human capital due to insufficient number of professionals in the country, severely weakened through the exodus of professionals towards the U.S. To give an idea of the magnitude of the problem, there were 6,250 medical doctors in Cuba in 1959 and 3,000 migrated to the U.S. in the first decade; similarly, from 2,500 engineers, only 700 remained in the country. As a result of the government commitment and with the participation of the society, by the end of this period (1959 - 1975) Cuba had 9,438 medical doctors working in hospitals and 5,400 scientists and engineers in 100 institutions of research and development (Hernández Elías and Márquez, 1976; Escobar Rodríguez, 2007).

Through the Cuban Academy of Sciences several institutions were created: Institute of Geography, Institute of Geology, Institute of Meteorology, Institute of Sugar Cane, Institute of Geophysics and Astronomy, Institute of Mathematics and Physics, Institute of Oceanology, Institute of Zoology and the Institute of Botany. In

1965 the creation of the National Centre of Scientific Research marked the vision of a multidisciplinary scientific research of excellence, which played a decisive role in the formation of personnel for the next generation of scientific institutions. With the creation of the National Health System another 13 National Research Institutes in specific medical fields were created: the National Institute of Oncology and Radiobiology, National Institute of Gastroenterology, the National Institute of Cardiology and Cardiovascular Surgery, the National Institute of Nephrology, the Institute of Neurology and Neurosurgery, the National Institute of Angiology and Vascular Surgery, the Institute of Endocrinology, the Institute of Haematology, the Institute of Hygiene and Epidemiology and Microbiology, the Carlos J. Finlay Institute and the Pedro Kourí Institute of Tropical Medicine (Beldarraín Chaple, 2005).

In the Ministry of Industry when Ernesto (Che) Guevara de la Serna was still the Minister, another nine research institutions were created between 1962 and 1965 (Yaffe, 2009, 171): the Cuban Institute for Mineral Resources (1961), the Cuban Commission for the Mechanisation of the Sugar Cane Harvest (1961), the Cuban Institute of Mineral and Metallurgy Research (1962), the Office of Automation and Electronics (1962), the Cuban Institute for Technological Research (1962), the '*Ciro Redondo'* Experimental Farm (1962), the Cuban Institute for Research into Sugar Cane Derivatives (1963), the Cuban Institute for Development of the Chemical Industry (1964) and the Cuban Institute for Machinery Development (1963) . Many of these research institutions started with the assistance of foreign experts, both from the socialist and capitalist countries.

In this period new universities were founded: Polytechnic Institute '*José Antonio Echeverría'* (IPJAE) in 1964, University of Camagüey (UC) in 1967, University of Matanzas (UM) and University of Pinar del Río (UPR) in 1972 and University of Holguín (UH) in 1973.

By the end of this period science continued towards institutionalization with the creation in 1974 of the National Council of Science and Technology under the 1271 Act.

2.5.5 *Cuban science: period of centralized direction (1976 -1991)*

This period starts with a science policy constructed collegially by all working in science, technology and education in all institutions of the country and approved by the First Congress of the Cuban Communist Party in 1975 as part of the programme for continuing the development in science and technology.

Human resources in R&D working in areas of national interest continued increasing from 10,073 university graduates in 1981 to 15,808 in 1985 and the evolution of the new system in science and technology was critically reviewed in the Second Congress of the Cuban Communist Party in 1980 (Pruna Goodgall et al., 2014, 234).

Science was declared a priority for the development of the country and receives central attention from the state, which lead to a centralization of many activities. Emphasis was addressed to the introduction of results from the science and technology and institutions were adopting the structure of research and development (R&D) and in some cases creating infrastructure for technology and production. The National Program in Science and Technology was also established according to the needs of Cuban society. New universities were created: University of Granma (UDG) in 1976, University of Ciego de Avila (UCA) and University of Cienfuegos (UC) in 1978 and the Higher Institute of Technology and Applied Science (InSTEC) in 1981. The country had by the end of this period one hundred and seventy eight institutions of research and development (Escobar Rodríguez, 2005). Some institutions adopted the infrastructures for Research / Development / Production or Service, as a consequence of the increasing co-operation between academic and research institutions with areas of production. Among relevant institutions for their role in R&D were: Biological Front (1981), Centre of Biotechnology and Genetic Bioengineering (CIGB, 1986), Centre of Immunoassay (CIE, 1987) Centre for the Production of Laboratory Animals (CENPALAB, 1987), National Centre for the Production of Bio-products (BioCEN, 1987), C.J. Finlay Institute for Vaccine Production (1991).

Another important feature of this period was the creation of new centres of R&D throughout the country, some of them as regional units connected to the main institutes in the capital ensuring the transference of high standards to conduct scientific research. Thus, in the field of biotechnology, for instance, two new Centres were built: Biotechnology and Genetic Engineering at Camagüey (1986) towards the East of the country and the other in the central region of Santi Spíritus (1990).

These R&D institutions were adopting international standards along the research-development-production process and implementing national guidelines regulating the quality control such as *Good Laboratories Practices* (GLP); *Good Manufacturing Practices* (GMP) and *Good Clinical Practices* (GCP).

Crucial in this period was the role of the government, through the State Council facilitating the interactions and actions between different sectors of the economy as part of the process of consolidating the national scientific capacity as the following examples illustrate:

- *Separating pharmaceutical industry from the government quality control of pharmaceuticals*: The Cuban pharmaceutical industry had a long tradition of high quality production of generics to satisfy the domestic demands and represented a national state-consortium of enterprises (Industria Médico Farmacéutica, IMEFA) in the Ministry of Public Health with its own centre for R&D (Centre for Research and Development of Medicaments, CIDEM) and the office for the Registry of Medicaments. Towards the end of the period (1989) the State Regulatory Agency for the Control of Medicaments (Centro Estatal para el Control de Medicamentos, CECMED[12]) was created totally independent from the IMEFA but subordinated to the Ministry of Public Health, ensuring the absence of conflict between the industry and the public health.

[12] http://www.cecmed.cu/acerca-de/historia

- *New regulatory and compliance services*: The need for more efficient processes of approval of new medical-pharmaceuticals and biotechnological products for clinical use prompted in 1991 the creation of the National Clinical Trials and Coordinating Centre[13] (CENCEC) with a design typical of the Contract Research Organization (CRO). Conceived as a high-level scientific unit with separate legal status inside the Ministry of Public Health, CENCEC was ensuring full ethical, scientific and methodological rigor in compliance with international standards required in the approval of pharmaceutical products for marketing in Cuba and abroad (Pascual et al., 2011)

- *Intersectoral links*: The new innovative sector of Cuban biotechnology with highly specialised personnel originally formed in the Ministry of Higher Education and in sectors of the Ministry of Public Health, including IMEFA started undergoing profound organizational integration with the state controlled health system allowing a smooth process of knowledge-sharing and incremental innovation (Cárdenas O'Farrill, 2009).

### 2.5.6 *Cuban science: period of science and technological Innovation (1992-present)*

Science and technology in Cuba was having its own dynamics regardless of the political instability surrounding the ex-socialist countries with which the economy was closely integrated. The economic situation of the country was worsened by new opportunistic re-enforcement of the U.S. embargo (economic, financial and commercial embargo, which Cubans call '*U.S. Blockade*') against Cuba. A brief description of the national situation at the beginning of this period can be seen in some numbers: the GDP decreased by more than 35%, an average of 16 hours of electric cut-off to the population, the intake of calories was reduced to 1800 per capita, and the proteins bellow 36 g/day, and those figures, as Agustin Lage referred, were only to mention a few (Lage Dávila, 2013, 120). However, even in

[13] http://www.cencec.sld.cu

those difficult times, the Cuban government, in particular Fidel Castro, insisted that the country more than ever had to continue the development of science as the only way to overcome the national economic crisis. In this period two new universities were founded: the Latin American School of Medicine (ELAM) in 1998 and the University of Information Science (UCI) in 2002.

In the context described above, one of the principal characteristics of this period was the emphasis on innovation, which in 1995 took an explicit form under the National Science and Innovation System (García Capote, 2015; Escobar Rodríguez, 2007, 23). Therefore, the earlier configuration of institutes in Research-Development-Production (R-D-P) incorporated Innovation as an important feature. Academic interests gave way to the enterprise targets, and production of goods with innovative values was strongly stimulated.

Science affairs, in this period, were elevated to ministerial range with the creation of the Ministry of Science, Technology and Environment (CITMA) the 21st April 1994, by the 147 Act. Among other functions of this new Ministry were:

- *Proposing and evaluating the scientific and technological strategies and policies according to the economic and social development of the country, settling objectives, priorities, lines and programmes of research and leading and controlling its execution.*

  *- Leading and controlling the elaboration, execution and evaluation process of the scientific research and technological innovation programs.*

  *- Promoting and facilitating scientific community participation in the elaboration and evaluation of science and technology strategies and policies.*

  *- Suggesting the strategies and polices for the process of planning and science and technical innovation budget elaboration according to the agreed priorities. Distributing and controlling the execution of the agreed budget for the national, territorial and specific priorities.*

*- Leading, coordinating and controlling the process of integration of the scientific, technological, productive and other factors in generation and usage of scientific - technical knowledge through the scientific poles, the different themes and other integration ways, that may be settled, related to high priority activities. Coordinating the integration of other factors as the Juvenile Technical Brigades, the Innovator National Association and the Science and Technical Forum.*[14]

The grassroots movements such as the Forum of Science and Technology[15], increased their impact nation-wide by gaining more representation in more working places across the country. Thus networks with territorial scope were part of the national effort and other NGOs such as National Association of Innovators (*Asociacion Nacional de Innovadores y Racionalizadores, ANIR*), Youth Technology Brigades (*Brigadas Técnicas Juveniles, BTJ*) joined accordingly. The total number of science and technology practitioners reached 300,000 members by 2008 (Núñez Jover and López Cerezo, 2008).

In 1985, in total Cuba had 208 PhD degrees obtained abroad and 573 PhD graduates from Cuba (Mezke and Fernández de Aliza, 1990). By 2003, in total there were 2472 Cuban PhD graduated abroad and 3957 in Cuba (Hernández Pérez, 2005). In 2010, Cuba had 0.9 million people out of a population of 11 million with higher education qualifications (Clark Arxer, 2010) and more than 5,000 people with MSc and PhD degrees were in the workforce.

In 2006 there were 119 institutions of R&D contributing in the National Program of Science and Development in 14 provinces, and another 34 institutions were active in science and technology (Clark Arxer, 2010).

---

[14] http://mipais.cuba.cu/cat_en.php?idcat=81&idpadre=6&nivel=2, information created by CITMATEL, accessed: 28/09/2014

[15] ***Forum of Science and Technology***, created in 1980 to solve the problem of the high cost of importing spare parts from socialist countries. The concept of this movement involved integration, cooperation and mass participation

### 2.5.7 *The rise of the Biotechnology industry in Cuba*

Years of consistent investment on science and technology by the Cuban government paid for the incredible take-off of Cuban biotechnology. The Biological Front created in 1981 to develop the production of natural Interferon[16] became a model of R-D-[Innovation]-P for further expansion in the Centre of Genetic Engineering and Biotechnology (1986). In 1992 with the creation of the West Havana Bio-cluster (West Havana Scientific Park, or '*Polo Científico de la Habana'*) Cuba optimized even more her capabilities. This new organization was under control of the Council of State, comprising of 52 institutions and enterprises related to biotechnology, covering research, education, health and economics, as well as regulatory agencies (Cárdenas O'Farrill, 2009 and 2014; Clark Arxer, 2010). Representative of each institution of the Bio-cluster, the regulatory agencies and the Council of State formed the Strategic Decision Body, which made the definition of objectives according to the economics and social development goals of the country (Sáenz, 2005; Reid-Henry, 2008; Cárdenas O'Farrill, 2009).

As Cárdenas O'Farrill argued, the three social conditions yielding innovation and economic development are contextualized in the backbone of Cuban biotechnology. They are: the strategic control over the allocation of resources, long-term financial commitment by the Cuban State as investor and organizational integration as a network of institutions co-operating with each other to develop products and processes. López Mola and colleagues (2006) added another important feature among others, the "close cycle" as an operating capacity, which has been recognized as a unique feature of the Cuban biotech industry (Haseltine, 2012). The closed cycle approach, William Haseltine, the funder of the Human Genome Sciences in Rockville, Maryland explained, means that

> *'The same team stays with the project from inception and invention to marketing. This approach seems to me to be a recipe for success, as it*

[16] ***Biological Front***: [Frente Biológico] was created to produce natural Interferon gamma for the treatment of Dengue, which the frequent outbreaks was a concern of the Cuban National Health System. The nation wide network of Blood Transfusion Centres was of relevance in the process of production of this cytokine.

*assures that the deep insight and knowledge acquired at all stages of development are preserved and reflected in the outcome'.*

Common practice in most pharmaceutical companies follows a contrary process, with different highly specialized teams working until they finally reach the marketing group, who may know a lot about the commercialization or market, but have very little or erroneous notions of how the product actually works.

In a report to the World Bank, Klapan and Laing (2005) commented about Cuban pharmaceutical production:

*'Cuba's pharmaceutical production capacity is backed by strong government support. In 1993, it was estimated that 1150 biologic and diagnostic products, as well as 30 non-prescription drugs and 132 generic products, were manufactured in Cuba. The growth of the local pharmaceutical industry, which by the mid-1990s was bringing Cuba some 100 million dollars a year in export earnings, has not only covered domestic demand for medicines, but has also led to the development of products that compete on the international market'.*

To have an idea how this co-operative body of institutions belonging to the *Polo Científico* can accelerate technology and innovation by sharing knowledge and ensuring constant learning during the whole process, it is worth to mention the Centre of Molecular Immunology. Created in 1994, under the economic restrictions described above, this *start up* institution (originally a research group in the Institute of Oncology and Radiotherapy, in the Ministry of Public Health) that at the time only had one product (a monoclonal antibody for the treatment of patients after organ transplant) with small production below 100 thousand pesos/year, managed to increase the export capacity by 300 times in the following 12 years (Lage Dávila, 2013, 146). The productive capacity for the international demand was limited and two joint venture firms were developed in India and China by 2006. By 2013 the Centre of Molecular Immunology (CIM) had 524 patents and commercial agreements with Europe, Japan, Canada and even the U.S, in spite of the embargo. The Director of the CIM, Dr Agustin Lage Dávila (2013, 158), explained in relation to the closed cycle that,

> ‘*The researchers learned how to take into account the production and commercialization of their product coming from research, at a very early stage; the producers/engineers became familiarized with the design for scale up as soon as a product showed efficacy; the directors of institutions (R/D/I/P) not only assumed but also encouraged in all of those involved in the closed cycle of each product, the sense of responsibility, efficiency along the whole process rather the fragmented vision’.*

However, this closed cycle doesn’t mean that the firms are organized around one product, because they change continuously. Instead, those institutions are organized around the capacity to create and absorb knowledge for new products and technologies and in this way ensuring the process of innovation.

Until this point the success and innovation capacity of the biotechnology industry in Cuba has been noted. But there is another feature equally important: the socialist character of the Cuban biotechnology industry, something that sometimes is misinterpreted. The Cuban biotechnology industry is a socialist enterprise. It combines an orientation toward exporting novel products to the world market, therefore following its rules; and fulfilling the national demands and social programme driven by co-operation among institutions. The institutions are de-centralised for the management of their commercial affairs, which contribute to a better capacity of adaptation to any particular external event. However with the state being the owner, the institutions will be protected in a long term, against external negotiations, or any other instability of any particular institution. Another advantage is the patents, which belong to the State and not to the firms; therefore it works as an *open bank of knowledge* for the benefit of all. Again it is a concept ensuring cooperation rather than competition between institutions accelerating the process of innovation in products and processes.

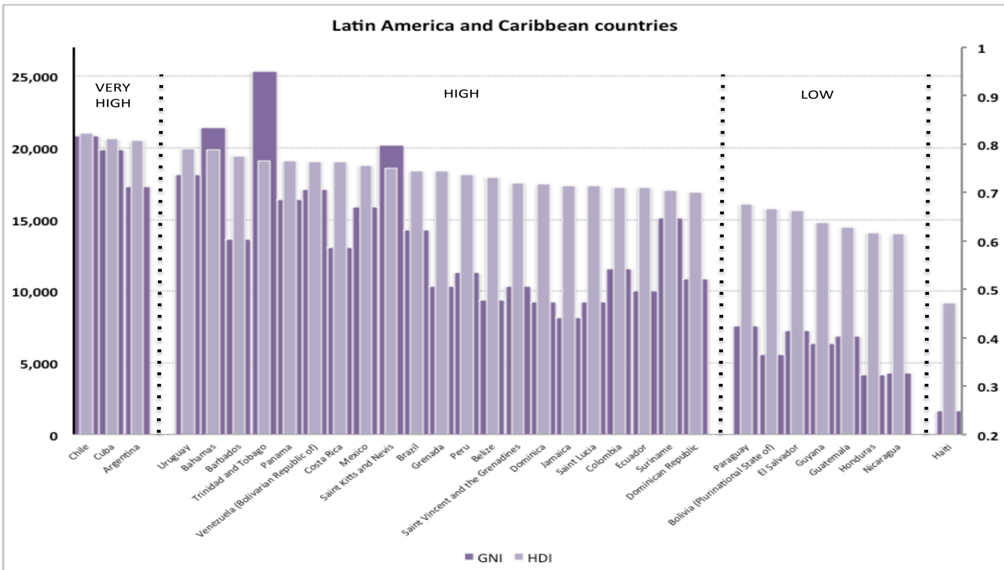
Experts evaluating models of development have reviewed the Cuban biotechnology industry (including as well the pharmaceutical) as a successful example for developing countries. Klapan and Laing (2005) analysed the models of Cuba, China and India as positive examples in which a new concept is in place: genomics and biotechnology *by* the developing countries, rather than genomics *for* the developing countries and consequently, the implications those models mean for the social goals. Halla Thorsteinsdóttir, in her lecture about Innovation Systems at the II Congress on Biotechnology for Asian Development (2004), pointed out the strength of the Cuban biotechnology model based on the long term commitment of government and financial support, the optimization of local capacities, the linkage between research institutions and policy makers in the government, the priority given to meet local health needs and the close linkages between the research institutions and the health system. The latter in particular became a source of innovation, an efficient process of planning and carrying out clinical trials and disseminating information about Cuban products to the general public. Moreover, the author mentioned how the social norms influence the innovation system by creating social and political motivation to show that the Cuban system works, shown in the pride of the country for being able to build up capacity in a science intensive sector such as biotechnology. Other views related to the capabilities in developing countries to harness genomics and biotechnology to improve global health equity also mention the Cuban model (Singer and Daar, 2001; Thorsteinsdóttir et al., 2004; Daar et al., 2007). But Cuba is not the only country in the global South that has taken advantage of developing health biotechnology. India, Brazil, South Africa, China and Egypt are all participating in the global trade, with 12.5% annual increase in the rate of South-South trade. Although the entrepreneurial collaboration with the North is more prevalent in all of these countries (Melon et al., 2009), Cuba seems to have the higher percentage of South-South entrepreneurial collaboration involving research and development and end-stage commercialization (Thorsteinsdóttir et al., 2010).

Interesting, analysis of the Cuban biotechnological industry has been put forward by Cardenas O'Farrill (2014) in the context of the evolution of the international pharmaceutical industry. He argued that while the industry (international) was moving away from a monolithic blockbuster business model (Pharma.1) to a more collaborative global and value-driven model (Pharma.2) both focusing in developing and marketing drugs, Cuba was ahead running a new Pharma.3 model in which the centre of attention was the health outcome (Gibbons, 1999).

## 2.6 SCIENCE IN LATIN AMERICAN AND THE CARIBBEAN COUNTRIES

Recent developments in the region of Latin American and Caribbean countries has called the attention of scholars, organizations and governments worldwide as a region that has consolidated social, economic and, political achievement for their population although yet bearing the great income inequality (Kapcia and Newson, 2014). Beyond the heterogeneity between and within countries of the region, the report of the United Nations Commission for Latin America in 2007 still found that more than a third of the population (195 million) are poor and another 75 million live in very poor conditions (Uthoff and Beccaria, 2008). Figure 2.2 shows both the gross national income per capita (GNI per capita, in PPP$) and the Human Development Index (HDI, max. value 1) for thirty-four Latin America and Caribbean countries.

Figure 2.2 GNI per capita and HDI in Latin America and the Caribbean




Source: United Nations Development Programme, Human Development Reports
http://hdr.undp.org/en/content/table-1-human-development-index-and-its-components#h

Despite the income inequality, more than 75% of countries of the region are included in the range of very high- and high HDI with only one country, Haiti in the scale of very low HDI. In terms of representation in the world stage, the governments and their central bank governors from three countries of the region (Argentina, Brazil and Mexico) are participating in the G-20 summit since 1999.

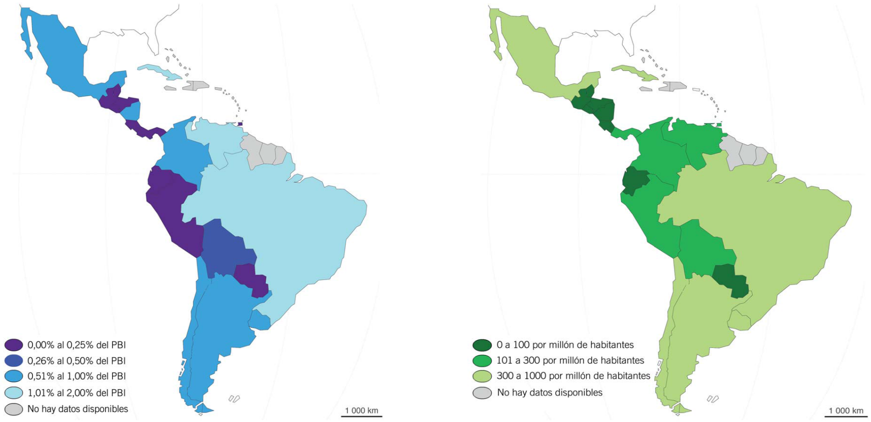
### 2.6.1 *Science, technology and Innovation among countries of the region*

The region went through moderate prosperity after the Second War World in terms of creating science and technology capacity in the academic sector with different degrees of success that later failed under the neoliberal approaches of the 1980s. Reforms in the organization of research and development started in the mid-1990s with Argentina, Brazil, Chile, Colombia, Mexico and Venezuela implementing institutional reforms. The process continued and in the XXI century the new legislations were incorporating innovation in the science and technology system (Albornoz, 2010, 78) with Mexico and Argentina completing the goal in 2000 and 2001 respectively, and Brazil and Chile in 2004 and 2005. The legislation in the case of Brazil connected the innovation policy to the objective of exports, establishing priority areas for the government actions, similar to the process that took place in Cuba in 1994 (section 2.5.7).

In terms of what has been achieved in science, the region is still lagging compared to more advanced economies: with almost 600 million inhabitants representing 8.6 % of world population and generating 4.7% of world GDP, Latin America only produces 2.9% of the world scientific publications (Lemarchand, 2010). Nevertheless some changes are perceptible, as the growth of scientific publications in the region has increased by 9% per year between 2000 and 2010 (Huggett, 2012). However, the main contribution came from the emerging economy of Brazil with more than 38,000 scientific articles, while Honduras in the opposite extreme only produced 58.

The geographic situation of how government in the region is supporting the development in science can be seen through the distribution of the gross expenditure in research and development (GERD) and the density of scientists and engineers per country as shown in Figure 2.3. The data was published in the UNESCO regional office in Montevideo (Lemarchand, 2010).

Figure 2.3. Gross expenditure in R&D and density of scientists and engineers in LAC




GERD (Gross Expenditure in Research and Development) left and Scientists per million of population in Latin America on the right (Source: Lemarchand, 2010 Graphic 17 and 27, pages 39 and 57 respectively. Original data source UNESCO, 2009). Cuba and Brazil are the only two countries of the region with both GERD between 1% to 2% and more than 300 scientists per million population.

Focussing on South America, Richard Van Noorden a science editor of *Nature* magazine (2014) revealed the strength of the region, as Brazil, which represents the third of the LAC population has been dominating in number of publications (46,300 articles in 20 years), while Argentina is having more scientists (3 per 1000 per labour force) and both countries are at the centre of the co-authorship network in the region. South American countries with less scientific productivity are more collaborative and for all countries the main international partner is the United States.

The Commonwealth countries of the Caribbean represent a population of approximately six million inhabitants and are integrated in the CARICOM[17]. The improvement in science and technology has been slow, dominated mainly by Jamaica; Trinidad and Tobago and Barbados but still research and development is not yet well connected to the productive sector (Ramkissoon and Kahwa, 2011). The region suffers the exodus of their tertiary educated labour force with Haiti having the highest rate (83.4%) in the world (Docquier et al., 2009) and one of the actions taken by the CARICOM countries was the creation in 2008 of the Caribbean Diaspora for Science, Technology and Innovation.

[17] ***CARICOM*** was created in 1972 by the head of the governments of the Caribbean Community of the Commonwealth to improve the standards of living and work in the region. The treat consists in a free trade market, free of movement of labour and capital and coordination of agricultural, industrial and foreign policy.

## 2.7 CUBAN MIGRATION

### 2.7.1 *Brief description of Cuban migration in different periods*

*Cuba as destination country:*

During the Spanish colonisation of the Island the native population was almost exterminated and Cuba became a country of immigrants. By 1750 the Cuban population was 160,000 of which a quarter was African slaves (Knight, 2008). Another two waves of African slaves (around 220,000) and Chinese indentured workers under contract (around 120,000) arrived in the country between 1847 and 1889 to work for the sugar and tobacco plantations. Other skilled migrants accounted for the demand of the growing economy including engineers and professionals and they were from United Kingdom, United States and France, among others (Curry-Machado, 2003).

Immigrants from other Caribbean islands of Spanish and French origin also immigrated to Cuba from Haiti and Santo Domingo by the end of nineteenth century. After the Spanish war ending in 1899 to 1923 around 750,000 Spanish entered the country although only 40% remained, and it seemed that Cuba was the bridge towards the U.S. and other Latin American destinations. During this period other nationalities also settled in Cuba from Europe (Italian, English, Polish, etc.) and the United States, Syria (Catholics) and Turkey (Jewish) but in smaller proportions. Immigration from other islands of the Caribbean also arrived representing more than 310,000 in 1920 (Bejarano, 2015). In 1921 the first U.S. law controlling the immigration by limiting to 3% of any nationality to enter the country except Cuba and Canada, derived in an increase in European immigration to Cuba as a temporary destination to reach the U.S.

*Cuban migration towards United States*

With the increasing working class in Cuba from the tobacco industry, workers found better opportunities in the neighbour United States opposed to the colonial authoritarian government of the island. Under the Emergency Immigration Act

1921[18] the movement of Cubans to the U.S. became more regular and a working class in Tampa and Cayo Hueso gained in size and influence helping to change of the colonial system in Cuba (Casanova Codina, 1995).

After 1959 the migration flows increased and had a political /ideological character, from 71,000 in 1950 to 163,000 in 1960 and in the next two years 14,000 unaccompanied children whose parents opposed the system were flown to the U.S. under the operation called Pedro Pan (Rosenblum and Hipsman, 2015). Other conflicts followed and more emigrants flew to the United States (Martín Fernández et al., 2007), but the characteristics of the migrants were changing, and by the post 1990 period, the landscape of the almost 1.8 million of American citizens of Cuban origin form two different types: the political (1959-1980s) and the economic (post 1990) (Eckstein, 2004).

*Worldwide migration of Cubans*

Over 150 destination countries have attracted the new Cuban migrants in the last two decades. They are essentially young almost 50% are between 20 to 40 years old from which 56% are women, this particular situation is expected to affect the Cuban population patterns as it is already showing signs of ageing (Delgado Vázquez, 2014). According to OECD data (Brücker et al., 2013) the total Cuban migration to these countries increased by 50% between 1990 and 2010, but in the case of Europe the Cuban migrant population increased more than 3 times from 25,193 to 114,708.

### 2.7.2 *Mobility of Cuban academics and scientific networks*

Mobility of Cuban researchers has been crucial for the development of Cuban science and technology in general, especially in higher education. In 1983 the total of Cuban academics were 14,075 from which 9.2% had their education abroad and 1,125 doctorates from which 60% did the post-graduate studies abroad (Holtz, 2014) being the mainly in the Soviet Union and East Germany.

---

[18] ***Emergency Immigration Act 1921***, known as Emergency Quota Act 1921 restricted the immigration establishing quotas per countries except Cuba and Canada

After 1990 the University of Havana faced shortage of resources, then mobility and scientific collaboration were essential to overcome this difficult time. In 2013 the University of Havana held 263 international projects in 27 different areas and 53 networks in 22 areas (Alonso Becerra and Rodríguez Díaz, 2014). Alonso explained the increasing collaboration with Latin America sharing 53% of the total agreements covering, programme exchanges, students and faculty visits, and networks. This new landscape of Cuban collaboration is also a consequence of increasing socio-economic and political changes taking place in Latin America.

### 2.7.3 *Cuba: managing migration*

In 1998 the Division of Consular Affairs and Cuban Residents Abroad (DACRE in Spanish) within the Foreign Ministry of Cuba was the country's department to assist the newly growing migration. Although in 1977 a group of Cuban expatriates[19] (Maceítos) in the United States visited the country and the links have remained for all of these years, it was only in 1994 that a new summit took place with Cuban emigrants from the rest of the world. On this occasion many diasporas were registered as cultural associations with different local names in different destination countries. During the last decade the cohesion between these diasporas with Cuba has been essentially political engaging with the international movement of solidarity against the American Blockade and for the freedom of the Five[20]. The network of Cuban artists working abroad is the only type of diaspora that has maintained professional links with the Cuban Ministry of Culture and other organizations such as the National Union of Cuban Artists and Writers (UNEAC).

In 2011 the Cuban Research Group at the Florida International University (FIU) coordinated an academic committee to analyse the relations of the Cuban diaspora in America with Cuba aiming to identify areas of interest for the future development of Cuba (Aragón et al., 2011).

---

[19] ***Maceitos*** were fifty-five young Cuban Americans who left the country as children under the operation Peter Pan. Through this operation more than 14,000 children were sent by their parents to the US after 1959 to avoid communist education.

[20] Five Cuban anti-terrorists imprisoned in the U.S. from 1996 until 2015

The Cuban Research Institute at the Florida International University has listed fifteen non-profit organizations of Cuban Americans with different missions among them the Cuban American Association of Civil Engineers (CAACE) created to assist members living in the U.S. to develop the highest professional skills according to the national requirements and the National Association of Cuban American Educators (NACE) with similar aims; another organization the Cuban Americans for Engagement (CAFÉ) advocatdes the pursuit and implementation of a new relationship between the U.S. and Cuba based on principles of exchange, engagement, normalization of relations, and diplomacy. Another nine institutions including ENCASA, the Emergency Network of Cuban American Scholars and Artists, which advocates for change in the U.S. relationship with Cuba (this refers to the American Embargo) are also listed, however the rest of them pursue political agendas opposing the Cuban social system.

## 2.8 SUMMARY

This chapter described key points underpinning the research subject:
How science has become a global enterprise with strong centres of knowledge in the developed North attracting an increasing mass of worldwide students and researchers.

The mobility of scientists around the world is an important part of the creation of knowledge, cross-fertilization of ideas and skills and innovation. Mobility of scientists promotes international collaboration and might contribute to building scientific capacity in less developed areas.

Globalization and the high demand for tertiary educated professionals prompted the internationalization of higher education with a massive growth of the number of university students worldwide making the universities key global players for development.

The mobility of PhD students in science and technology as well as post-docs working in high ranking academic institutions were an important source of the circulation of knowledge within the developed world but a risk to the South if the mobility of those advancing their careers turns into migration.

The views dealing with the mobility and migration of the tertiary educated, especially those graduated in science and technology, is evolving from *brain drain* to *return of the brain drain* and *brain circulation* in Latin America: The need for an observatory to monitor the scale of the process and the need to create policies to improve the work with the scientific diasporas to overcome the global trend and turn the process into a borderless extension of the national capability.

The chapter reviews the chronology of the development of science, technology and innovation in Cuba in the context of a socialist economy. Particular interest was given to the success of the Cuban biotech industry created as a strategic decision coupling the human capital attained to research institutions and the national health system to boost the economic growth. Cuba remains one of the few or probably the only country in the region without a policy or a strategy to work with her scientific diaspora.

The relations between Cuba and the United States appear to have entered a period of normalization in December 2015, but as an on-going process it is not included in this thesis.

# CHAPTER 3
# LITERATURE REVIEW: CORE METHODOLOGIES

## 3.1 INTRODUCTION

The previous chapter was an overview of different lines of research contributing to the evolving paradigm of brain drain and exploring how in the context of science as a global enterprise scientists have organized themselves in ways that offer a new examination of the same old problem.

In this chapter, given the research questions and the environment where those questions are embedded, the literature review will focus on pointing out the advantages and limitations of strategies evaluating similar problems from information science as a discipline. Information science will provide the means to make the motto *Nullius in verba*[21] of convincing results to withstand critics and to find new avenues for translating the results to *praxis*. Moreover the articles chosen to review have been recognized as classics in the field and highly cited.

## 3.2 BIBLIOMETRIC EVALUATION OF BRAIN DRAIN/ BRAIN GAIN/ BRAIN CIRCULATION

### 3.2.1 '*Studying the brain drain: can bibliometric methods help?'*

Contributed by Grit Laudel (2003)

Journal of publication: *Scientometrics*

In 2003 the anthropologist Grit Laudel pioneered the idea of evaluating the brain drain using more robust methodologies to avoid arriving to conclusions that were not adequately supported. First addressing the definition of brain drain, Laudel argued some authors considered brain drain when a country or a region lost their best scientists to another country. However she questioned the ambiguity of the methodologies used to define or measure who are the *best scientists*, mainly

[21] Latin expression for "on the word of no one" or "Take nobody's word for it" and it is the motto of the Royal Society. John Evelyn and other Royal Society fellows chose the motto soon after the founding of the Society.

because it is relative to a specific field of research. In her research methodology she proposes three steps:

1. *Delineating a speciality*, in her case it was Angiotensin[22], because it was an easily identifiable biomedical term attracting specialists from different disciplines opposed to the field classification of Institute of Scientific Information (ISI) which was too broad to fulfil the purpose of selecting an area of scientific research. In her article Laudel reviewed thoroughly why co-citation analysis and co-word based methods still failed to delineate a fine-grained structure of research areas.
2. *Identifying the speciality elite*, which in the case of her study was the list of participants in the Gordon Research Conferences[23] on Angiotensin to start with, then using *ISI Essential Science Indicators* selecting those top scientists according to their performances.
3. *Identifying the international mobility of elite scientists*, for this purpose Laudel found that the most suitable method of studying mobility of scientists was the use of bibliometrics by searching author affiliations in the databases of their publications and follow the individual mobility through different organizations across fifteen years of search.

1. *Delineating speciality*. This methodological paper applied to the research topic of Angiotensin provided a robust evidence of brain drain towards the U.S. However, the approach leads more to brain gain by the U.S. than identifying those countries losing their elite scientists. Nevertheless, it is a classic paper often cited because of the clarity of the methodology and therefore it is an important contribution to our research.

2. *Identifying the elite scientists*. The elite of scientists in such narrow subject is likely to be an international invisible college of scientists. Then by looking into the narrow field such as Angiotensin, it is more likely to end in a mixture of nationalities with a

---

[22] **Angiotensin** is an oligopeptide hormone responsible for the constriction of blood vessels and therefore for the increase of the blood pressure. This oligopeptide also stimulates the release of aldosterone, another hormone that promotes sodium retention in the kidney, which increase the blood pressure as well.

[23] ***Gordon Research Conferences*** are prestigious scientific meetings where top scientists are chosen to present frontier research not yet published and researchers from all over the world attend to learn from the debates. They started as summer sessions in he Department of Chemistry of John Hopkins University in 1920.

probability of finding a particular representation of a nation proportional to the size of the number of scientists in that country. A small country will have if any, an insignificant number of scientists in such a narrow field of research. The purpose of this present research is to characterize the Cuban scientists working in European institutions of S&T probably at different stages of their careers and they are not necessarily elite members of a particular research field. However using tools such as *ISI Essential Science Indicators*, or a similar bibliometric engine and database will allow to follow places of research and the scientific performances of the sample of Cuban scientists in Europe.

Regarding how to find a scatter sample of scientists, in the current study the use of different professional social networks such as *ResearchGate*[24], *LinkedIn*[25] and Academia.edu[26], was the successful choice, which was not available or did not have widespread use at the time of this classical methodological paper by Grit Laudel. Those professional social networks (PSN) provide reliable information about where the scientist has completed the studies and the organizations were they worked, as well as the present affiliation. The PSNs allow establishing either a direct contact with the scientist or directing them to a website for further collection of information, or survey questionnaires.

3. *Identifying the international mobility and migration of elite scientists*. One of the procedures used by previous researchers to find out information about the scientists

---

[24] ***ResearchGate:*** Founded in 2008 by a virologist and computer scientist, Ijad Madisch. According to *The New York Times* the website began with very few features, and then developed over time based on input from scientists. Adoption of the site grew rapidly. From 2009 to 2011, the site grew from 25,000 users to more than 1 million (Information from in Wikipedia.org)

[25] ***LinkedIn:*** Founded in December 2002 and launched on May 5, 2003, it is mainly used for professional networking. In 2006, LinkedIn increased to 20 million viewers. In June 2013, *LinkedIn* reports more than 259 million acquired users in more than 200 countries and territories (Information from in Wikipedia.org)

[26] ***Academia.edu:*** Launched in September 2008 it is the site for over 11 million academics registered as users in 2014. The platform can be used to share papers, monitor their impact, and follow the research in a particular field. Richard Price founded *Academia.edu*. *Academia.edu* is part of the open science or open access movements. *Academia.edu* seems to reflect a combination of social networking norms and academic norms (Information found in Wikipedia.org)

was looking at their Curriculum Vitae in the Internet. Other methods reviewed such as searching biographical information in Scientific Associations were equally unsuitable to find addresses over time. Laudel demonstrated that bibliometrics as a tool was the best methods for tracking the mobility and migration of scientists through different organizations, and for her study she used three databases: *PubMed*, which is biomedical orientated; *Web of Science* with wider scope and *INSPEC*, which also covered physicists and engineers.

The main problems found were first, the affiliations for all authors were missing and therefore, it was necessary to conduct an additional search for the original journal (either online or from the hard copy). Secondly, homonyms were common and additional checks had to be performed by looking to the names of associated co-authors.

This methodology seems robust, but there is a pitfall in the *nationality* associated to the *elite scientist* by using the address of their first publication, assuming it came from their PhD studies. The international mobility of PhD students is considerably high (DAAD, 2014; Stephan, 2012, 152) and therefore her result probably underestimated the magnitude of the phenomena.

Briefly, Laudel's approach started with the list of participants at the Gordon Research Conferences[27], selecting 215 researchers in angiotensin field after using ISI Essential science indicator and citation score. Those 215 top scientists generated 13,202 articles in ten years and by using co-citation analysis 150 were chosen as *elite scientists*. The result showed that 59 elite scientists out of 131 always remained in U.S.; 34 moved to the U.S. of which 14 moved back to the country of their PhD studies and 16 migrated to the U.S.; another 3 moved from the U.S. to another country and 35 elite scientists remained in the country where they did their PhD.

The paper is a classic in terms of methodology to prove that the brain drain in science is a real problem as the author concluded:

---

[27] ***Gordon Research Conferences*** are a group of prestigious international scientific conferences organized by non-profit organizations. The conference topics cover frontier research in the biological, chemical and physical, and their related technologies. The conferences have been held since 1931, and have expanded to almost 200 conferences per year.

‘*These results confirm science policy’s fear of a brain drain: A drift of elite scientists towards the USA appears to exist’*

There is no contribution identifying which countries were affected by the brain drain.

3.2.2 *‘The evolution of the brain drain and its measurement’*
Contributed by Andrew Plume (2012)
Journal of publication: *Research Trends*

The review of this article is included here because the author addresses the brain drain in a particular country, in this case United Kingdom. However Andrew Plume’s approach also reveals the advantage of *brain circulation* or brain networking arising from a theoretical framework of mobility and migration of scientists (Ciumasu, 2010). Here Plume uses the *Scopus* author’s profile data to derive a history of the mobility of the author. Different from the previous described method used by Laudel, Plume defined the author *origin* by taking as *a proxy* the location shown in the affiliation of his/her first published article. Another important contribution is that the study was not confined to an *elite* of scientists, neither to a particular field of research, but to differentiating them according to their mobility pattern.

Conceptual and methodological issues:

1. *Unambiguous author identification*. This problem is frequent in bibliometric research due to common family names in almost every language, or different variants of the same names. Hispanic scientists for instances, have two surnames and often one of them is attributed to a middle name, increasing the variants of names from the same person. *Scopus*[28]*,* the database used by Plume has an improved authors-profiling algorithm in order to identify individual researchers precisely with the *Scopus* Author Identifier (SAI). Each author has as a result a unique ID number. This SAI, according to Plume, processes different spelling or combinations of the name of the

[28] ***Scopus*** is another database owned by Elsevier covering approximately 20 thousand peer-reviewed journals in scientific, technical, medical and social sciences. This database also covers patents.

author as it appears in different publication by using a sophisticated algorithm based on some data element associated with the article, subject of research, co-authors, etc.

2. *Defining an UK researcher*. Databases of publications in scientific and technical sciences do not capture the author's nationality or place of birth because it is not reflected in any scientific article. Plume makes the assumption that a scientist is from the country shown in the affiliation of his/her first publication, or from the place shown in affiliation of the majority of the publications. The design of this study responds to the interest from the Department of Business Innovation and Skills (BIS) to look at research mobility (BIS, 2011) in UK, therefore a UK researcher was defined as any author with at least one article using UK address in the author's affiliation. Some criticism might be applied to the way researchers were classified as British, but Plume explained that the opposite can also happen and therefore he assumed that the error is evenly distributed. However this is a point to be considered. The size of the sample in his study was over one million names of UK researchers and therefore those errors are unlikely to change the general findings of the study.

3. *Active researcher.* A definition of what should be called an active researcher had to be put in place to eliminate a high proportion of authors with relatively few publications because they left research and therefore should not be considered career researchers. Thus an active researcher in his study is one who has published at least once in the last five years of the period from 1996 to 2010; and at least 10 articles in the entire 15 years, or for those with less than 10 articles in the whole period, but with more than at least 4 articles in the last five years (2006 - 2010). After applying this filter for active researchers, the number of researchers was reduced to 210,923 from the original 1.5 million UK researchers. Here could be another source of lack of precision. The author did not comment about the cases of changes in surnames due to marriages mainly in female researchers.

4. *Definition of short- and long-term mobility*. Andrew Plume claims that bibliometric tools help to understand patterns of mobility and migration of scientists by using the author's affiliation field associated to each publication through his or her active life as a researcher. This is another approximation by assuming that any particular scientist is producing science in a given place. Scientific mobility is part of the natural

dynamics of modern science and not all movements due to collaboration are shown in the author's affiliation, the researcher might sign using the country providing the funds and not where the research was partially carried out as part of the international collaboration. However, given the impossibility to follow with such precision the movement of scientists, it is a plausible approximation. Andrew Plume explained that all scientists could be followed because *Scopus,* the database he used, shows all author's affiliations of each publication, a feature not always available in other databases. The cut off time fixed by Andrew Plume to classify the scientist mobility was 2 years giving the following categories shown in the following table 3.1:

Table 3.1 Categories of movement of scientists (source: Plume, 2012)

| Type of mobility | Length | Direction |
|---|---|---|
| Migratory (**M**) | Stay abroad for two or more years | Return home $\mathbf{M}_{\boldsymbol{in}}$ |
| | | Remained abroad $\mathbf{M}_{\boldsymbol{out}}$ |
| Transitory (**T**) | Stay abroad less than 2 years | Mostly publishing as UK: $\mathbf{T}_{\boldsymbol{in}}$ |
| | | Mostly publishing as non-UK:$\mathbf{T}_{\boldsymbol{out}}$ |
| No mobility (**H**) | Researcher without any apparent mobility (only UK address in author's affiliation) Home | |

*5. Indicators to characterise the groups*: Those indicators chosen for this study with the purpose of understanding the contribution of mobility of UK-scientists to the creation of knowledge in UK were: productivity and seniority. *Productivity* refers to the number of articles per year since the first publication of each author normalized to the mean of all UK researchers in the fifteen years period 1996-2010. *Seniority* refers to the length in years of their scientific contribution, as the number of years since the first publication appears during the fifteen years between 1996 and 2010 and then normalizing to all researchers in the same period.

*Significance of the Laudel and Plume papers*

These details from these two articles addressing the subject of brain drain or brain circulation are reviewed to stress the importance of defining the nature of the problem you want to understand and the questions to answer, before defining the methodology and consequently choosing those bibliometric indicators, which might help.

*Which scientists would be included in the study?* When focusing on *elite scientists,* as in the work of Laudel (2003), the methodology aims to choose the best in a particular subject, which might not be big in terms of number of scientists; therefore you finish with a very small sample but very well defined as an elite. Another paper in 2009 also worked with a very small sample drawn from the list of top physicists in the world by the number of times they were cited (http://www.isihighlycited.com) and from that list other filters were applied to end with a sample of 150 (Hunter et al., 2009) world elite of physicists.

In the other extreme and less orientated to a subject or a discipline is the work of Plume (2012), in which the designed methodology aims to analyse the overall contribution to science from the movement of researchers of any particular territory by evaluating stocks and flows and their attributes of quality (productivity and seniority).

*Where to find the scientists?* The databases used in these two articles were different. The study of elite scientists by Laudel covered three databases: *PubMed, Web of Science and INSPEC* with the purpose of searching every possible discipline contributing to the specific subject of Angiotensin, from crystallography to biochemistry or social sciences. The study of mobility by Plume used only *Scopus*, as a database where almost all articles with UK address in the author's affiliation are stored.

There are other bibliographic databases or engines available with different scope and designs to carry out bibliometric studies that are taken into account in the current study.

*Who are the most productive researchers?* The research carried out by Plume showed that the mobile scientists are the most productive active researchers in UK while those who published only with UK affiliations were the less productive. The transient researchers account for the larger group (44.4%) with the highest productivity, but those transient based in non-UK institutions are by far the more productive and their main countries were United States, Germany, France, Italy and Australia.

## 3.3 STUDIES EVALUATING PATTERNS OF MOBILITY OF SCIENTISTS

Mobility of scientists is essential for the advance and development of both the researcher's personal career and for science as a whole but in the process it generates poles of high quality of science at the expenses of weakening of human capital other regions. In this section another three articles are reviewed in detail concerning the mobility of scientists using different definitions for the term mobility and therefore the outcome of their findings do not necessarily complement each other.

In the previous section both articles used the scientific publications of the researchers as the starting point to establish the country of origin of the researcher. In this section two of the reviewed methodologies used a different approach to find the country of origin of the scientists by sending questionnaires to the sample of study. The third article intends to study mobility between stages of the researcher's career, from the country of PhD research to the country of post doc research and more importantly the link between mobility and international collaboration.

### 3.3.1 *'Patterns of international mobility of researchers: evidence from the GlobSci survey'*

Contributed by Chiara Franzoni, Giuseppe Scellato and Paula Stephan (2012)

Journal of publication: *Nature Biotechnology*

This paper was the first study to look at the mobility of a considerable number of scientists away from their country of origin working in sixteen other core countries. The study explores the reasons behind the decisions of mobile researchers to return to their countries of origin. It also provided a new data on international mobility patterns of researchers working in four different fields of science, exploring the links between migration and international collaboration. The leading researcher, the economist Paula Stephan has published many articles and books in the field of the economics of science relevant to the present research, but mainly addressing the patterns of the science in the U.S. in relation to the foreign-born scientists and engineers (Stephan and Levin, 1991; Levin and Stephan, 1999; Stephan and Levin, 2001; and Stephan, 2012, 183).

The methodologies used in many of those articles analysing the contribution of foreign-born scientists and engineers to the U.S. are based on the classical work of Alfred Lotka (1926), Derek de Solla Price (1986) with regards to the small proportion of scientists (~6%) writing the majority of papers (50%), as well as the classical work of Garfield (1979) in the skewed distribution regarding the way articles were cited.

*Methodology and methods in the GloSci survey relevant to the current research*:

*1. Selecting the fields and the countries*. The authors defined the study in four fields of sciences: biology, chemistry, earth and environment and material sciences, although the authors do not specify the reasons for this particular choice, they found previously that those fields of sciences attracted three times more foreign-born researchers than fields in engineering (Stephan and Levin 2001). The countries selected are leading and emerging countries generating 70% of all articles in the chosen fields of science. The countries were: Australia, Belgium, Brazil, Canada, Denmark, France, Germany, Italy, India, Japan, Netherlands, Spain, Sweden, Switzerland, United Kingdom and the United States. China was originally included, but the authors decided to withdraw China from the sample due to the very low response rate to the survey they sent to the authors with Chinese addresses.

2. *Selecting the active researchers for the survey.* Active researchers were those who published in the year fixed for the study: 2009. To construct the sample they selected all journals of the disciplines mentioned above classified by the Institute for Scientific Information (ISI) and sorted by impact factor of the last available report from Web of Science (*Journal Citation Report Thomson and Reuters*). They proceeded by randomly selecting the journals of each quartile of the impact factor distribution. The aggregate selection corresponded to approximately 30% of journals publishing in the four disciplines (biology, chemistry, earth science and material science). They downloaded full bibliographic data of all published articles included in the selected journals, and then retrieved the e-mail address of the corresponding author of each

survey articles (in case of multiple corresponding authors, they select the first in the list). They randomly selected another record in cases of authors appearing repeatedly. The main language of the survey was English but to ensure high response they also made the invitation e-mail and the questionnaires in the other six relevant languages. The online questionnaire was developed through the platform Qualtrics[29]. The content included a diverse set of 32 pages with more than 200 questions designed to evaluate determinants on flows and international collaboration linked to the mobility.

*3. Questionnaires and dataset.* The authors argued that the best possibility of finding characteristics of the authors not available from bibliometrics or Curriculum Vitae was going to be through the questionnaire. A question was used to determine the country of origin by asking the authors to refer to the country of residence at the age of 18. If the respondent is working in a country different from the country of origin they were asked to answer and rate (1-5) 12 reasons behind their decision to stay. In their dataset Franzoni et al. recorded the individual information obtained from downloading bibliographic data of their publication and the characteristics of the corresponding author and co-authors of the surveyed articles (international collaboration, emerging or multidisciplinary field of research, etc.). It also included age, gender, job position, type of affiliation, international mobility data (reason for leaving the country, period of education or working abroad) and the type of initial entry to the host country.

4. *Econometric analysis*. The methodology in this section was developed to provide an econometric model to investigate the correlation between mobility and the scope and quality of the international research network. The interest in identifying links between mobility and international collaboration is relevant to the present research, although this present study has not encompassed a specifically econometric approach.

Through the methods described Franzoni et al. reached 47,304 records of articles corresponding to approximately 30%, of all four disciplines chosen. The response rate from the authors was 40%, however they only included questionnaires fully

[29] ***Qualtrics*** is a private research software company, based in Provo, Utah. The company was founded in 2002 by Scott M. Smith, Ryan Smith, Jared Smith and Stuart Orgill [http://www.qualtrics.com/]

answered and therefore they processed 17,182 authors in which the country of origin was known.

The authors do not mention how representative was the sample regarding the total number of scientists per each of the sixteen countries included in the study. However calculating how representative those samples were will be an important starting point for informing the size of the sample of the Cuban researchers in Europe. For that purpose the number of researchers per country of study was added according to the UNESCO science report in 2010. Table 3.2 shows the number of surveyed researchers in the country of work, those who answer the survey and the total number of scientists in countries of study and the proportion the *GlobSci*-sample represents of the total number of the scientists per country.

The numbers in the UNESCO report are researcher headcounts, except Australia, India, Canada and the U.S., which represented the full time equivalent (both values for the year 2007). The overall representativeness was 0.4%, however the difference between countries varied from 0.19% for Japan and 1.31% for Italy and the reason seems to be related to the response rate as found in the supplemented data not shown in the published *Nature Biotechnology* article.

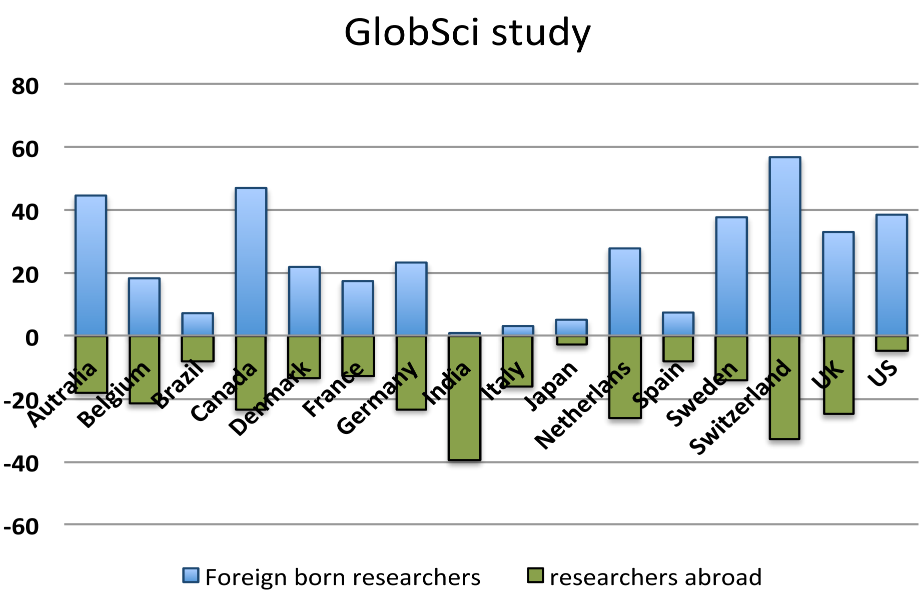
Table 3.2 Size and representativeness of the sample in *GlobSc*i study

| Country | GlobSci Surveyed researchers | Of which complete | UNESCO number of researchers | Sample representation (%) |
|---|---|---|---|---|
| Australia | 1571 | 629 | 87140 | 0.72 |
| Belgium | 706 | 253 | 51278 | 0.49 |
| Brazil | 1532 | 702 | 210716 | 0.33 |
| Canada | 2455 | 902 | 139011 | 0.65 |
| Denmark | 513 | 206 | 42992 | 0.48 |
| France | 3839 | 1380 | 215755 | 0.64 |
| Germany | 4380 | 1187 | 273542 | 0.43 |
| India | 1380 | 525 | 154827 | 0.34 |
| Italy | 2779 | 1792 | 137163 | 1.31 |
| Japan | 5250 | 1707 | 883386 | 0.19 |
| Netherlands | 1036 | 347 | 45554 | 0.76 |
| Spain | 2303 | 1185 | 206190 | 0.57 |
| Sweden | 882 | 314 | 73117 | 0.43 |
| Switzerland | 919 | 330 | 43220 | 0.76 |
| United Kingdom | 3695 | 1205 | 378710 | 0.32 |
| United States | 14059 | 4518 | 1425550 | 0.32 |
| Total | 47299 | 17182 | 4368151 | 0.39 |

*Summary of the results and relevant points*:

At the time of starting the present study the *GlobSci* research was the most complete and broadest study carried on in this type of research. It included 16 countries of which two Brazil and India have never been studied before. The result for foreign-born researchers in the U.S. is in agreement with robust data from the Statistics department of National Science Foundation for foreign-born doctorates. It also provides strong evidence regarding the migration of scientists towards advanced economies in four areas of science studied with Switzerland, Canada and Australia accruing over 40% of foreign born researchers; United Kingdom, United States and Sweden following closely and Germany, Netherlands and Denmark having between 20-30% of researchers living in another country at the age of 18. The country with more scientists abroad was India with 39.8% of them living in the country at the age of 18, but the country with the unexpected higher percentage of foreign born researchers was Switzerland with 56.7%. The country with the lowest emigrant scientists was Japan with only 3.1% and followed by United States with 5%. Figure 3.1 shows the results for the 16 countries of the *GlobSci* study.

Figure 3.1 Mobility of scientists in 16 countries of the *GlobSci* study.




Graphic made with the values reported in Franzoni et al., 2012. For a particular country such as Australia, 44.5% of the researchers working in this country are foreign-born (blue) while 18.3% Australian are working abroad.

The second most important finding was that 40% of those foreign-born scientists reported having kept research links with the country of origin using econometric analysis to support their findings. Through the analysis of determinants they found that the likelihood of having an international collaboration was almost double (13.8 percent) than the native scientists even when they had experience working abroad.

In terms of international collaboration the *GlobSci* study found that the internationally co-authored papers with foreign-born or returnee corresponding author tend to have on average a higher scientific standing than those of native non-mobile corresponding authors. Moreover, the quality of those research articles seemed to be driven by migrants who did not get the PhD in the destination country but rather they came for a post doc position.

3.3.2 *'Science on the Move'*

Contributed by Richard Van Noorden (2012)

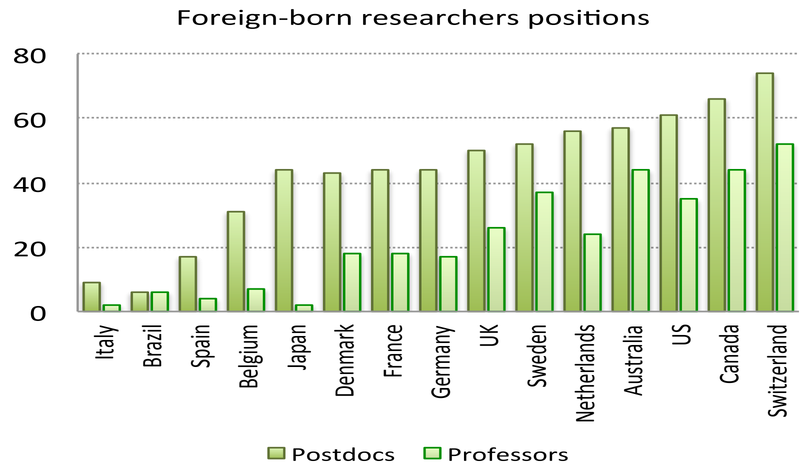
Journal of publication: *Nature*

This paper came out simultaneously with the Chiara Franzoni and collaborators contribution in 2012 and published in *Nature* (London) and some of the *GlobSci* data are also included in this editorial article. The results came from a large questionnaire the *Nature* magazine sent to readers of the journal. The size of the sample corresponded to 2,300 readers, but they were mainly from United States and Europe.

This paper is included the literature review chapter because of the particular feature found regarding the seniority of the researchers. The interpretation by Van Noorden of the *GlobSci* data referred to the foreign-born post docs and professors inferring that the difference in proportion of each group is due to the high mobility of young researchers. As a working hypothesis it might justify the questions the survey of *Nature* asked to 2,300 readers concerning mobility, however as it is discussed later the sample in this article is *readers* of Nature magazine.

The author did not describe any methodology underpinning the research, however the questionnaire had 42 questions and 100 sub-questions which made it possible to identify the changes in the landscape of science as Van Noorden depicted (Figure 3.2).

Figure 3.2 Foreign-born researchers by their job-position in the destination country




Source: Data taken from Van Noorden's article

The paper is also an account of the opinion of experts in international mobility of scientists and successful scientists apparently interviewed by the author Van Noorden, (but not clearly stated). Interestingly 36.4% were responders who answered YES to the question: *Are you currently living outside the country of upbringing (where you attended secondary school)?* This was the author's approach to identify foreign-born readers of the *Nature* magazine.

Questions related to their attitudes towards migration show that, as pointed out by the author, the younger were also more willing to move,

> *'Those who had just obtained their PhDs were much more likely to be living outside their country of upbringing than those with more senior position'.*

Supported by the survey and the views of researchers and experts in the field of science policy, Van Noorden argued that the countries with high GDP attract foreign-born scientists, but the wealth is not the unique reason as the case of Japan showed few foreign-born researchers in senior positions. Countries with a dynamic, flexible and competitive funding and advancement of science are attractive to scientists, who also look at how their families fit into the new society. Another point stressed by Van Noorden is how '*countries should have a strong-enough base science to interact with* *a globalized and mobile world*' referring to Germany that encourages scientists to go abroad and at the same time develops a strategy by which researchers return home.

Although this article placed interesting questions to the readers of *Nature* sensing trends in mobility and migration of scientists, from the point of view of the methodology it is very weak. The main critic is that the readers were assumed to be scientists. The answers are not associated with any qualitative description such as field of research neither to any other attribute of the researcher performance such as their publications. If the objective was to predict how scientists would behave in the future it might need to account for what they have done up the present in science.

Analysing this article confirms the need to support any investigation on mobility, migration or networking of scientists with bibliometric tools using scientific information databases accounting for the researcher behaviour.

### 3.3.3 '*Studying Scientific Migration in Scopus'*

Contributed by Henk F. Moed, M'hamed Aisit and Andrew Plume (2013)

Journal of publication: *Scientometrics*

The main purpose of the authors was to investigate to what extent did *Scopus* enable the study of a researcher's scientific career? The author explored in this pilot study a possible methodology to follow patterns of migration of researchers between countries using publication data. They also have another set of important questions, which are relevant to the present research:

- The movement of young researchers away from the country where they obtained the PhD
- The relationship between the degrees of migration and collaboration with the countries involved
- How bibliometric statistics of number of active researchers correlate with the OECD statistics of number of researchers per country.

The importance of this article is related to the evaluation of the advantages and limitations of using the database of *Scopus* in the present research.

The scope of the investigation described by Moet et al. responded to the main interest of examining and testing *Scopus* for the purpose of analysing migration of researchers and institutional collaboration:

1. *Definition of the sample*: The pilot study was designed for a longitudinal analysis of a set of researchers who started their career in the XXI century and followed for 10 years.

2. *Author affiliation-linking and author-profiling in Scopus:* Studying migration of researchers through the publication history of authors requires details of all author affiliations contributing to the publication. This information is not always complete for all co-authors in databases of scientific publication, but it is recorded in *Scopus* for all authors if it was declared in the original article. According to Moed and collaborators, *Scopus* provides the author profiling by assigning to each researcher a unique identification number built through an algorithm to ensure precision.

*Methodological assumptions discussed in this article included*:

1. *Active researchers*: They reviewed the contribution of Derek de Solla Price (1980) and his definition of types of researchers as: continuants, new movers, movers, transients and active but not publishing, according to the pattern of publications before and after any particular year as shown in Table 3.3. This classical definition might be used in the characterisation of the active researchers included in the present study and it is illustrated in the following table of characterisation of authors in a year T:

   For the trend analysis they suggest the use of the aggregate number of publications as a good proxy for the number of active researchers in the period analysed (1999-2010).

Table 3.3 Classification of the active researcher according to their pattern of publications

| Type/Year | T-4 | T-3 | T-2 | T-1 | T | T+1 | T+2 | T+3 | T+4 |
|---|---|---|---|---|---|---|---|---|---|
| Continuants | | | X | | X | | | X | |
| Newcomers | | | | | X | | X | | |
| Movers | | X | | | X | | | | |
| Transients | | | | | X | | | | |
| Active but not publishing[30] | | | X | | | X | | | |

2. *Author affiliation*: They used the author's affiliation recorded in *Scopus*. The author affiliation of *Scopus* is extracted from the original articles. They previously found that less than 9% of this information was missing because it was not in the original article.

3. *Diachronous and synchronous approaches*: This approach was used to analyse the movement of PhD students assuming them to be Newcomers (1999-2000) and followed them as inactive or active abroad or in the country where they started for the rest of the period up to 2010 (diachronous approach). For those active researchers in the synchronous approach, they analysed those who were active in 2008-2010 and started publishing in 1999-2000 either in the country of analysis or abroad.

The terms diachronous and synchronous were originally used by information scientists studying the age distribution of journals according to the way they were cited. The diachronous approach consists of analysing the distribution of citations gained over time to a publication (prospective analysis) in a given year by subsequent literature. The synchronous approach on the other hand, considers papers cited by a publication of a particular year and then analyses retrospectively the distribution of their age. These approaches are relevant for the impact factor of journals (Gänzell, 2004).

[30] Moed found consistently that the per cent of researchers which are not publishing in a particular year, but having at least one article in the four previous and at least another in the following four years is approximately 15% (comment in Moed et al., 2013)

Moed and his collaborators gave an original use to the terms synchronous and diachronous as they apply it to the analysis of the movement of young researchers for the time span from 1999 to 2010. First they selected researchers *newcomers* in 1999-2001 for each of the five countries they were looking at and then searched *prospectively* for the country of affiliation in those *active* in 2008-2010, meaning in the assumption the place where they moved to after 10 years. Secondly, the *retrospective* analysis, taking those active researchers in 2008-2010 for each of the countries they were studying and then looking back at where was the affiliations of those *newcomers* in 1999-2001. This model allowed them to characterise the inwards and outwards movements of young researchers in the five countries of study.

The methodology seems appropriate for evaluating the mobility of researchers at least for the countries they studied such as Germany, Italy, Netherlands, United Kingdom and the U.S. For instance, it was possible to identify that young Egyptian researchers went to Netherlands in 1999-2001 for a PhD and returned to their country of origin by 2010. However, the degree of certainly can only be acceptable because those five countries are countries with a large population of active researchers: in other words they are destination countries. Newcomers in 1999-2001 in those countries were between 31,900 for Netherlands and 210,500 for United States. The model might not have the same outcome for either small countries or countries with a small number of active researchers.

Regarding the correlation between mobility and international collaboration results include other countries, such as: Australia, Austria, Belgium, Brazil, Canada, Czech Republic, China, France, Hungary, India, Italy, Japan, Korea, Russia, Spain, Sweden, Switzerland, United Kingdom and the United States. Although they found values of 0.8 and 0.9 for the correlation coefficient of Pearson for mobility and international collaboration, the way they related the two variable $x$: per cent of international co-authorship and $y$: per cent of outwards researchers were not directly linked, then the results only can be interpreted as two independent process, but behaving similarly.

They acknowledge that the *split author* and *merge authors* is a source of error in *Scopus* author profiling. The first one, from the author's point of view, the recall is low, but the precision is high; while in the second type of error, it is the opposite: the recall is high from the author point of view, but the precision is low. The authors insisted that the objective of the study was to follow patterns of mobility of scientists using *Scopus* not at the individual level but assessing migration at higher aggregation levels, particularly among nations. Nevertheless there is no attempt to calculate or estimate this source of error.

## 3.4 INTERNATIONAL COLLABORATION AS SCIENTIFIC NETWORKS

### 3.4.1. '*International collaboration: a new dynamic for knowledge creation*'

Contributed by Caroline S. Wagner (2004)

*Doctoral Thesis, Amsterdam School of Communication Research, University of Amsterdam*

The document chosen for review is a doctoral thesis awarded to Caroline S. Wagner in the Amsterdam School of Communication Research in which the author provides evidence for the new dynamic of global science including in the analysis countries of the developing world. Preliminary observations behind this work were:

- *The rapid increase in international co-authorship in scientific literature from 8% in 1980 up to 15% in 1998*
- *The international collaboration was becoming more geographically disperse and new countries were improving their scientific capabilities (Wagner et al., 2001)*

The research questions are placed in the context of global science aiming to study the new dynamics of the international collaboration of scientists in time and fields. Essentially the ideas underpinning her work are based on the fact that communications (scientific publications) leave traces that can be studied as indicators (Leydesdorff, 1990) and second the field of authors' affiliations of scientific publications in electronic databases was available to study the geographic contribution of science in time.

The methodology of choice for Wagner was based on network analysis, a strategic tool used previously by others but for different purposes, such as characterizing the evolution and topology of co-authorship collaboration in mathematics and neuroscience (Barabasi [31] et al., 2002) using authors information in electronic database.

1. *Source of scientific publications*: The author stressed the importance of choosing a reliable database in which all author affiliations were properly identified, deciding then for the CD-ROM of *Science Citation Index* for the years 1990 and 2000.

2. *Co-authored publications*: Defined as those publications having at least two co-authors, and international publications as those having at least two different international addresses. Collaboration then should be understood as co-authored publication.

3. *Type of publications*: No distinction was made between types of documents and therefore, journal articles, reviews, letters and proceedings were equally processed.

4. *Codification of International linkage*: The unit of analysis was at a national level based on the fact that science is still funded through political governance structures. International linkage was assumed to represent international collaboration, however the authors reviewed some critics of this assumption when co-authors are included by their ranking and might not mean necessarily direct collaboration in the signed article. She argued that even in this case, when analysing country linkage, the inclusion of those not directly involved in the research probably are involved in supporting the international collaboration.

5. *Attributing articles to participating countries*: Different types of counting were reviewed to account for the occurrence of countries per document. The author discussed those that are currently used by other authors: fractional, link, integer counting. *Fractional counting* is the number of any particular author (in

[31] Barabasi et al. 2003. Although not reviewing this paper here because of the complexity of the mathematical modeling of the complex systems analysed, it should be noted they processed 210,000 articles of neurosciences and 70,901 papers of mathematics.

her case country) represented by the share of each participant. *Link counting* is the number of links represented among participants with each bilateral counting of <1>. *Integer counting* gives the value <1> to each occurrence of authorship by country participating in the document. The option used by Wagner was *integer counting* as the best for analysing the international collaboration. If in a document more than two authors belong to a given country, the integer counting should be assigned as one for that country as shown in Table 3.4.

Table 3.4 Comparison of different methods for counting participating countries

| TYPE OF COUNTING | COUNTRY OF AUTHOR AFFILIATION (number of authors) | | | | |
|---|---|---|---|---|---|
| | U.S. (1) | SPAIN (1) | GERMANY (1) | BELGIUM (1) | FRANCE (2) |
| FRACTIONAL | 0.16 | 0.16 | 0.16 | 0.16 | 0.32 |
| LINK | 5 | 5 | 5 | 5 | 4 |
| INTEGER | 1 | 1 | 1 | 1 | 1 |

6. *Occurrence tables and matrices*: The data was processed and two occurrence tables were generated. The first occurrence table involved the accounting of participating countries per document, which was used for creating an asymmetric matrix with one axis for countries and the other for documents. This matrix was then used for Factor Analysis. The second occurrence table involved a binary matrix of equal axes representing participating countries and the frequency of sharing documents recorded in each cell. This matrix is used for network analysis.

The work of Wagner has provided a rationale for the use of bibliometric method with the purpose of viewing the international linkages as a network of interconnecting communications. The analysis of international co-authored documents through the prism of network communication allowed an integral vision of the dynamic of science and its evolution. Wagner demonstrated that the global network of science was expanding and becoming more decentralized with new countries joining the dominant clusters of developed countries. The experimental design also allowed the author to show that more countries from the periphery were now taking part in the global science landscape as they joined in clusters of strong hubs of science, and increasing in their own connectedness in certain regions (Latin America), although still others remained disconnected (Arab countries).

As Wagner emphasized the science system is evolving into a network structure operating at global level and it is predominantly self-organized. In a subsequent study Wagner and Leydesdorff (2005), showed that this type of network was not random. It seems she argued that the science system at global level is providing a new system of reference other than those of the national systems.

Another important evidence coming from Caroline Wagner is that the network representation of the global science reflected the historic context in which the network was evolving as well as the dynamic of it. Because the two points of study were 1990 and 2000 the following events were clearly shaping the global network: the break-up of Soviet Union and the end of the bi-polar world; the re-unification of Germany; the growth of information technology and communication; the rise of the European Union and the growth and ways science was funded and the globalization of industry.

In any quantitative analysis, the robustness of the finding depends on the size of the sample. In this particular case Wagner processed 51,596 and 121,832 internationally co-authored documents in 1990 and 2000 respectively, which generated 147,441 and 393,503 country addresses respectively.

The research undertaken in the present study is limited to a very small sample and is not aiming to confirm, neither to confront the conclusion arrived by Wagner, but to build on her contribution of this ecosystem and explore which features might be emerging in the network of scientific diasporas that could add another layer of strength to the national scientific capacities of countries of the periphery and the consequences it might have for science governance in both sending and destination countries.

### 3.4.2 '*Network structure, self-organization and the growth of international collaboration in science*'

Contributed by Carline S. Wagner and Loet Leydesdorff (2005)

Journal of publication: *Science Policy*

This article is a further investigation of the study on international scientific collaboration viewed as a global network of science. The specific hypothesis that the authors intend to test is that the international collaboration followed through co-authorship publications is a self-organized network that can be studied through social network analysis.

Essentially the authors explained that previous research still could not fully account for the rapid increase of the international collaboration and therefore they were expecting that the distribution of international collaboration followed a power distribution characteristic of networks of preferential attachments in which some nodes have few links while others have huge numbers of connections. The typical distributions found in the network analysis of co-authorship for different disciplines are called scale-free networks. In those cases the $P(k)$ distribution has a power-law tail. Other network distributions have exponential decay and are called exponential networks.

Wagner and Leydesdorff processed their 2000 data of international co-authorship for individual disciplines and using the new open source LOTKA[32] software they analysed the $P(k)$ distribution for each one. They explained that this kind of distribution analysis was not available in the Statistical Package for Social Sciences (SPSS). Then the objective was to show that the distribution of international co-authorship per discipline of science in a given year (static) would have the typical fat-tail shape on the right side of the log-log graph and a hook shape on the left side of a scale-free network (Barabási et al., 2002). Their results evidenced that indeed, the international collaboration (co-authorship) is a network of preferential attachment, except for mathematical logic because of the size of the sample (N=147). All

[32] LOTKA software is based on the work of Albert Lokta describing the frequency of publication by authors in any given discipline as $y= a/x^n$. In which the number of authors making x publications in a given period is a fraction of the number making a single publication.

parameters were shown and the scale exponent $\gamma$ were always between -2.25 and -3.61 as well as cluster coefficients.

Interestingly, they also discussed a sociological explanation for the deviation from the power distribution that could be due to the type of scientists participating in the network according to their pattern of publications: newcomers, continuants, etc. (Price, 1990) shown in Table 3.3. Their interpretation is that the fitting in the middle of the power-law distribution is determined by the continuants representing in the networks the hubs to which many are willing to connect. Then, at both ends of the distribution will be the newcomers (hook end) and the continuants and terminants representing large numbers of scientists within the network seeking reputation and reward in terms of international collaboration using mechanisms of preferential attachments.

This article was the first demonstrating that the international collaboration is a self-organized network supported by preferential attachments of the participants by processing large amount of data per discipline of science.

Moreover the interpretation that those nodes with large amount of links are the results of the highly active continuants and therefore key elements of the network might support the analysis of the network of Cuban Researchers in Europe and the implications it might have for science policy.

## 3.5 CUBAN SCIENCE AND SCIENTIFIC COLLABORATION

### 3.5.1 '*Challenges in the study of Cuban scientific output*'

Contributed by: Ricardo Arencibia Jorge and Félix de Moya Anegón (2010)

Journal of publication: *Scientometrics*

The study of the Cuban science system has been of interest among national and international researchers and this paper began reviewing those that have contributed the most in the period just before the transformation of the Cuban science that took place after the collapse of the Soviet Union.

First they referred to the article by Lancaster and collaborators concerned about the possibility of political influence in the patterns of use of information sources by Cuban scientists during the period from 1950 to 1983 (Lancaster et al., 1986). The authors found that Cuban scientific production increased substantially after the Cuban revolution with more international collaboration with the Eastern Bloc, from only 3% in the period from 1950 to 1964 up to a third had been collaborative after 1965. Collaboration with Western scientists was consistently low through the whole period and the languages of publication were Spanish (55%) and English (35%). The conclusion, however was that Cuban scientists cited Eastern sources more than expected only when publishing with Eastern scientists or in Eastern journals. Cuban scientists cited more Western science (60-65%) and very little citation of Latin American documents, which the authors accounted for the fact that Cuba was ahead of Latin America.

Arencibia-Jorge and Moya de Anegón then referred to the study of Moral (1989) from the Cuban Academy of Science evaluating the output of applied research and development in Cuba using the analysis of patents as an information source during the period 1968 – 1983. Interestingly the countries with more applied patents in Cuba were Switzerland, France, England and the German Federal Republic and the absence of Eastern socialist countries in the top eight countries.

The third important contribution made for the period previous to the collapse of the Soviet Union was carried out by researchers in theory and history of science of Cuba and East Germany (Mezke and Fernández de Alaiza, 1990).  This was the first time that input/output analysis was used to evaluate Cuban scientific performance using the input data from the National Statistics Office (ONE) and the bibliometric data for the period 1973-1984 using the *Science Literature Indicators Database* of the National Science Foundation (NSF) available at the University of Sussex, United Kingdom. There were important findings in this study indicating that Cuban scientific productivity was small and visibility low and did not correspond with the government input in R & D. However the authors predicted an increase in productivity in the near future depending on improvements upon the solution of the qualification of human resources, sufficient provision of funds and the continued implementation of the demand-orientated structure in the system.

The economic crisis of the 1990s due to the collapse of Cuban trading with the socialist countries, pushed the Cuban scientific community to play a decisive role in the economic and social development of the country generating new sources of wealth and improving the social applications of their scientific results. The early investment of the government creating scientific capabilities (see section 2.5) was decisive in this new era of Cuban science. The scientometric analysis of this period showed more than 40% growth of the Cuban scientific production in the mainstream journals from 236 articles in 1988, to 734 articles in 2003. However this study also found problems in the way Cuban articles were represented in different databases. There were numerous articles evaluating at micro- and meso- levels the Cuban scientific production in this particular period post 1990, such as the scientometric study of AIDS research (Macías Chapula, 2001), the achievement in the production of vaccines (Guzmán Sánchez et al., 1998), the representation of Cuban clinical trials in high impact journals (Araujo Ruíz et al., 2002), the productivity and the visibility of Cuban neuroscientists (Dorta Contreras et al., 2010) and many others published both in Cuban journals and international journals such as *Scientometrics*.

The aim of Arencibia Jorge and Moya de Anegón was the scientometric evaluation of Cuban science through the input/output analysis of the period 1996-2007. Socioeconomic indicators were obtained using the National Statistics Office (ONE, Cuba). Taking into account previous concerns about the way Cuban science was studied, the authors also assessed two different databases: *WoS (ISI)* and *Scopus.*

An important finding of this paper was that journals of non-English languages were under-represented in *ISI* databases with *Scopus* having a better coverage of Latin American journals and therefore showing a better representation of science in the region.

For the relevance to the research undertaken in this thesis some of the results concerning the databases chosen for the purpose of evaluating Cuban scientific productivity in the period 1996 - 2007 are summarised (Table 3.5).

In terms of evaluating the input/ output of Cuban scientific production the authors pointed out that there was a moderate to significant correlation between R&D expenditures and scientific production in *WoS* (r =0.89) and *Scopus* (r = 0.73). However they do not comment on the difference found when using *Scopus* in which two periods showed very different correlations between expenditure and output with r = 0.86 (1996-2000) and r = 0.07 (2001-2007).

Table 3.5 Comparative impact indicators period (1996-2007)

| Indicators | Cuba in WoS | Cuba in Scopus |
|---|---|---|
| Number of articles | 8642 | 13548 |
| Number of Journals | 1 | 20 |
| Citations | 50026 | 53643 |
| Cited articles | 5713 | 6977 |
| Percentage of cited articles | 66.1 | 51.5 |

When evaluating scientific indicators comparing Cuban output with some Latin American and the Caribbean countries the author found that although Cuba is still in the core group (top seven countries) the average of citation per articles is lowest in this group, even when comparing to countries such as Jamaica and Trinidad and Tobago placing Cuba in the 165$^{th}$ place of the world ranking. It has been acknowledged that international collaboration improves citations however, this is not the case of Cuba having 54% of international collaboration, which is a subject they think deserves further investigation.

Part of the research carried out in this thesis refers to some characteristics of the Cuban national and international collaboration for which this article and the next were essentials to be reviewed for the research carried out in this thesis.

3.5.2 '*Intersectoral relationship, scientific output and national policies for research development: a case study on Cuba 2003-2007'*

Contributed by Ricardo Arencibia Jorge, Elena Corera Alvarez, Zaida Chinchilla Rodríguez and Félix de Moya Anegón (2013)

Journal of publication: *Revista cubana de Información en Ciencias de la Salud*

The authors of this article are from the National Centre of Scientific Research in Havana Cuba and from the Institute of Public Policy, CSIC, in Spain and they aimed to evaluate qualitative and quantitative characteristics of scientific production through different sets of bibliometric indicators for the period 2003-2007.

One of the main interests was assessing the Cuban scientific output through the triple-helix model of Etzkowitz and Leydesdorff (2000) taking into account the particular characteristic of the country in the process of normalization of the data. The data source was *Scopus* and the retrieved data was classified in six sectors: Higher education, health, science & technology, government administration, enterprises and others.

The quantitative indicators were total publication output, annual percentages, annual growth rate and total number of institutions involved in the scientific publications. The qualitative data were elaborated from a set of impact indicators: total of cited articles, percentage of cited articles, average citation per articles, H index and R index. Each of this impact indicators were obtained for each sector studied. H-index and R-index are functions of aggregation operators merging several numeric values to measure the quality of science. The authors of this article also used social network analysis to visualize the inter-sector collaboration.

This article complements the previous one giving more details at institutional level and the evolution of their output by sectors. Although the period was only five years (2003-2007) there was a remarkable increase in the number of institutions publishing in general. The health sector was the one with the highest increase from 77 institutions in 2003 to 158 in 2007. The key moment, they argued was 2006 in which universities of the health sector began an intensive scientific production in journals indexed in *Scopus*. The authors explained that strategic decisions were taken by researchers of national institutions publishing in mainstream international journals to increase the global visibility. Also the science and technology sector with half of the output reaches more citations for the same strategic decision of selecting international scientific publishers.

In terms of Inter-sectoral links the authors concluded that there are strong links between higher education and health sector, and less strong between them and the science and technology sector, which might be improved with the latter attracting more students in research projects. All the remaining links were weak and the health sector showed a minor proportion of international collaboration compared to the rest of the sectors. The authors concluded that a better fit of the Triple Helix might be achieved after the new configuration of biotechnology enterprise (BioCubaFarma) that took place in 2012, in which institutions of high output and quality of scientific publications became part of the pharmaceutical industry sector of the country.

However other authors have analysed the Inter-sectoral communication through other parameters rather than scientific publication, instead evaluating the operational fluxes of documents (Cárdenas O'Farrill, 2009 and 2014) concluding that it is targeting this horizontal communication that has made the Cuban biotechnology a successful model of Pharma.3 long before other pharmaceutical companies.

For the purpose of the research taken in this thesis, one of the most interesting findings in the work of Arencibia Jorge and collaborators was the increase in the number of institutions participating in the scientific output, denoting the growing strength in the country's scientific capability. In a period of five years the participation grew by 78% from 178 institutions to 317.

The article of Arencibia-Jorge and collaborators represents a view for debate and it was considered in the design undertaken to evaluate the Cuban pattern of national and international collaboration as part of the capacity building in science, technology and society of the country.

## 3.6 DIASPORA NEXUS: SENDING AND DESTINATION COUNTRIES RELATIONS

The objective of the literature reviewed in this section is to provide the contextual framework in which the results of the study of Cuban researchers in Europe might be inserted. The articles will not be reviewed to assess their conformity or not in this field of social sciences related to migration in general and policies in particular, which are not disciplines directly involved in the present study. However, discussing them here might shed light on why there is not yet a Cuban scientific diaspora centred for development.

The first article provides the essential elements accounting for the views of international organizations and scholars regarding to *Diaspora Centred Development*. This is a new approach dealing with the consequent of migration and the ability that diaspora might have contributing to the development of their former homeland. The case for turning the brain drain into brain circulation or knowledge gain is a particular case of this new global approach when referring to highly skilled migrants and what is now accepted as a new paradigm.

The other two articles discussed in this section come from Cuban scholars living in and outside the country and none of them addressed the scientific diaspora and therefore there is no evaluation by them of the potential this particular segment of the Cuban diaspora might have for science and education in Cuba.

### 3.6.1 '*Towards a new generation of diaspora centred development: Current practices and emerging priorities'*

Contributed by: Mark Boyle and Rob Kitchin (2011)
Published in: *Global diasporas and development: socioeconomic, cultural and policies perspectives*, Springer, India

This article was chosen for the clarity in depicting the actors and actions required to improve and harness the potential of diaspora communities, with some strategies and perspective for the future. Although they did not address specifically scientific diaspora, neither the intrinsic characteristic as network structure, the authors drew important element concerning national policies in both destination and sending countries, including the diaspora itself.

The authors offer an analytical view of how diaspora can contribute to their homeland identifying the range of channels through the current practices in which those network organizations should ensure their impact upon the development in the country of origin.

1. ***Type of channels***: The authors identify nine different types of diaspora channels, which members of the diaspora might seek to lever, harness and harvest:
   Diaspora advocacy: when members are advocates, activists and ambassadors within the diaspora communities using their linguistic skills, cultural insights, knowledge and contacts in the destination country to promote peace and security in the homelands and to enhance the strategic diplomatic and foreign policy objectives of the homeland.
   Diaspora Capital Market: when members have the capacity to provide some sort of investment, holding deposit accounts, securitizing remittance flows, providing transnational loans to other diaspora
   Diaspora Direct Investment: when member of the diaspora community can assist companies in their homeland and / or outsourcing contracts to SME (small medium enterprises) in their country of origin.
   Diaspora Knowledge Networks: when members can assist companies in sending countries by providing knowledge, contacts, sharing knowledge, mentoring organizations, training talented colleagues, joining think tank consultation groups and advisory councils.
   Diaspora Philanthropy: when members of the diaspora community provide private and voluntary donations for charitable and public good through vehicles such as Religious organizations, Corporations, Foundations, Volunteer Citizens and University and College Alumni Associations.
   Diaspora Remittances: Refers to remittances flows of person-to-person transfers from migrant workers to the workers' homeland family.

Diaspora Return Migration: Members can promote bilateral and multilateral agreements to restrict recruitment from the vulnerable and at-risk countries, increase accountability among recruitment specialists and employers, establish protocols for the treatment of foreign workers and facilitates return migration
Diaspora Corps: In those situations in which members can establish volunteering schemes to promote short-term assistance to vulnerable population that are short of skills, or to assist administration of aid not least following a natural disaster or a human induce disaster.
Diaspora Tourism: Through the visits of members of the diaspora the origin country receives an important source of revenue of foreign currency, but also incorporates medical tourism, business-related tourism, heritage tourism, educational tourism, etc.

The authors argued that through those channels the diaspora are having a positive impact in their home countries generating new ways of relations, as they pointed out:

> '*The diaspora communities have and are moulding their homeland in ways which we are only now understanding*'.

Perhaps one of the reasons why it has taken so long to appreciate the potential of the diaspora communities is due to the fragmentation of the research on diaspora and the early approach of viewing the problem of emigration as a policy failure. The magnitude of movement of people seeking better live around the world today as a consequence of the wealth divide is stressing social structures in both sending and destination countries and it might be plausible to think the potential of these self-organized organizations could provide (Palacios-Callender and Roberts, 2015).

Interestingly those channels above mentioned are not exclusive to one particular diaspora, such as scientific diaspora, but are present at different time and situations in a diaspora community of any given country. Possible outcomes will be included in the chapter eight.

In this article the authors emphasized the three stakeholders behind the success of any attempt to benefit from the activities of the diaspora communities.

2. ***Stakeholders: three actors behind diaspora scheme*:** The activities of sending countries, the activity of the diasporas in the global North and activities in the destination countries in the global North (Figure 3.3).

Sending countries are exploring new institutional capacities to accomplish the task of interacting with their diaspora including models of governance through the creation of new ministries, departments, and units within the government and flexible cross department groups. Effectiveness of diaspora contribution has been observed when they were motivated to help through the sense of loyalty to the nation; when they are able to exercise the rights as citizens of both sending and destination countries (dual citizenship). Overall the sending countries are:

a) Working on the process of *nation building*
b) Improving Information and Communication Technology
c) Creating new citizenship rules

Boyle and Kitchin recognized that the global diaspora in the North have already shown their capacities as self-organized organizations: from hometown associations to agricultural cooperatives, from churches and religious groups to learned medical and scientific academics, from SME to pension funds, from satellite TV media to social networking. However they pointed that in terms of governance the diaspora communities still has to be prepared for new interests in both sending and destination countries, such as:

> '*Minimise the exploitation, capitalise upon their potential, enhance their own agendas and interests and, consolidate rather than threaten their links with home and host*'

Although they mentioned how the government in the destination countries of the North have been participating building partnership with diaspora communities, still there is a need for improvement and they might considered new initiatives that might include their own external aid and development programmes, their support during periods of natural or human disasters, among others.

The authors considered that destination countries willing to help the new generation of diaspora centred development should '*promote and undergird as opposed to frustrate and undermine the reach of diaspora back to homeland*' which related as well to the risk it might occur when old ties of colonial relations might emerge having the negative patronising effect.

The theoretical model discussed by Boyle and Kitchin might offer solutions to old problems, the authors themselves mentioned some realities to overcome depending on the circumstances of the countries involved. Risks of hindering those promises exist when the destination countries try to harness the knowledge, contacts, linguistic skills and cultural insights of such diaspora for their own political agendas aborting any engagement of the diaspora and the sending states. Boyle and Kitchin reflected on the importance of choosing the locations of dialogues, which might generate tension between western centric development ideas, post-colonial critiques to the limitations of western centric epistemology and the diaspora catch in the middle.

The model as they described seems to place those diaspora in the developed world, and indeed their observations might be relevant in the case of Cuba and United States, and the lack of trust between both states and different political agendas inside the diaspora communities of Cuban Americans. However they did not cover the diaspora within the developing countries, which might give an edge to the sending and destination countries for further social and economic integration.

The authors explained how those pioneering countries and cutting edge diaspora strategies and schemes undertaken in different setting were progressing as they mentioned the case of *Diaspora Matters*, a not profit company based in Dublin that has produced a *Global diaspora strategies toolkit* (Aikins and White, 2011).

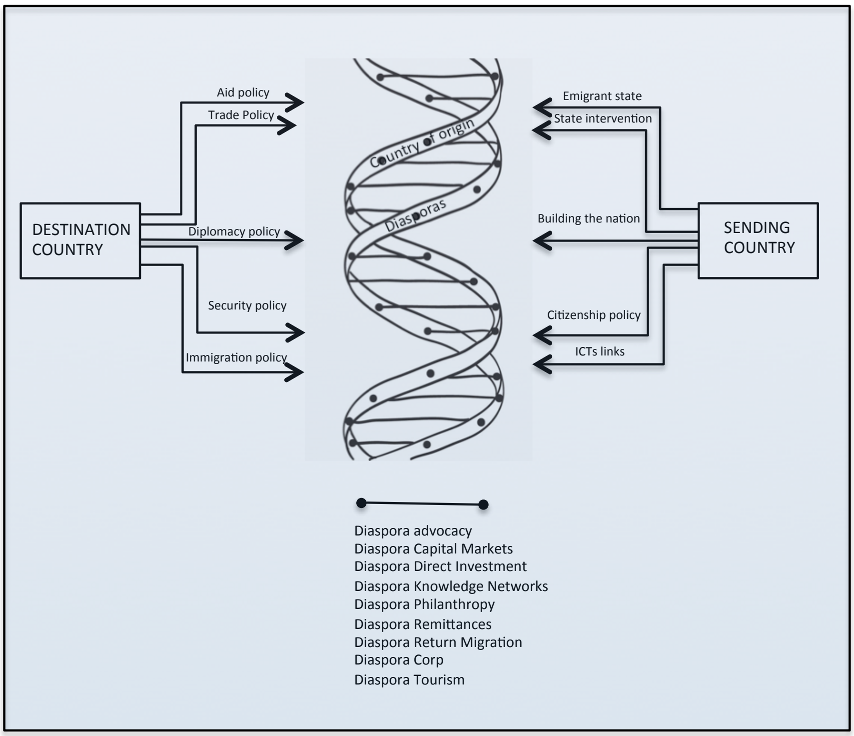
The subject has reached international organizations and Global Commission on International Migration[33] proposed essential principles for action (GCIM, 2005, 2012) since 2005, recognizing that human migration is an integral component of the global

---

[33] ***Global Commission on International Migration*** (GCIM) was created by the initiative of Secretary General of the United Nation Kofi Anan in 2003

economy with the potential of playing a valuable role in human development. The essence of fulfilling the promises and avoiding adverse effects in the process requires policies based on shared objectives and common vision.

Figure 3.3 Diaspora centred development by Boyle and Kitchin




Source: Boyle and Kitchin (2011), *Diaspora for development: key stakeholders*.

### 3.6.2 '*Cuban Diaspora in the 21st Century*'

Contributed by: Uva de Aragón, Jorge Domínguez, Jorge Duany, Carmelo Mesa Lago, Orlando Márquez and Juan Antonio Blanco (2011)

*Report of the Research Committee working at the Cuban Research Institute*, Florida International University (FIU), United States

The analysis of the report '*Cuban Diaspora in the 21st century'* by Cuban scholars living outside the country of origin is a clear evidence of one of the problems mentioned earlier by Boyle and Kitchin regarding those circumstances in which there is an ideological and political confrontation between sending and destination countries.

The content of the report referred and described the Cuban diaspora in United States and emphasised the economic potential for contributing to Cuban development.

The Cuban diaspora in the United States of the 60s up to 90s was mainly represented by upper and middle class Cubans interested in deposing the Cuban socialist government with a segment of that diaspora involved in the organization of the Bay of Pigs military attack in 1961 and supported terrorist organizations acting in the destination country since then. Through the years some changes started taking place and in 1993 the first poll organized by FIU found that 87% respondents favoured increasing international pressure on Cuba and 73% said they would approve of armed action by the exile community. Even today most of Cuban Americans serving in the U.S. Congress boycott the progress in the U.S. and Cuba relations[34] and the lifting of the American Embargo to the island.

The fact that the Committee decided to put aside the report until the results of a new poll of Cuban residents in Miami (September 2011), might indicate the need to legitimise their claims of the existence of a genuine diaspora centred development in the United States. The poll showed that the 65% respondents supported the idea of re-establishing diplomatic relations with Cuba, 45% of poll respondents were in favour of the US embargo; while 55% rejected it. The result of the poll confirmed previous evidence of a new generation of Cuban emigrants in the United States with different characteristics from the previous ones who prefer to call themselves exiles (Eckstein, 2004).

The report has half a section on reviewing the state-diaspora relations (sending countries only) and the other on possibilities and challenges of the Cuban diapora (addressing only those living in the U.S.) and therefore the section on diaspora-destination states relations, in this case how the United States might contribute to the aims of the diaspora was missing.

The section of state-diaspora relations is a review of the Cuban migration law in the context mainly of other Caribbean countries to discuss the relations of states with

[34] Cuba – US diplomatic relations were restored 20th July 2015, after severence since 1961 during the Cold War.

their diasporas taking the classification of Peggy Levitt and Glick Schiller (2004). The classification of countries are: '*strategically selective states (Haiti, Ireland, India), transnational nation-states* (Dominican Republic, Salvador, Mexico) *and disinterested and denouncing states (Cold war Cuba, Slovakia and Vietnam)'.* It is out of the purpose of this thesis to argue in favour or against this classification. However, at the time this report was finished the Cuban government was anouncing changes in the migration law that was later modified as the decree law 302 (6th October 2012 and in vigor since January 2013). The decree law overhauled and liberalized the restriction of Cubans traveling abroad and returning to the country.

There is a brief mention of *brain circulation* in the section of *Policies improving State-Diaspora Relations* refering initiatives of other countries: '*Some other countries [Phillipines, China and India] have encouraged the return of well-trained workers by offering more flexible entry visas and simplified requirements for living and working in the country of origin'* (Aragón et al., 2011, 36). No more description of *Cuban brains* in the U.S. was presented, nor was mention made of the Cuban American scientists and engineers willing to collaborate with their homeland.

There were 64,000 Cuban-born scientists and engineers in the US representing 1.9% of all immigrant scientists and engineers in U.S. in 2003[35] (Kannankutty and Burrelli, 2007) but there was no reference to this potential in the report, and therefore an area for research in the field of Cuban scientific diaspora will be highly relevant.

3.6.3 '*Cuban emigration since the end of the XX century and begining of the XXI: an insight from the city of Havana'*

Contributed by Consuelo Martín Fernández, Antonio Aja Díaz, Angela Casaña Mata and Magali Martín Quijano (2007)
Report presented by the scholars at Territorial Projects of Social Sciences, Havana City, CITMA, December, 2007.

This is a research report to the Cuban Academy of Science by Cuban social scientists from two research institutions of the University of Havana involved in

[35] There were 3,352,000 foreign-born out 21,647,000 scientists and engineers in the U.S. in 2003, source in Kannankutty and Burrelli, 2007; source: National Science Foundation Division of Science Resources Statistics

migration studies: Centre for Demography Studies (CEDEM in Spanish) and Centre for the Study of International Migration (CEMI in Spanish).

The report summarized different studies about migration in Cuba supporting different conclusions. One of them was that Havana City holding 19.6% of Cuban population had the highest proportion of legal emigrants (48.3%) in the country, but also evaluated the migration from other provinces to Havana as a possible departure port. Other aspects evaluated was the composition in terms of gender, age, educational attainment and sectors of the economy of this emigrant population, concluding that the Cuban migration was mainly persons between 25 to 40 years old of which 54.1% were female, worsening the ageing pattern of Cuba population.

The report also addressed how changes in the migration policies and regulation taking place since 1995, modified the relationship of the emigrants with the nation, and more exchanges and temporal returns were observed. Visits to the country and remittances to families increased, with 83% sending money, food, medicines and clothes twice or three times a year, 36% of the interviewed would like to visit without restrictions, and none of the interviewed would like the U.S. embargo to continue. Multiple studies were carried out characterising those visiting temporally and they mentioned a typical opinion of the emigrant interviewed:

> *"They want the restrictions lifted and costs of trips reduced, these facilities will improve family relationships expanding the life choices and enjoyment with your family during your stay in Cuba".*

The report was extensive and offered a deep analysis of the consequence of the hostility of the U.S. policy towards Cuba in terms of migration, but also explained that the Cuban pattern of migration was not far away from the rest of Latin America and the Caribbean, and regarding the later, Cuba is less affected by the brain drain with only 12% of professional emigrants. However the scholars argued, when taking into account that the professionals in Cuba represent 7% of the population, that it was clearly a selective migration of this sector of the Cuban population. They also suggested studies to evaluate qualitatively the implication of this loss of human resources.

In terms of professional migration, the Cuban scholars criticised the global situation in which the demand for knowledge in developed countries and the race for talents had been given more priority neglecting the damage it is generating in those sending nations in the South. This view was also shared by scholars in Europe who think the brain drain and it consequence are not going away with the approach of brain circulation or brain gain (Gaillard et al., 2015).

The scholars acknowledged in the report the recommendations of the International Organization for Migration (Global Commission on International Migration, 2005) concerning programs helping highly skilled returnees to contribute to the development in their country of origin, however no evaluation of potential of such programs was assessed for Cubans highly-skilled migrants, or reference to a policy dealing with the problem at the time.

The timeframe of the report was five years before the decree law 302 ($6^{th}$ October 2012 and in vigor since January 2013), and it is expected that an even larger number of returnees may arrive in the future. The new emigration law allows citizen to stay abroad up to 24 months without losing the Cuban residency, therefore it is easy to work abroad and come back to vist the country every 2 years without losing your rights as Cuban citizen. This particular situation might benefit the return of scientists, specially those who went abroad for a PhD or a postdoc position. The job market in science is temporary, depending on grants that are available for periods of three or five years in a highly competitive world for international scientsists. Probabilities of researchers facing hard periods seeking a job might increase the likehood of their possible reuturn.

The present study of Cuban researchers in Europe will provide the characterisation of this part of the Cuban scientific community with potential to contribute to the country's development and might open fruitful exchanges between Cuban scientists in the country and abroad. Although the United States is the principal hub for science in the world, and the main destination country for Cubans, restrictions are still in place to start any successful model, while experinece from the present study might be useful for future extension of the model.

## 3.7 SUMMARY

This chapter of literature review aimed to analyse in detail cornerstone articles in the international and Cuban literature contributing to the main pillars of this thesis:

- Bibliometric evaluation of scientific capacity of Cuba underpinning the integration of Cuban scientists abroad with the Cuban system
- Bibliometric evaluation of the movement and migration of Cuban scientists in Europe
- New bibliometric tools to evaluate the international collaboration as a free-scale network
- New consideration in the Diaspora for Development: Global and Cuban approaches.

Through the literature reviewed here researchers in this particular field have supported their findings through history of science, information science and science policy but also by the social network theory. The single journal in which those articles were mainly published was *Scientometrics*, indicating the relative strength of quantitative methodologies of information science in the shifting of the paradigm of brain drain and brain circulation.

The last two sections intended to balance views of scholars geographically situated in different part of the nexus: country of origin and the bigger Cuban diaspora in the United States. Interestingly it might show different aspect of the same phenomena missing in other studies of the diaspora. However, none of them developed in particularly the subject of the present study: the Cuban scientific diaspora.

# CHAPTER 4: METHODOLOGY AND METHODS

## 4.1 INTRODUCTION

The problem of investigation leads to the theories and not the other way around. Dissecting the problem from what is known and what still requires explanations and maybe solutions will lead to the use of the appropriate methodological tools to reveal new knowledge from which further investigation will follow.

In social sciences the problems of investigation are not static, neither isolated, they are embedded in a changing context influenced by socioeconomic and geopolitical factors, then the theory underpinning the problem should also link the outcome to the historical context and vice versa.

## 4.2 FROM THE PROBLEM-QUESTIONS AND RATIONALE TO THE THEORY SUPPORTING THE RESEARCH

Previous investigations have been supporting the theory that diaspora can be instruments for development but both terms are still too general. Diaspora comprises different types (Boyle and Kitchin, 2011) and their contribution to development is also specific. The framework of this investigation is concerned with scientific diaspora networks helping the science, technology and innovation systems in the country of origin, a subject that has not been investigated before in the Cuban context.

The specific questions refer to 1) the existence or not of a Cuban scientific diaspora in Europe, 2) how effective could their contribution be, given the scientific capacity achieved in Cuba? and 3) which would be the optimal nexus in this transnational attempt of joining the Cuban scientific community?

Although the terms *scientific diaspora* and *transnational knowledge networks* have been used freely up to this part of the thesis, it is necessary now to refer to the previous definitions and adopt the appropriate operational terms. A lack of consensus has been recognised in the definition of the terms and the difficulties it might generate for policymakers (Seguin et al., 2006). This also applies to the terms *expatriate, exile and emigrant* and therefore these shall also be discussed now.

The term scientific diaspora (networks) refers to '*self-organized communities of expatriate scientists and engineers working to develop their home country or region, mainly in science, technology, and education*' (Barre et al., 2003, 121), which has been used since then by many researchers (Meyer and Wattiaux, 2006; Tejada et al., 2013; Meyer et al., 2015) working in collaboration with UNESCO. The points of emphasis here are *the cultural ties and the actions as collective transnational practices* in the organization of a given community of expatriates with the intellectual capacity and the purpose to contribute to the home country.

The term *transnational* in this context refers to those highly skilled migrants with the means to move as part of their routine life, forward and backward between the home country and the country of residence facilitated by the fast growing telecommunication technology and low-cost air travel. The connections with the country of origin span different levels, from links with family (remittances) and friends, to participating in a wider sector of the society. Modernity has enabled a two-way system changing the previous mode in which migrants used to leave their home forever. Transnational is also related to the theory of transnationalism and its implications in culture, economics and politics, in both sending and destination countries (Portes et al., 1997); and will not be discussed in this thesis. Transnational in these views has an individual connotation even when describing transnational communities in a way they operate regularly in both sending and destination countries pursuing an individual benefit (Portes, 1996) and they are mainly entrepreneurial migrants.

The need to explain the above definitions lays in the importance of establishing which attributes of the Cubans working in European institutions of S&T are of interest in this study and the purpose of establishing a collaborative sense as a community living abroad to contribute to the country of origin through national institutions. Therefore Cuban scientists and engineers working in Europe will be studied as active researchers through the pattern of national and international collaboration shown in their scientific publications. Scientific collaboration is the essential part of the model studying this community and could be fully assessed by bibliometric methods. This definition also helps to adopt the theory underpinning this research.

The efficiency of the scientific diaspora transferring knowledge and participating in the development of the home country leads to the second question: '*How effective could their contribution be, given the scientific capacity achieved in Cuba'?*

It has been discussed among UNESCO's experts, if the weak National Innovation Systems (NIS) in the South could be the drivers of the brain drain (Arocena and Sultz, 2006). The authors argued that the three fundamental elements of NIS are: institutions, interaction and capacity to create and use new and economically viable knowledge. Then networks of institutions and interactions facilitate the diffusion of technical knowledge in productive sectors. Interestingly the authors referred to the model of the *Sábato Triangle* proposed by the Argentinians Sábato and Botana in 1968, which resembles the '*Triple Helix'* model later developed by Etzkowitz and Leydesdorff in 2000. In the triangle formed by the vertices Government-Academia-Business (or Industry in Etzkowitz and Leydesdorff's model) the sides should be more important that the vertices to encourage development. If on the other hand, the sides are weak, each vertex will try to find links with external counterparts and this will generate brain drain. Strong NISs are those supported by actors of the networks collaborating between institutions. Another aspect of making the NIS more effective in the South, they mentioned, are those policies focussing on national needs that not only might help to halt the brain drain, but could foster the brain re-articulation to the national system through scientific cooperation and collaboration.

Assessing the Cuban pattern in national and international collaboration through bibliometric study could provide an indication of how well the country might be prepared to foster the contribution of those that have continued their further education and advanced their knowledge abroad.

The last of the three questions relates to a possible implementation of the results: '*Which would be the optimal nexus in this transnational attempt of joining the Cuban scientific community for the benefit of the country'?* Once having the quantitative results of the two previous questions supported by the qualitative dimension of the interviews with the Cuban scientists living in Cuba and abroad, an integrative analysis about the existence or absence of the conditions to transform a possibility in reality, should provide evidence based elements of a process in evolution that might have an impact in Cuba. There is an international consensus that the efficiency of the scientific diaspora networks requires, first the supporting initiative of the country of origin in which a sustainable platform can make use of their potential and second an active role from organizations and the states of the destination countries (Meyer et al., 1997; Seguin et al., 2006; Boyle and Kitchin, 2011; Tejada, 2013). This third question therefore requires the discussion of science policies, and an additional groundwork with Cuban institutions through Action-Research, which was not undertaken in the present investigation, but could be achieved with the active involvement of stakeholders in future projects. At this stage the thesis will only provide some insights and few recommendations.

## 4.3 CORE THEORY UNDERPINNING THE RESEACH ASSUMPTIONS

### 4.3.1 *Heuristic approach underpinning the present assumptions:*

Scientific diaspora networks from different countries have been studied before supported by theories depending on one hand, the characteristics of the diaspora itself and on the other hand the resources and the expertise of the researcher including the institution in which the research is taking place. The studies might cover the world diaspora of a particular country of origin (Jonkers, 2015; Meyer et al., 1997), or the settlement of a successful diaspora in a destination country (India) with potential to contribute to the country of origin, or concentrating the study of different diaspora in a particular destination country willing to offer a platform to help the delivery of diaspora projects (EPFL, 2007).

This study is an exploratory investigation of the Cuban scientists and engineers working in European institutions of S&T, which is a fraction of the world distribution of this community but with the potential of being a successful scientific diaspora mainly because they belong to a recent wave of young migrants. Although the United States is the main destination country and therefore with the highest concentration of Cuban s&e, the composition is not homogeneous as earlier Cuban emigrants (1960s) received their education in the U.S. and therefore it is not possible to identify their Cuban origin through the methodology used in this study. Moreover due to the current situation of the Cuba-U.S. relationship there is no ground for implementing applications from this study, as evidence were shown in previous research (Eckstein, 2004).

The background of the researcher undertaking this investigation is in biomedical sciences and therefore more familiar with quantitative methodologies, especially grounded in information science, which is also the expertise in the group of Information Management and Knowledge Management in the School of Computing and Engineering at University of West London.

#### 4.3.2. *Theory of 'Science of Science'*

This phrase of 'science of science' is how Derek J. de Solla Price started the prologue of his masterpiece '*Little science, big science'* in 1963 when giving a series of four lectures in the annual George B. Pegram Lectureship at Brookhaven National Laboratory in June 1962. Price was a physicist and a historian of science, but in this lecture he also contributed to the sociology of science. Since then his contribution has been recognised as the essential theory by bringing together the history of science, scientometrics and information science from which modern science is evaluated (Garfield, 1984). Relevant to this investigation is the distributions of the expansion of science at any given time and how it follows exponential growth and logistic decay as distribution functions (Price, 1963, 61) fuelled by the nature of the social organization of the scientists. The scientists' claim of his/her contribution to science is made through his/her publications, which also show his/her prestige, institutions where the work were done, reflecting her/his priorities and represents a vital passport for her/his career prospect (Merton, 1957).

The theoretical analysis of Price also reflected on the statistical distribution of publications according to the productivity of scientists analysing the Lotka' law (1926) and its comparison with Pareto distribution (Price, 1963, 43, 57) giving the explanation of the transition from *Little science* to the exponential growth of the *Big science* as a consequence of the *invisible colleges* of researchers collaborating in almost all branches of sciences (Price, 1963, 90). In another contribution working with Donald Beaver (1966) they further demonstrated how scientific collaboration had an impact not only in the production on scientific papers, but advancing the research front. Furthermore collaboration, seen as teamwork, was also supporting the relationship dependency with the hierarchically stratified professional community of scientists behind professional mobility (Beaver and Rosen, 1979). Eugene Garfield also pointed out that one of his big contributions was the theory of networks of scientists published in 1965 (Price, 1965) following the '*Little science Big science*' theme in terms of citations in different fields of science. Price also reflected on the value of the quantitative measurement of science for policymakers at national levels (Price, 1963, 92; Price, 1980).

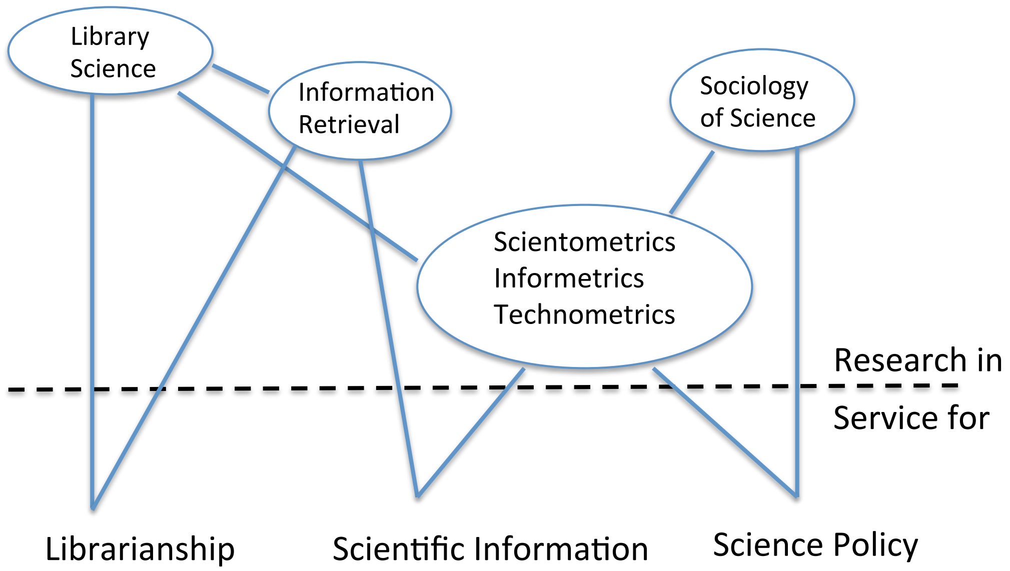
Those principles and rules explaining the normative of science will be underpinning the investigation of the Cuban pattern of scientific collaboration, and on the demography and productivity of Cuban scientists in Europe and their patterns of scientific collaboration.

4.3.3 *Diversification of quantitative studies of science: bibliometrics*

Wolfgang Glänzel (2003), Professor of Scientometrics and Probability Theories at Katholieke Universiteit Leuven marked the contribution of the work of Derek de Solla Price laying the foundation of the present and relative young discipline of *scientometrics*. Named for the first time by Nalimov and Muchenko in 1969, who defined scientometrics as the application of mathematical and statistical methods in the analysis of science, they viewed scientometrics as an information process; while in the same year Pritchard defined the term bibliometric as the application of those methods to books and other media communication. An important core subject in information science and bibliometrics is the study of citations of scientific papers by publishing authors exploring diffusion of knowledge, visibility and obsolescence of scientific publications and different theories have been used for these aims. The main contribution in this area was made by Eugene Garfield with the creation of the Science Citation Index in 1964 (Godin, 2006). However, in the present study citation analysis will not be considered as not being relevant to the essential research questions.

According to Glänzel (2003), bibliometrics supports both research and services of library science and librarianship; information retrieval for librarianship and scientific information; sociology of science and science policy as shown in chart 4.1

Chart 4.1 Links between related fields of basic and applied research using bibliometrics




Links of bibliometrics with related fields and application services

The basic unit in bibliometrics is the scientific paper forming the *elements* in bibliometric analysis; these elements are *publications, authors, references* and *citations.* Depending on the kind of research there are also units such as *journals, author's affiliation* and *countries*. The types of evaluation applying mathematical and statistic methods are represented through bibliometric indicators.

#### 4.3.4 *Scientific collaboration at the core of the experimental model: graph theory*

The analysis of scientific collaboration is also included in the scope of bibliometric research, however it is discussed separately here because through this lens the problem of investigation might reveal new important features linking the outcome (scientific collaboration) with the evolution and implementation of new strategies to support the interactions within these two scientific communities and the international community at large.

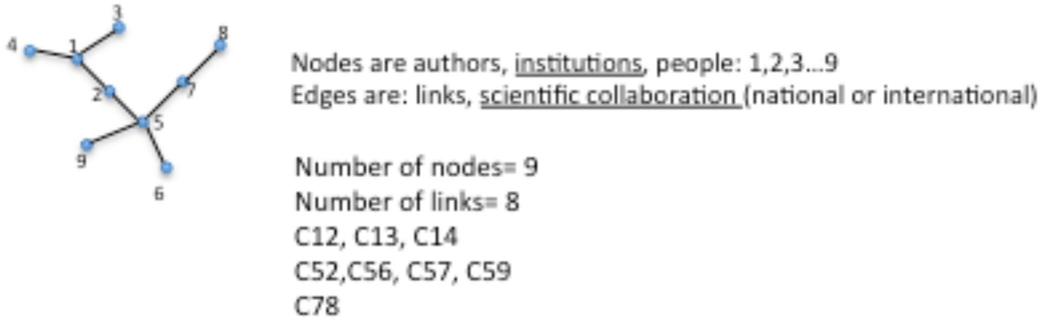
The increase in scientific collaboration was at the heart of the transition from '*Little science to Big science*' called then *invisible college* by Price in 1963. In the horizontal organization of the Mode 2 of science (Nowotny et al., 2003) and the Triple – Helix organization of science and innovation in developed countries, collaboration involves institutions and organization from Academia-Government-Industry (Etzkowitz and Leydesdorff, 2000). More recently it has been revealed that the global network of international collaboration evolves towards more clusters and new countries and regions emerging in an extended network in which scientists seem to collaborate in a self-organized mode (Wagner and Leydesdorff, 2005) of what is called the *new invisible college* (Wagner, 2008).

*Some elementary assumptions in Graph Theory*

Collaboration as co-authorship in scientific publications can be studied through network relations through nodes and edges. Graph Theory underpins the mathematical assumptions in network analysis in which a Graph $G\ (N,E)$ consists of a set of nodes ($N$) and a set of edges ($E$). The earliest contribution to the field came from the Swiss mathematician Leonard Euler in 1736 when trying to solve the Konigsberg Bridge problem through the graph representation of paths. In graph theory the edges connect pairs of nodes and representing that, the edge E is linking nodes $u$ and $v$, is as $(u,v) \in E(G)$.

Nodes or vertices could represent authors as individuals (Barabási et al., 2002) or countries (Bornmann et al., 2015) and edges could represent scientific collaboration in a define discipline (Barabási et al 2002) or international collaboration (Wagner and Leydesdorff, 2005) or hyperlink connections through the internet between countries (Woo Park et al., 2011) as shown in figure 4.1

Figure 4.1 Nodes and Edges in Graph Theory




In this case institutions 1 and 5 are the ones with more collaboration and 2 plays a role of connecting to hubs of active institutions. The graph of interest is *undirected*, meaning that the link C12 = C21 and the matrix is *symmetric* (or adjacency matrix). When creating the matrix of the above graph or network, edges or links are one (1) and zero (0) for the presence or absence respectively, as the previous graph will generate the following matrix (Figure 4.2).

Then the eight (8) collaborations of the nine (9) institutions will produce an adjacency matrix with 18 cells with 1s and the rest 0s.

Figure 4.2 Adjacency matrix of the graph in 4.1

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | **1** | **1** | **1** | 0 | 0 | 0 | 0 | 0 |
| 2 | **1** | 0 | 0 | 0 | **1** | 0 | 0 | 0 | 0 |
| 3 | **1** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | **1** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 0 | **1** | 0 | 0 | 0 | **1** | **1** | 0 | **1** |
| 6 | 0 | 0 | 0 | 0 | **1** | 0 | 0 | 0 | 0 |
| 7 | 0 | 0 | 0 | 0 | **1** | 0 | 0 | **1** | 0 |
| 8 | 0 | 0 | 0 | 0 | 0 | 0 | **1** | 0 | 0 |
| 9 | 0 | 0 | 0 | 0 | **1** | 0 | 0 | 0 | 0 |

The degree of distribution of a network is the fraction of nodes with k degree as $P_{deg}$ (k). The degree of a node *i* is just the number of links it has.

In an adjacency matrix the degree of *i* nodes is the sum of the $i^{th}$ row of C

Ki = Σ Cij

As

K1 = 3;  K2 = 2;  K3 = 1;  K4 = 1;  K5 = 4;  K6 = 1;  K7 = 2

K8 = 1;  K9 = 1

And the degree of distribution $P_{deg}$ (k) shown in figure 4.3 is:

$P_{deg}$ (1) = 5/9

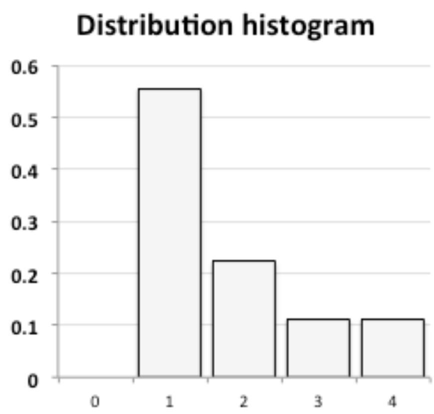
$P_{deg}$ (2) = 2/9

$P_{deg}$ (3) = 1/9

$P_{deg}$ (4) = 1/9

A real network has many nodes and most of them have a very small degree and few nodes have a large degree being connected to many nodes. Large degree nodes are called Hubs. The types of distribution was discussed in section 3.4.2

Figure 4.3 Degree distribution of graph 4.1

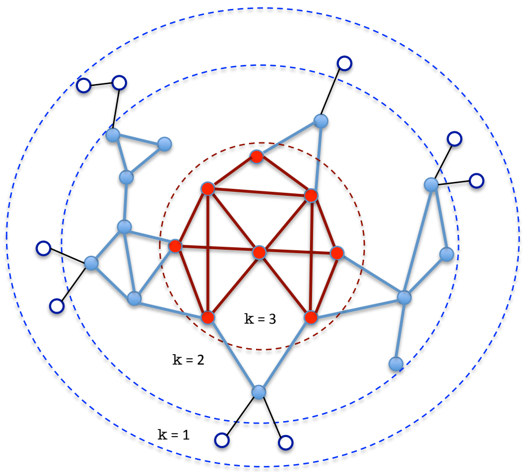



The degree of centrality of a given undirected network is related to the numbers of ties or edges the nodes have, indicating the position and strength of the nodes in the network contributing to the network structure. In terms of social capital, the node's position is a source of opportunities and advantages depending on the nature of what is flowing through the network. The highest possible centrality is the total number of nodes minus one, meaning that there is at least one node to which all the rest are connected. The degree of centrality can be measured using different functions and algorithms such as beta centrality, Eigenvector or $k$-stage reach centrality depending on what is the characteristic of the network to evaluate.  In the case of Cuban researchers in Europe (CRiE) the ties are links with co-authors generating scientific collaborative publications between the CRiE institutions and any other one. For a node (institutions) with a high number of strong ties (collaborations and the times they occur) will be also important the position in terms of cluster of other institution and for that characteristic we used the k-core analysis available in the UCINET software (Borgatti et al, 2013). The description for the algorithm developed for UCINET is:

> '*A k-core in an undirected graph is a connected maximal induced sub-graph which has minimum degree greater than and equal to k. For a valued graph it is required that the sum of all edges incident with a node to be greater than k*'

The format of the *K-core* analysis is expressed in a hierarchical clusters showing at the centre or core those structures with more loops and connections. A representation of k-core or shells is shown in Figure 4.4

Figure 4.4 Representation of a network in hierarchical k-cores




4.3.5 Theory of Evolution of Cooperation

The theory of the evolution of cooperation might explain steps either taking place in the present stage of collaboration within the scientific community of Cubans in the country and abroad or might be required for the transformation of the collaboration in an efficient network of transnational knowledge for the benefit of the home country. The application of the theory of evolution of cooperation is not in the current research, which aims to describe where exactly is the system of study, but having the theory in mind will allow extracting the best information for future studies. Therefore the theory will be discussed in general rather than implementing its application.

In the theory of evolution by natural selection it is assumed that the strong and selfish individuals, maximizing their own resources at the expense of others are the best fitted to survive. However there are other forms in evolutionary systems in biology and in society that progress successfully through cooperation. There are many examples in the history of human civilization supported by evolving cooperation rather than competition (Nowak, 2012).

The theory implies the need of some mechanisms for the cooperation to evolve and succeed and even when it takes place naturally, those mechanisms will increase the level of cooperation or facilitate the emergence of those systems (Nowak, 2012). Martin Nowak explains the similarity with the evolutionary game theory, that if there are two strategies taking place: cooperation (C) and defection (D) then,

$$\begin{array}{cc} & \begin{array}{cc} C & D \end{array} \\ \begin{array}{c} C \\ D \end{array} & \begin{pmatrix} R & S \\ T & P \end{pmatrix} \end{array}$$

The game is a cooperative dilemma if two co-operators get a better pay-off than two defectors, that is when R > P but still there are at least one of the following incentives to defect in different situations when playing against (a) a defector then T > R, or it is better to defect when playing against a defector (b), P > S or it is better to be a defector when playing against a co-operator and a defector (c) T > S. Without going any deeper in the mathematical model which also includes the loner (L) defined as those who do not participate in the game, the rational of the model implies that for the members of a population interacting for payoff through the evolution of cooperation at least one of five mechanisms should be in place.

Those mechanisms are *kin selection, direct reciprocity, indirect reciprocity, network reciprocity and group selection*. Kin selection operates when the donor and the recipient on an altruistic act are genetic relatives; *direct reciprocity* requires repeated encounters between the same two individuals; *indirect reciprocity* is based on reputation as a helpful individual is more likely to receive help; *network cooperation* refers to clusters of co-operators outcompeting the defectors and *group selection* takes place when there is competition between groups, but in the wining group co-operators prevail (Nowak, 2006).

The fact that scientists are members of the particular population (community) under study, the idea of modelling the system to evaluate (and facilitate) the evolution of cooperation is very attractive mainly because the payoff trade in this case is a public good (generation of knowledge through publication) and therefore reputation and prestige are probably ruling the prevalence of cooperation.

4.3.6. *Some reflections about Actor Network Theory (ANT)*

Theories in science information were developed originally from a history of science and all the quantitative reasoning underpinning the analysis were based in mathematical and statistics analysis taking scientific publications as tracers of the work of scientists. In Actor Network Theory (ANT), when specifically used in the context of science, contributions along the history of science are made placing the scientists and her/his work in a network of human and non-human actors interacting in time and space.

Adopting theories, rules and principles of science information at this stage of an investigation seems to be the methodology of choice in as much as no previous work has been done gathering basic information about the existence or not of a relevant community of Cuban scientists in Europe.

However, further investigations based on the ANT might expose features of this event otherwise difficult to reveal by quantitative studies, after all, as Donald Beaver himself affirmed "*quantity is only one of the quality*" (2012). Perhaps what makes ANT attractive for further studies is its unconventional character following the scientists in action. Analysing two of the rules shows how much can be added to the current investigation:

Rule 5 '*We want to be as undecided as various actors we follow as to what techno-science is made of; every time an inside/outside divide is built. We should study the two sides simultaneously and make the list, no matter how long and heterogeneous, of those who do the work*' (Latour, 1987, 258).

This rule refers to concentrate the attention to all other components different than the scientist him/ herself when following science in action. Creation of a particular piece of knowledge is only possible when a set of conditions are met including the support of other practitioners different than the scientists, the laboratories, those that participate in training, funding, taking decisions, and so on, without whom the discovery, or the new knowledge might not be produced (Latour, 1989, 146):

Rule 6 '*Confronted with the accusation of irrationality, we look neither at what rule of logic has been broken, nor at what structure of society could explain the distortion, but to the angle and direction of the observer's displacement, and to the length of the network been built*' (Latour, 1987, 258).

Exploring the characteristics of the network created by a particular group of Cuban scientists when choosing a discipline of science and how it branches out connecting with new realities in Europe through ANT might provide a different understanding on how a harmful event such as brain drain might offer new possibilities of connecting the network of techno-science, transforming the scatter resources into a net that may reach everywhere (Latour, 1987, 180). Interestingly this approach could be seen as a continuation of the ethno-science work of Simon Reid-Henry (2010) '*The Cuban cure: reason and resistance in Global science*'.

## 4.4 ADOPTING MIXED METHODOLOGIES IN THE STUDY OF THE CUBAN SCIENTIFIC COMMUNITY IN THE COUNTRY AND ABROAD

### 4.4.1 *Quantitative approach*:

Bibliometrics provides the methodology for mapping the human capital of Cuban scientists in and outside the country, the dynamic and their contribution to science taking scientific collaboration as the main feature that can facilitate the connectivity between the two groups. Additionally the use of the network analysis of the scientific collaboration of CRiE supports evidence of interaction between the two groups of Cuban scientists.

4.4.2 *Qualitative approach:*

The degree of characterisation of the Cuban scientific community using quantitative methodologies has limitations that can only be complemented by using qualitative methodologies. There are a wide range of research methods and tools in qualitative methodologies but given the background of the investigator undertaking this research, who is a transnational scientist herself (pharmaceutical and biomedical sciences that have worked in Cuba and United Kingdom), the appropriate choice is auto-ethnography.

Auto-ethnography is an emerging qualitative research method allowing the author to explore realities from her/his own experience to extend understanding about a societal phenomenon through a new and ideologically challenging genre of enquiry (Wall, 2006).

Semi-structured interviews of Cuban scientists used a core group of questions including specific points regarding scientific collaboration that are well established in sociology of science (Beaver, 2001). The process of interviews was carried out more as a conversation between colleagues who know the subject of debate rather than as an outsider searching for clues, especially those concerning working in science in Cuba and abroad.

In this thesis only the raw material is presented and discussed leaving the more elaborated style of auto-ethnography for further publications.

## 4.5 METHODS AND EXPERIMENTAL DESIGNS

### 4.5.1 *Cuban scientific collaboration and the contribution of Cuban Researchers in Cuba*

The experimental design elaborated here is built upon previous contributions from scholars either from information sciences, science policy and geography of science (Arencibia-Jorge, et al, 2010, 2013; Pérez-Ones and Nuñez-Jover, 2009 and Reid Henry, 2008; 2010).

Scientific collaboration of Cuban scientists is the essential part of the current research as the main ethos in sociology of science that can provide the functional relation between Cuban scientists in Cuba and those dispersed in the Europe diaspora.

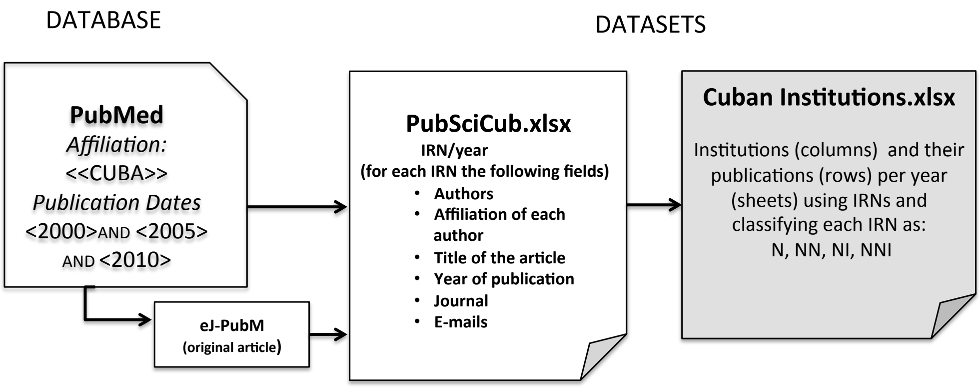
The period of those mentioned studies spanned from 2000 to 2007. To overlap the period and extending it to 2010, the present study will analyse years 2000, 2005 and 2010. Records of publications in 1990 and 1995 were also searched, but data was excluded in this study because the low coverage of original publications.

a) *Databases for bibliometric studies*: *PubMed, Web of Knowledge and Scopus:* The best database to study Cuban science have been demonstrated to be *Scopus* (Arencibia-Jorge and Moya Anegón, 2010) and the three most productive sectors: higher education, health sector and science and technology (Arencibia-Jorge, et al., 2013). *PubMed* was the database chosen after a preliminary search in the three databases *PubMed, Web of Knowledge* and *Scopus* for the years 2000, 2005 and 2010. By choosing *PubMed* the sample of study was selectively representing those Cuban institutions crediting the authorships of the scientific articles, in as much *PubMed* was not showing all authors' affiliations until 2014. Therefore the decision to collaborate or not was made by the Cuban institutions. *Scopus* and *WoS* were showing all scientific publications in which Cuba participated regardless of their leading role in collaboration. The retrieved data was designated as *SciPubCuba* dataset.

b) *Identifying national and international institutions:* To find all participating institutions in the retrieved sample of *PubMed*, a second search was carried out using the *PubMed* link to the original article in which all author affiliation was shown. Some references were linked to the *Latin American repository library online* (Scientific electronic library online, *ScieLO,* Brazil) from which all authors' affiliations were also taken using *ScieLO* access to original document. All gathered information was added to the *CubaPubMed* dataset previously created. Institution names were disambiguated from alternative English translations of the same name helped by author knowledge of those places in question and by searching in the Internet about their location and function. In some cases, electronic e-mails to the corresponding author were sent to confirm the name and location of the affiliations. Disambiguation of different names or acronyms in Spanish was also performed as well as a manual inspection to eliminate false document. International institutions were identified by the name of the country and disambiguation of institutional names was not necessary.

*c) Creating Datasets SciPubCuba and CubanInstitutions: SciPubCuba* was our reference dataset in which each document corresponding to a scientific article received an identification reference number (IRN) for each studied year. PubMed reference number was also kept as a second alternative identification. *CubanInstitutions* was our working dataset created in Excel with the names of Cuban institutions as their names were appearing in the search. A record of Cuban institutions and their IRN per publication per year was created to count and classify their articles according to the nature of their collaboration. Figure 4.5 shows the experimental design used creating the two datasets.

Figure 4.5. Diagram of the experimental design




*SciPubCuba* outputs are net publications ascribed to only one institution with a unique IRN and PubMed number. Thus, total net publications (TNP) was the aggregate number of publications for the years 2000, 2005 and 2010 and it was obtained from this reference dataset, therefore

$$TNP = \Sigma(IRN_i)_{2000} + \Sigma(IRN_j)_{2005} + \Sigma(IRN_k)_{2010}$$

In this case *i, j and k* are unique articles in 2000, 2005 and 2010 respectively.

*d) Classifying scientific collaboration: CubanInstitutions* was the working dataset created with the list of Cuban institutions (column) and their articles (IRNs per row) per year (sheets). Articles per institution were then classified in four types: only one institution (N), more that one national institution (NN), only one national institution with one or more international collaboration (NI) and more than one national institution with one or more international collaboration (NNI).

Institutional publications (IP) accounted for all articles in which the institution participated regardless of the position of the author affiliation and is obtained by counting their IRNs (integer counting) per institution and year. The total institutional publications (TIP) were obtained by adding the IPs of all institutions in aggregate for the years 2000, 2005 and 2010. Therefore,

$$TIP = \Sigma(IP_i)_{2000} + \Sigma(IP_j)_{2005} + \Sigma(IP_k)_{2010}$$

In this case *i, j* and *k* = institutional publications in 2000, 2005 and 2010 respectively *e) The role of the Cuban leading institutions in the scientific production*: For the purpose of this study, which focused on biomedical science, publications of the Cuban institutions were classified according to the amount of their IPs in the aggregated years regardless of the status or tiers of the institution in the National Science and Technology System. The top 20 more productive institutions were called Central group; those institutions with less than 5 institutional publications were called Distal group including 156 out of 201 Cuban institutions; and those in between these two groups including 25 institutions were called Middle group. Although it is an arbitrary division, it allows us to create a setting in which more active researchers working in top institutions (Central) publish with transient collaborators in geographically dispersed institutions (Distal), typical behavior in scientific communication first described in the study of the Information Exchange Group 1 (IEG 1) on Oxidative Phosphorylation and Electron Transport Chain (Price and Beaver, 1966). Other scatter or skew distributions have been described for journals, known as Bradford's Law, or for author productivity, known as Lotka's Law (Lotka, 1926; Sen, 2010). However we are not aiming to prove if Cuban scientific publications in biomedical sciences follow or not any particular distribution. We are interested to study the relationship between contributing institutions with different resources and expertise through their national and international collaboration for the development of national scientific capacity.

f*) Classifying Cuban institutions according to their main function*: The institutions were also classified according to their principal role such as higher education, research and development, services and production, etc. In the majority of cases the name of the institution indicates their function as universities (and polytechnics) and were considered higher education (HE) and science & technology (S&T); in the case of medicine, Cuba has national institutes of different specialties such as Institute of Cardiology and Cardiovascular Surgery (in Spanish as ICCC), classified as research institutes-hospitals; other research institutions (R&D) in the Ministry of Health were not hospitals such as Centre for Pharmaceutical Chemistry (in Spanish as CQF), Centre for Research and Development of Medicaments (in Spanish as CIDEM); Teaching hospitals were separated from general hospitals (GH) and specialized hospital (SH) such as maternity hospitals, which are mainly service (S); other national, provincial or municipal institutions were also classified as centres aiming to improve the Public Health such as National Centre for Quality Control of Medicaments (CECMED), or Provincial Centre of Hygiene and Epidemiology of Santiago de Cuba, or Municipal Unit for Surveillance and Control against Vectors in Cumanayagua, Cienfuegos. Although classification of all institutions might look too specific, it was decided to keep details showing the geographic distribution of them especially in the Distal group.

g) *Multivariable analysis of the collaboration between top institutions and periphery for both national and international collaboration*: Once the three groups of institutions were established the nature of national and international collaboration between Central institutions with the other two groups was explored through graphical representation of the multivariate data available in Excel. Data were prepared in two spreadsheets of collaborative IPs per institution of the Central group for the analysis of the national and international collaboration. For both set of data IPs showing collaboration within Central and with Middle and Distal were counted and each institution received equal recognition regardless of the position of the author affiliation, but counted only once in case of more than one author per institution.

h) *Other sources of information*: Other sources used supporting the analysis of scientific outputs in the context of Latin American and the Caribbean were: *Science Citation Index (SCI)*, *Thomson and Reuters* and *SCImago journals and country rank* (SJ&CR), powered by *Scopus* database, Elsevier as well as Science and Engineering indicators (NSF 2000 and 2014) from National Science Foundation, United States of America. Additionally we used the World Bank data for normalizing the number of publications per inhabitants of the countries of interest available at The World Bank website[36].

[36] ***The World Bank*** http://data.worldbank.org/indicator/SP.POP.TOTL Information accessed on 17th September 2014.

4.5.2 *Cuban Researchers in Europe (CRiE)*

a) *Destination countries of Cuban Researchers in Europe*: The database of the Organization for Economic Development and Cooperation (OECD) for migrants according to their education attainment, gender and over 25 years old (Docquier and Marfouk, 2006) was used establishing which European countries attracted more tertiary educated (Ter-Ed) Cubans in 1991 and 2001. The stocks of Ter-Ed Cubans in Europe were 17,535 in 2001, representing a 171% increase compare to 1991. The main country attracting Ter-Ed Cubans was Spain with 10,880 highly skilled migrants, following Germany and Italy with 2,931 and 1,061 respectively. Another five countries (Sweden, France, Switzerland, United Kingdom and Netherlands) hold 2,082 Ter-Ed Cubans, which represent all together almost 97% of the total of them in Europe.

b) *Estimation of the size of the sample (triangulation method)*: In 2010 there was an increase of 91% of Ter-Ed Cubans in 15 countries of Europe compared to 2001 (Brücker et al., 2013) calculated using the brain drain database of the Institute for Employment Research (IAB), Germany. According to statistics of Cuban consulates there were an estimation of 119,916 Cubans in Europe in 2007 representing 7% of the total migration (Martín Fernández et al., 2007). The authors referred that approximately 12% of them are professionals (the data was provided by Cuban consulates around the world), meaning that 189,655 Cuban migrants around the world hold a university degree out of 1,580,462 migrants; and in Europe approximately 14,400 Cubans with higher education out of 119,916.

Table 4.1 shows that the proportion of Tertiary educated Cubans represented 34% and 37% in 2000 and 2010 respectively calculated using the database of (Brücker et al., 2013). The definition of tertiary educated included graduates from technological schools, colleges and higher education institutions.

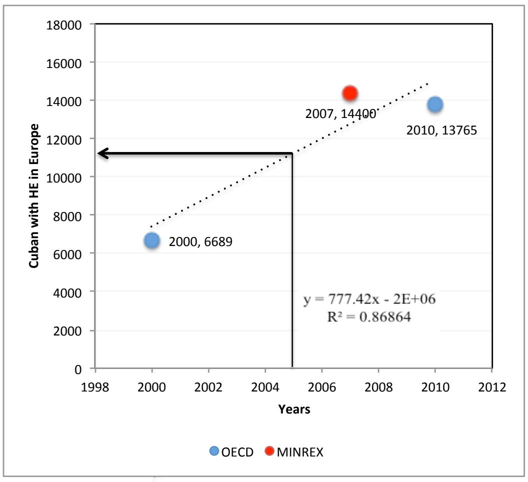
Table 4.1 Composition of Cuban migrants

| | Region | 2000 | 2010 |
|---|---|---|---|
| **Tert-Ed** | US | 224903 | 349878 |
| | Europe | 17480 | 33388 |
| **total Tert-Ed US+Europe** | | 242383 | 383266 |
| **Total** | US | 660233 | 925329 |
| | Europe | 55741 | 114708 |
| **Total US+Europe** | | 715974 | 1040037 |
| Tert-Ed (%) | total | 34% | 37% |
| Euro Tet-Ed (%) | Europe | 31% | 29% |

Source: Table made using database from Institute for Employment Research (IAB) of the German Federal Employment Agency (BA) (Brücker et al., 2013).

The estimation of 12% as professionals in Europe using the database from the Institute for Employment Research would be between 6,600 and 13,800 Cuban professionals in 2000 and 2010. The estimation by triangulation of the data from two different sources would be approximately 10,600 Cubans with higher education in Europe by the 2005 as shown in Figure 4.6

Figure 4.6 Size of the sample of Cubans with HE in the middle of the period of study (triangulation)




c) *Cuban scientists and engineers (s&e) in Europe*: *size of the sample*. There is no data available regarding the number of Cuban scientists and engineers in Europe. Therefore for having a reasonable estimation it should be considered the composition of higher education graduates from Cuban universities. Data from the Cuban National Statistic Office (ONE) indicates that graduates from those relevant branches represent 9% of the total HE graduates as shown in Table 4.2

It will be difficult to assume that this composition found in Cuba would be the same in those higher educated Cubans living in Europe because other factors might be influencing the decision to migrate such as the specific demands in Europe for different expertise or those who decide to migrate regardless of their qualification, but to find a job rather that a career. Nevertheless it is assumed that the size of the population of Cubans graduated in science and engineering might be between 9 and 12% (Table 4.2) of the 10,600 previously estimated, which is between 960 and 1200 Cubans with a degree in science or technology.

The first restriction is that there is no list of Cuban scientists and engineers in Europe, or any other list from which those names could be extracted. Cuban s&e in Europe might be working in different institutions and organizations belonging to the private or public sectors and even not related to their professional background.

Table 4.2 Proportion of Cuban graduates in HE per branch of sciences (2006 -2012)

| Branches of Sciences | 2006/07 | 2007/08 | 2008/09 | 2009/10 | 2010/11 | 2011/12 |
|---|---|---|---|---|---|---|
| **Total** | **44,755** | **71,475** | **74,845** | **84,779** | **85,757** | **89,558** |
| Technological Sciences | 4,078 | 4,770 | 5,383 | 5,779 | 5,407 | 5,920 |
| Natural Sciences and Mathematics | 583 | 559 | 607 | 559 | 572 | 621 |
| Agricultural Sciences | 823 | 729 | 1,061 | 1,153 | 1,349 | 2,709 |
| Economics | 2,408 | 3,056 | 4,486 | 5,412 | 6,914 | 10,159 |
| Social Sciences and Humanities | 2,911 | 5,446 | 8,161 | 12,655 | 15,418 | 17,515 |
| Pedagogy | 23,016 | 23,485 | 17,340 | 18,049 | 18,395 | 15,219 |
| Medical Sciences | 8,396 | 24,441 | 22,841 | 26,596 | 25,591 | 28,745 |
| Physical Culture | 2,309 | 8,786 | 14,777 | 14,357 | 11,905 | 8,441 |
| Art | 231 | 203 | 189 | 219 | 206 | 229 |
| | | | | | | |
| **Related to S&T** | **5,484** | **6,058** | **7,051** | **7,491** | **7,328** | **9,250** |
| **Proportion of the total** | **12%** | **8%** | **9%** | **9%** | **9%** | **10%** |

Source: ONE (Oficina Nacional de Estadistica, Cuba). Graduates related to S&T (and % of the total) calculated for this thesis.

For the purpose of this study aiming to evaluate the potential of Cuban s&e working in European institutions of Science and Technology the main feature to include them in the sample of study will be the place where they work.

A preliminary attempt to reach those s&e was used addressing the departments of Human Resources of the top European universities found in the *ARWU* (Academic Ranking of World Universities) list (Appendix 1). Through their websites names and e-mail addresses were used to send a questionnaire in which they could provide number of Cuban researchers and other Hispano-American researchers (see Appendix 2). Once having the numbers of Cubans and Hispano Americans in areas of science and technology from those high-ranking universities, a second search to find those researchers was planned using bibliographic databases such as *WoS*. This procedure was abandoned due to: low reply from Human Resources and very low yield from searching *WoS* by Spanish names[37]. Other problems were: if the researcher published for the first time outside Cuba, there was no way of identifying the country of origin (false negative or missing a Cuban expatriate researcher) and if a non-Cuban but with Hispanic surname has published with Cuban Institutions, the researcher could be taken as a Cuban scientists abroad (false positive).

After this first attempt a new approach was assessed including methodologies applied for studying hard-to-reach populations including snowball and respondent-driven sampling (RDS) also called chain-referral sampling (Heckathorn, 2011), and finally used a combination based on chain referral sampling (Figure 4.7) was used.

The initial snowball started with six *seeds* in which five were not s&e in Europe but provided names and surnames to further connections and searches, however because it was not possible to reach the subjects face-to-face, further connections beyond the second wave were limited as it is show in the figure 4.8. With those 38 names the search for more s&e continued through professional networks such as *LinkedIn, ResearchGate* and *Academia.edu.* Additionally a website was created called *Transnational Knowledge Network-Cuban scientists in Europe* with a link in each of my personal pages in *ResearchGate* and *LinkedIn* with a brief explanation of

---

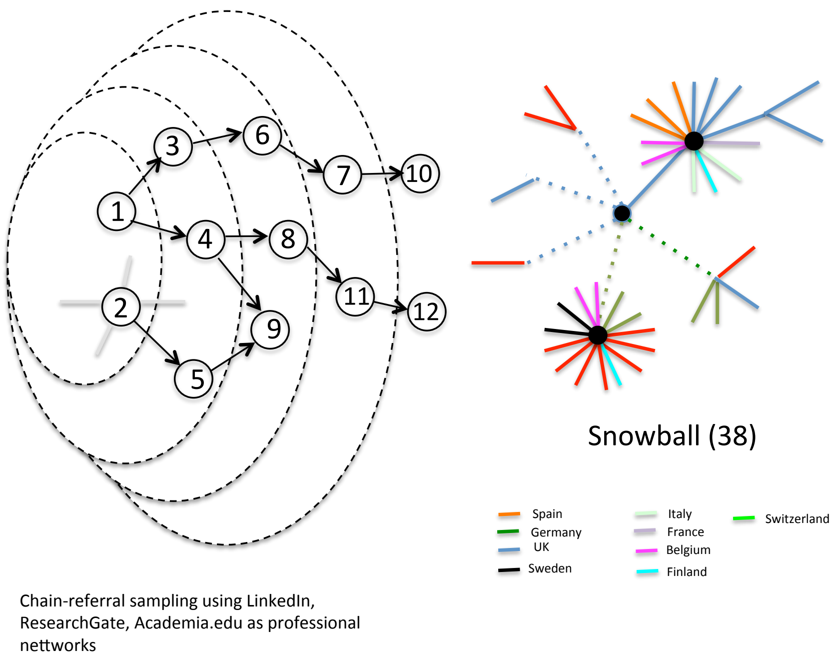
37 Case of the University of Vienna: *Records of publications for 2012-2013 were searched for Hispanic surnames for a total of 34 out of 3170*. For each name a new search was carried out looking for previous publications in which any Cuban institution was registered in the address domain. Only one name: Rodriguez, Roberto with 169 publications had a Cuban institution (University of Ciego de Avila) in the address domain. However, the fields of research were very different (Biodiversity, Plant Biology, Cancer, Anthropology, Proteomic, etc.) as well as countries (Spain, US, Chile, Cuba) suggesting that the WoS engine cannot differentiate researchers with the same name. The possibility of a Spanish scientists (Rodriguez, Roberto) publishing in collaboration with University of Ciego de Avila, Cuba cannot be ruled out.

the research and inviting Cuban scientists in Europe to participate (see Appendices 3, webpage and Appendix 4, collection data form).

Simultaneously as a new name of a possible s&e came out of the search, the public information available in those social networks was recorded for confirming first that the subject was working in a European institution of S&T and second that he or she had graduated from Cuban institutions of higher education (or through the Cuban HE programme in ex-socialist countries).

Summarizing the characteristics of the sample obtained, it is not representative of Cuban s&e in Europe because it is not a random sample and the non-probabilistic approach used the number of waves did not reach a threshold value large enough to eliminate bias from the initial selection of *seeds*. Therefore a good estimate could not be achieved.  Moreover not all s&e are members of the professional networks used here. The search stopped when 150 s&e were reached.

Figure 4.7 Methods studying hard-to-reach population




d) *Scopus as the database of choice*: Those s&e working in S&T might or might not be researchers; especially engineers who might choose to work in applied technologies in the public or private sectors. Since the focus of the research involves the demography and performance of Cuban s&e working in European institutions of S&T, the main attribute of those researchers will be their ability of publishing in scientific journals.

The advantage of *Scopus* compared to other databases is the unique identification number (UIN) for the researcher; in this way it allows tracing the scientific contributions and movements of the researchers along their scientific career (Plume, 2012; Moed et al., 2013).

Search in *Scopus* was carried out through the engine <Author search> with two fields to fill: name and surname. All options of Hispano Americans use normally two surnames (the first from the father and the second from the mother) and non-Latin databases are not designed for that tradition, therefore the first surnames are usually taken as a second name. With that in mind, combinations of names and surnames were applied for each Cuban s&e. Those without publication recorded in *Scopus* and therefore without an UIN were not included in the new sample of Cuban Researchers in Europe (CRiE).

For each CRiE the publication record in *Scopus* was downloaded as coma separated values (csv) Excel document choosing the option of *all available information*. Each downloaded document has the name, surname and Scopus number for identification and is kept as a reference.csv but not as working document.

e) *Codifying the CRiE into anonymous numbers*: Each reference.csv file is transformed in Excel workbook.xls and saved with a code number to ensure anonymity during the processing and analysis of the data. The code refers to the country where the researcher was working or did work at the time it was included in the list of Cuban s&e. Appendix 5 shows the code for countries.

f) *Period of study and definition of active researcher*: The period of study following the scientific publications of researchers was from 1995 to 2014. There are five years shift in relation to the previous study of *Cuban scientific collaboration and the contribution of Cuban Researchers in Cuba* (4.5.1) due to the late movement of researchers to Europe. Active researcher was defined as those publishing at least once in the last five years of the period of study and at least 15 articles between 1995 - 2014, or those with less than 10 articles but at least 2 in the last 4 years. The condition of active researcher is not restricted to the country of publication.

g) Selecting the cohort group of Cuban Researchers in Cuba (CRiC): The cohort group of Cuban Researchers working in Cuban institutions was obtained by searching in Scopus first for <Affiliation> retrieving 99 Cuban institutions of which 4 were counted twice (due to names in Spanish and English of the same institution) and a non-Cuban institution (US-Cuba Project, Global Options Group Inc., New York, searching 28th October 2014). For each institution Scopus lists the number of authors and documents. Choosing <authors> gives the list of researchers' names by descending order according to their number of publications. To ensure representation of all institutions a cut-off of number of publications per researcher was set to more than 47 articles per author. Those who stopped publishing in the last two years were excluded. The code for each institution is in Appendix 6.

The search in *Scopus* only showed 94 Cuban institutions out of 318 reported in a study about the scientific outputs of Cuban institutions in which Scopus was also used (Arencibia Jorge et al., 2013). In the case of researchers' names searching was also carried out using a combination of their first and second surnames. Two researchers were therefore eliminated due to merging authors with common name and surnames, inasmuch the fields and places of publications did not match. Table 4.3 shows the composition of CRiC per their research institution.

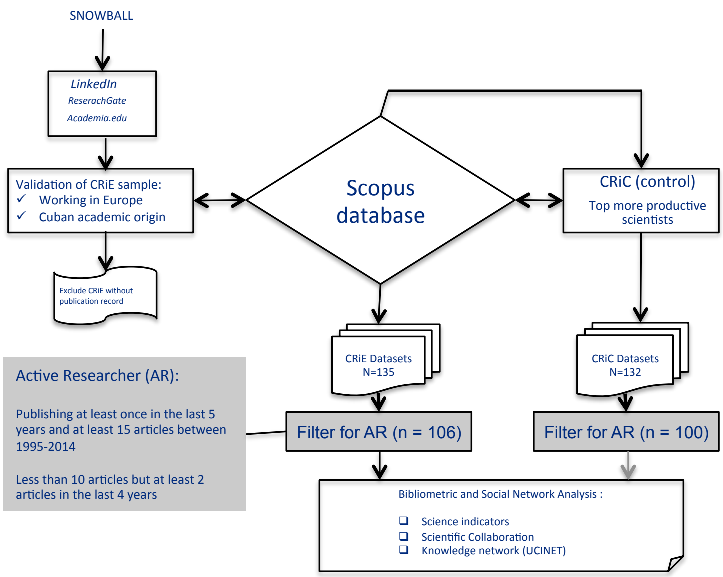
One hundred and twenty active researchers from 40 Cuban institutions had more than 48 publications of which 30 were women scientists (25%).

Table 4.3 Cuban researchers per Cuban research institution

| INSTITUTIONS | CODE | Scopus ID | Active Researcher | Included in the CRiC sample |
|---|---|---|---|---|
| **CQF/CQM** | **101001** | 1 | 1 | 1 |
| ICCC | 101002 | 2 | 1 | 1 |
| UH | 101003 | 19 | 18 | 17 |
| CNIC | 101004 | 9 | 9 | 4 |
| UCLV | 101005 | 6 | 6 | 6 |
| IF | 101006 | 2 | 2 | 2 |
| CIM | 101007 | 6 | 6 | 6 |
| InSTEC | 101008 | 1 | 1 | 1 |
| IIIA | 101010 | 1 | 1 | 1 |
| IPK | 101011 | 12 | 10 | 10 |
| CIGB | 101014 | 19 | 16 | 16 |
| CIRAH | 101015 | 1 | 1 | 1 |
| IPSJAE | 101017 | 1 | 1 | 1 |
| CNC | 101025 | 3 | 3 | 3 |
| CEADEN | 101028 | 3 | 3 | 2 |
| CIDEM | 101029 | 2 | 2 | 2 |
| UMCC | 101030 | 1 | 1 | 1 |
| ICIMAF | 101039 | 6 | 6 | 2 |
| ICA | 101042 | 7 | 7 | 7 |
| UCI | 101044 | 1 | 1 | 1 |
| UO | 101048 | 2 | 2 | 2 |
| HHA | 101049 | 3 | 1 | 1 |
| ISCM-H | 101050 | 1 | 1 | 1 |
| IHI | 101051 | 3 | 3 | 1 |
| INOR | 101052 | 2 | 2 | 2 |
| INHA | 101053 | 2 | 1 | 1 |
| INHEM | 101054 | 1 | 1 | 1 |
| INN | 101055 | 2 | 2 | 2 |
| CIREN | 101056 | 1 | 1 | 1 |
| INIFAT | 101057 | 1 | 1 | 1 |
| FCM-ME | 101060 | 1 | 1 | 1 |
| Univ Holguin | 101069 | 1 | 1 | 1 |
| CNICN | | 1 | 1 | 0 |
| INEEM | | 1 | 1 | 0 |
| HPWS | | 2 | 1 | 0 |
| ING | | 1 | 1 | 0 |
| CIMEQ | | 1 | 0 | 0 |
| ACC | | 1 | 1 | 0 |
| ICIDCA | | 1 | 1 | 0 |
| CENCEN | | 1 | 1 | 0 |
| | | 132 | 120 | 100 |

h) *Creating datasets for bibliometric studies*: Two working datasets were created for studying bibliometric indicators: the *CRiE-publications* and *CRiC-publications* with all the publication records of the researchers. For the *CRiE-publication* dataset additional information from Scopus was added including information of the European Institutions where CRiE have worked (identification number, total number of publications and total number of authors). By processing the number and distribution of CRiE publications per year they were classified first as active researcher and then as newcomers, movers and continuants as shown in Table 3.3 of Chapter 3 (Moed et al, 2013). The figure 4.8 shows the experimental design used in the study of CRiE.

Figure 4.8 Experimental design of CRiE study




*i) Bibliometric indicators*: The indicators used to study both communities of scientists CRiE and CRiC were *Productivity* and *Seniority* based on the study discussed in the section 3.1.2 (Plume, 2012). *Productivity* refers to the total number of articles since the first publication of each author (***P***), or during the period of study (1995-2014) as $\boldsymbol{P_{20}}$ and during the period publishing in Europe as $\boldsymbol{P_E}$. *Seniority* refers to the length of their scientific contribution, as the number of years since the first publication appears as ***S***, or during the same period 1995-2014 as $\boldsymbol{S_{20}}$ or related to the length of the time publishing in Europe as $\boldsymbol{S_E}$, Values might also be normalized for analysis. Indicators were also normalized taking the values (S or P) of both groups of Cuban Researchers (CR) in the twenty years period 1995-2014, using the equation:

$N_{CR} = (i - M)/SD$

Where $i$ is the value of the researcher's seniority (s) or productivity (p)

M: is the Indicator mean from all Cuban researchers: $S_{CR}$ or $P_{CR}$

SD: is the standard deviation of the indicators from all Cuban researchers: $\sigma$ ($s_{CR}$) or $\sigma$ ($p_{CR}$)

When normalized $S_N$ and $P_N$ values were between -1 and +1

j) *Types of publications by their scientific collaboration*: Articles per researcher were classified according to participating institutions in four types: only one institution (N), more than one national institution (NN), only one national institution with one or more international collaboration (NI) and more than one national institution with one or more international collaboration (NNI). National here refers to the country in Europe (or Cuba) from which the author is publishing.

*k) Network analysis of scientific collaboration of CRiE per country*: Further studies on how Cuban researchers were collaborating from their institutions in Europe were carried out using a network approach. Each European institution from which CRiEs were publishing, was classified as type I institution (examples in Table 4.4) and those collaborating institutes from the rest of the world were classified as type II institutions (example in Table 4.5).

Table 4.4. Classification of institutions for network analysis: Code for type I institutions (example)

| Region (Europe) | Country | Institution | Code |
|---|---|---|---|
| **201** | Belgium (1) | Vrije Universiteit Brussel (1) | **201001** |
| **201** | Belgium (1) | University of Antwerpen (6) | **201006** |
| **202** | France (2) | Universite de Nice-Sophia Antipolis (18) | **202018** |
| **203** | Germany (3) | J.W. Goethe University, Frankfurt (32) | **203032** |
| **204** | Finland (4) | Abo Akademi University, Turku (1) | **204001** |

Links between type I and type II institutions were obtained from publications of 106 CRiE and aggregate integral counts for each researcher collaboration $(x,y)_n$ with type II institutions. If the CRiE from institution type I collaborates with two or more researchers from one of the type II institutions in the same article, the link is counted as one. These three columns representing institutions 1) institution type I; 2) institution type II and 3) their links of collaborations (Table 4.6) were transformed in a symmetric matrix (Table 4.7) with an ad hoc programme and then processed through UCINET software to visualize the network of collaboration.

Table 4.5. Classification of institutions for network analysis: Code for type II institutions (example)

| Region | Country | Institution | Code |
|---|---|---|---|
| Central America and Caribbean (1*) | Cuba (01) | University of Havana (3) | **101003** |
| Europe (2*) | Slovenia (18) | University of Ljubljana (1) | **218001** |
| North America (3*) | Canada (01) | University of Alberta (4) | **301004** |
| South America (4*) | Brazil (01) | Universidad Estadal do Brasil (10) | **401010** |
| Africa (5*) | South Africa (01) | University of Cape Town (5) | **501005** |
| Asia (6*) | Singapore (06) | National University of Singapore (5) | **606005** |
| Oceania (7*) | Australia (01) | University of Adelaide (9) | **701009** |

All institutions were equally represented along rows and columns of the matrix. CRiEs per European countries were also processed separately to identify different patterns of networks. Links representing collaborations were aggregate values for the whole period of study, rather than snap shot in time, therefore the evolution of the network was not analysed.

Table 4.6 Types I and II institutions and the number of links (segment of the data)

| Type I | Type II | Links |
|---|---|---|
| 202001 | 101001 | 10 |
| 202001 | 101008 | 10 |
| 202001 | 211003 | 2 |
| 202001 | 202041 | 1 |
| 202001 | 101003 | 1 |
| 202001 | 202046 | 5 |
| 202001 | 201014 | 1 |
| 202043 | 101008 | 4 |
| 210011 | 101008 | 1 |
| 210011 | 210012 | 2 |
| 210011 | 214006 | 1 |
| 207025 | 202001 | 1 |
| 207025 | 101008 | 1 |
| 207025 | 210011 | 1 |
| 207025 | 202043 | 1 |
| 202018 | 101009 | 5 |

Table 4.7 Representation of the Matrix (segment) from the Table 4.4

| | 101001 | 101003 | 101008 | 101009 | 201014 | 202001 | 202041 | 202043 | 202046 | 210011 | 210012 | 211003 | 214006 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 202001 | **10** | **1** | **10** | | **1** | | **1** | | **5** | | | **2** | |
| 202043 | | | | | | | | | | | | | |
| 210011 | | | **4** | | | | | | | | **2** | | **1** |
| 210011 | | | **1** | | | | | | | | | | |
| 207025 | | | **1** | | | **1** | | | | **1** | | | |
| 202018 | | | | **5** | | | | **1** | | | | | |

Then the ad hoc program added zeros in those empty cells before using the adjacent matrixes for any particular application of the software UCINET.

### 4.5.3 *Qualitative study of Cuban scientists*

Once the bibliometric evaluation of indicators was finished an invitation for an interview was sent to researchers in both groups CRiE and CRiC by the e-mail address found in their publications as corresponding author. This was a unique opportunity to ask questions to the researchers who were well characterized by their scientific production and collaboration; their stories and personal experiences behind their success or difficulties provided another perspective to take into account.

The semi-structured interviews were designed in three sections: the first section covered a standard questionnaire for all researchers, seeking more details of their scientific careers and personal experiences in national and international collaboration, the second and third sections of the questionnaire were addressing more specific questions regarding the communication between CRiC and CRiE and among CRiEs from different European countries.

In the interviews researchers were allowed to tell stories behind a successful collaboration, or the difficulties and failures or explaining why they gave a certain rating to the national or international collaboration. The purpose was to obtain their perspective around collaboration, progress of their scientific careers and the social impact from their point of view. The specific subject about communication between the communities of Cuban researchers were treated more sensible and openly accordingly to their particular experiences.

The corresponding author is either the first author signing the publication or the more senior researcher head of the research group; therefore not all researchers were available.

Ten researchers in each group were finally contacted for semi-structure interview, those in Cuba were interviewed face-to-face and those in Europe either face-to-face or by video-call Skype.

a) *Consent form and questionnaire of semi-structure interviews*: Each researcher received an invitation to participate in the research as a consent form in which a brief description of the research was explained as well as the ethics protocol. Interviews were not recorded and the anonymity of the researchers was ensured identifying the transcriptions with a code. Documents were in English and Spanish but the interview was carried out in Spanish and the transcriptions in English. Both documents can be seen as Appendix 7 (Consent form) and Appendix 8 (Information to the participant and questionnaire).

b) *The content of the questionnaire and notes in the transcription*: The content of the questionnaire was discussed with the supervisor and colleagues with experience in the field such as Dr C.S. Wagner, from Ohio State University and suggestions were added to the final version. Intentionally questions such as reason why they move or migrate to Europe were not asked because in general Cubans find this kind of question intrusive and could lead to rejecting to be interviewed. The information wanted from the interviews was essentially about scientific collaboration and how and why the researchers relate to it having as a guide the points developed by Donald Beaver (2001).

c) *The process of transcription of the interviews and the interaction with the scientists*: During the interviews of around 45 minutes written notes were taken in the presence of the researcher. Transcriptions were finished in the next three days. Once the transcriptions were finished they were sent by e-mail to the researcher for corrections and approval of the content. Researchers were able to make changes and corrections as well as withdraw from the interview at any time, but none of them did.

d) *Interviewing scientists in Europe of different nationalities*: Additional interviews were carried out with other nationalities of scientific diaspora (1), returned scientists (1), and scientists abroad not linked to their diaspora (2) and the country of reference was Spain. Although they signed the same consent form, they were not particularly against being identified by their names. Nevertheless they will not be identified by their names, but by the institutions were they now work and/ or have worked.

## 4.6 LIMITATIONS AND SCOPE

The main limitations of this research were time and space. In order to draw a coherent picture of the problem of research the strategy was to cover as many areas as possible with potential for further development.

The risk of trying to cover a wide area of research conspires with the depth affordable in three years doctoral research and difficulties accessing the scientists distributed in Cuba and Europe, and who frequently travel as part of their work. However as methodologies show the evidence demands further investigation. The challenge is to demonstrate that the problem exists providing robust evidence of the situation, but what it cannot confirm is that the model Diaspora for Development might or might not be the solution of the problem.

There are many reasons why there is no previous research and one of them could be the late process of brain drain in Cuba, which might even be challenged as a statement.

## 4.7 SUMMARY

- This chapter offers the theory and methodology accounting for addressing the problem of investigation.

- Bibliometrics is a robust methodology showing evidences of the performance, organization and demography of science in the subjects of study, which in this case is applied to a country and to it scientists in and outside Cuba.

- The research is complemented with the voice of the actors through a new and ideologically challenged genre of inquiry, which is auto-ethnography

# CHAPTER 5: RESULTS - PART I

*'Quantity is only one of the Qualities"*
*Donald dB Beaver, 2012*

## 5.1 INTRODUCTION

The background chapter 2 (section 2.5) describes chronologically how science in Cuba evolved in the process of building the scientific capacity of the country. The socialist government started creating the human capital strengthening structures of education, health and industry and creating new national institutes of research where the state concentrated the resources. The government as the source of investment and its commitments through a long period of time seems to explain the paradox of '*Cuba emerging with a novel biotechnology industry while the country went through a period of economic crisis in the 1990s especially under the American Embargo*'. Adapting policies as the national science and innovation system evolved and focusing in sectors that can symbiotically interact with each other such as health-science-industry-society, the country managed to convert scientific advances in sources of export both as services and as biotech products.

The results presented here aim to demonstrate the existence of a sufficiently strong national science and innovation system to support the scientific collaboration between scientists working in Cuban institutions and those in European institutions of science and technology. Using bibliometric tools this research shows key features of Cuban scientific collaboration with potential to extend the interaction within the borderless Cuban scientific community.

The subject of research carried out in this chapter is now published in the *Journal of Documentation* (Palacios-Callender et al., 2016).

## 5.2 PATTERNS OF CUBAN SCIENTIFIC COLLABORATION AND SOCIAL NEEDS

International organizations and scholars have recognized Cuban scientific achievements even in those days when the country faced economic difficulties (Daar et al., 2002; López Mola et al., 2006; De Vos et al., 2012), pointing out strengths in the Cuban science and technology system. In this chapter the analysis is focused on the characteristic of Cuban scientific collaboration and the role this might have played supporting those achievements related to the health of Cuban population as well as creating strength in biomedical sciences.

Assessing scientific achievement of a particular country implies somehow the measurement of their scientific output, mainly through standard indicators internationally used to evaluate comparatively the science and technology performance of countries, nations or regions. However, the interest here is to investigate any distinctive pattern in Cuban scientific collaboration emerging from two characteristics that have been attributed to the culture and ethos of the Cuban scientific community when pursuing their aims: first, conducting their research through cooperation among institutions with different resources and expertise and second concentrating their effort on those topics affecting the Cuban population. Clark Arxer referred to these two features of the Cuban scientific community in the chapter about science in *Cuba* published in the *UNESCO Science Report 2010: The current status of Science around the World* (Clark Arxer, 2010, 127) when explaining the case of Cuban biotechnology as the typical approach of the country effort in research and development. Moreover, Clark-Arxer explained '*national collaboration replaces competition amomg individuals as a driven force of Cuban biotechnology*', a statement which is essential to demonstrate when studying Cuban scientific collaboration. Other features mentioned in this report included: the government as a source of investment, the implementation of a close linkage between research and commercialization, the generation of spin off state enterprises coming from scientific institutions and the harnessing of scientific effort for products that can reach foreign markets especially in the developed world (López Mola et al., 2006).

Perhaps one of the first comprehensive theories of scientific collaboration was developed by Donald dB Beaver and Richard Rosen in 1978 (Beaver and Rosen, 1978). Defining scientific collaboration as the collaborative scientific research acknowledged by co-authorships, Beaver and Rosen concluded that collaboration emerged as a result of the professionalization of science, first observed in France in middle eighteenth century, also found in other countries as the result of the financial support for scientific activities (Beaver and Rosen, 1979). In the article, the author's affiliation was not considered when counting scientific collaborative articles; the focus remained in demonstrating the origin of collaboration and the increasing number of co-authors, with the appearance of teamwork as a mode, later associated to the beginning of the '*Big Science'* (Price, 1963).

Some factors influencing this growth of scientific collaboration have been attributed to the interdisciplinary nature of the breakthrough in science and the increase in the connectivity between scientists all over the world by the revolution in digital communication and the access to the Internet (Stephan, 2012, 75), as well as the need of teamwork to overcome the degree of specialisation driven by the growth of knowledge (Price, 1963). In a study examining trends in collaboration between 662 major U.S. universities Benjamin Jones and collaborators (2008) found that collaboration measured as co-authorship between universities was steadily increasing from practically nonexistence in 1975 to represent more than 30% of the publications in science, engineering and in social sciences in 2005. The authors also found that collaboration between universities have a citation-impact advantage over collaboration within universities.

Evidence of how international collaboration in science emerged came mainly from studies analysing scientific publications dominated by advanced nations or those economies in transition with significant production of scientific articles (Luukkonen et al., 1992), but they were relevant establishing methodologically the best way of evaluating this trend of increasing collaboration between nations (Glänzel, 2001).

An interesting approach linking international collaboration with the process of building scientific capacity in less developed nations was carried out by the team led by Caroline Wagner at RAND (2001). In this comprehensive report the authors aimed to find whether collaboration between researchers from developed and developing countries contribute to the process of building scientific capacity in those nations less developed. The authors also found that sometimes the topics of the research collaboration were more likely related to the interests of the developed country, probably because they were also the source of funding.

It is therefore worthwhile to explore if any particular characteristic of the national and international collaboration of Cuban institutions might be playing a distinctive role for the country development. To study the national and international collaboration of

Cuban institutions we are selecting the field of biomedical sciences because improving the health of the population has been a priority of the Cuban government since 1959 (Marimón Torres and Martínez Cruz, 2010) achieving health indicators for Cuban population typical of developed countries (Keck and Reed, 2012). Perhaps one of the most successful examples of developing science to support high standard in public health is the case of immunology (Lage, 2008). The outcome of making this field of science strong having in mind the needs of the population can be seen in the Cuban approach in preventive medicine, national programme for vaccination, the control of infectious diseases and more recently immunotherapy in cancer. Additionally biotechnology in Cuba followed a particular path for development, which embodied the social character of Cuban science (Reid-Henry, 2010, 168). Moreover biotechnology has been delivering successful results to contribute to the country's economy (Pérez Ones and Nuñez Jover, 2009; Lage Dávila, 2013, 145).

Cuban scientific output and collaboration have been systematically studied by bibliometrists (Araujo Ruiz et al., 2005; Vega Almeida et al., 2007; Arencibia Jorge and Moya Anegón, 2010; Arencibia Jorge et al., 2013 and Zacca González et al., 2015) and their work has contributed to identify achievements and problems in the process of improving the national system of scientific and technological innovation. Building on their contributions, the present work intends to address the leading role of more advanced institutions in a process of extending the scientific capacity of the country in a period of economic restrictions.

Although the amount of scientific articles is a strong indicator measuring the effort of any particular country in the race to develop their capacities, there are other factors deciding the effectiveness of the inputs in developing S&T, among them, the technological infrastructure and the adequate or optimal institutional coordination and cooperation. However in developing countries the mobility of scientists turning into migration or long periods of staying away from the origin country is stressing the process of building capacities and emerging economies are taking new approach to harness this elusive human capital. Cuba has not yet established any mechanism for this problem. The results presented here indicate that the bases for taking into a good account the Cuban capital of her scientific diaspora do exist through mechanism of scientific collaboration.

5.2.1 *Cuban scientific outputs retrieved from PubMed*

Scientific output of Cuban institutions measured by the number of publications retrieved from the *PubMed* database is shown in Table 5.1, retrieved using advanced search. The number of total net publications (TNP) in aggregate for the year 2000, 2005 and 2010 was 861 from which 646 were further completed in the field of all authors affiliation using the electronic Journals linked to *PubMed* (*eJ-PubM*), representing 75% of the aggregated years. Cuban collaborative articles represented 60.2% of those articles that were completed with all affiliations.

Table 5.1. Cuban scientific articles in PubMed and those retrieved from electronic journals linked to *PubMed* (*eJ-PubMed*) indicating the scientific collaboration

| Year | No. articles in *PubMed* | No. articles in e-Journals (*eJ-PubM*) | Non collaborative articles | Collaborative articles | Collaboration (%) |
|---|---|---|---|---|---|
| 2000 | 236 | 147 | 83 | 64 | 43.5 |
| 2005 | 304 | 241 | 107 | 134 | 55.6 |
| 2010 | 321 | 258 | 67 | 191 | 74.0 |
| Total | 861 | 646 | 257 | 389 | 60.2 |

Pattern of collaboration was measured through the Cuban institutional publications (IP). All Cuban institutions shown in the author affiliations of the *eJ-PubM* sample were listed with their publications classified as N (only one Cuban institution) and NN (more than one Cuban institution), NI (one Cuban institution and one or more international institutions) and NNI (more than one Cuban institution and one or more international institutions) for the years 2000, 2005 and 2010.

The total aggregate number of institutional publications (IP) was used to classify the groups in Central, Middle and Distal as described in methods. Table 5.2 shows the distribution of Cuban institutions according to their output in scientific publications and their main function.

Table 5.2. Distribution of Cuban institutions according to the outputs in *ej-PubMed* and their principal functions

| Categories of Institutions | HE (S&T) | HE-Med. School | Teaching Hospitals | R&D | R&D&P or R&D&S | Res. Inst. (R&D and R&S) | Centres improving Public Health | GH & SH | P/S | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| **Central** | 6 | 1 | 0 | 2 | 5 | 6 | 0 | 0 | 0 | **20** |
| **Middle** | 2 | 1 | 0 | 7 | 3 | 13 | 0 | 0 | 0 | **25** |
| **Distal** | 4 | 7 | 26 | 31 | 4 | 12 | 28 | 33 | 11 | **156** |

**HE**: Higher Education; **S&T**: Science and Technology; **R&D**: Research and Development; **R&D&P**: Research, Development and Production; **R&D&S**: Research, Development and Services; **R&S**: Research and Services; **GH**: General Hospitals; **SH**: Specialised Hospitals (Maternity, Orthopaedic, Children, etc.) and **P/S**: Production and /or Services

Institutions in the Central group represented 10% and Middle and Distal groups 12.4% and 77.6% of all institutions respectively. Among the two hundred and one institutions listed 23.5% belong to Higher Education, 25.5% are institutions of Research and Development, 15.5% are Research and Services/Production and 35.5% are institutions either supporting the National Health System or dedicated to production or services. All institutions in both Central and Middle groups are all involved in research while in the Distal group it is only 54%.

(Appendix 9 corresponds to 201 Cuban institutions (Central group, Middle group and Distal group) retrieved from the author affiliations found in the articles of electronic journals linked to the publication records in *PubMed.*)

The total net scientific papers (TNP) in aggregate for the three years were 646 articles from *eJ-PubM*. However, when counting them as institutional publications the total number of scientific papers reached 980 articles (TIP) indicating the degree of participation of more than one institution per scientific article.

Collaborative papers including national and international institutions represented 60% of the 646 net publications (Table 5.3). The Central group as expected (Price and Beaver, 1966) representing 10% of all institutions generated 497 articles representing 76.9% of the total net publications while the Distal group of 156 institutions contributed only with 10.4% to the net publications. The proportion of collaborative articles including the participation of national and international institutions were 58.8%, 69.5% and 59.7% for Central (C), Middle (M) and Distal (D) groups respectively related to total net publications (TNP) per group (sub-TNP). However, the collaborative net publications is concentrated in the Core group and represents 45.2% (292 articles out of 646), while M and D only contribute with 8.8% (57 out of 646) and 6.2% (40 out of 646). Obviously these values do not fairly represent the real contribution of institutions in M and D groups to the collaborative scientific output of Cuban institutions since as net publications, articles are attributed only to the first author affiliation (or corresponding author).

Table 5.3. Net and Institutional Publications per group of Cuban Institutions (aggregates for years 2000, 2005, 2010)

| GROUPS | N | TNP | Collaborative (%) | N | NN | NI | NNI | TIP |
|---|---|---|---|---|---|---|---|---|
| CENTRAL | 205 | 497 | 59 | 205 | 164 | 144 | 117 | 630 |
| MIDDLE | 25 | 82 | 70 | 25 | 72 | 17 | 30 | 144 |
| DISTAL | 27 | 67 | 60 | 27 | 109 | 18 | 52 | 206 |
| SUB-TOTAL | 257 | 646 | 60.2 | 257 | 345 | 179 | 179 | 980 |

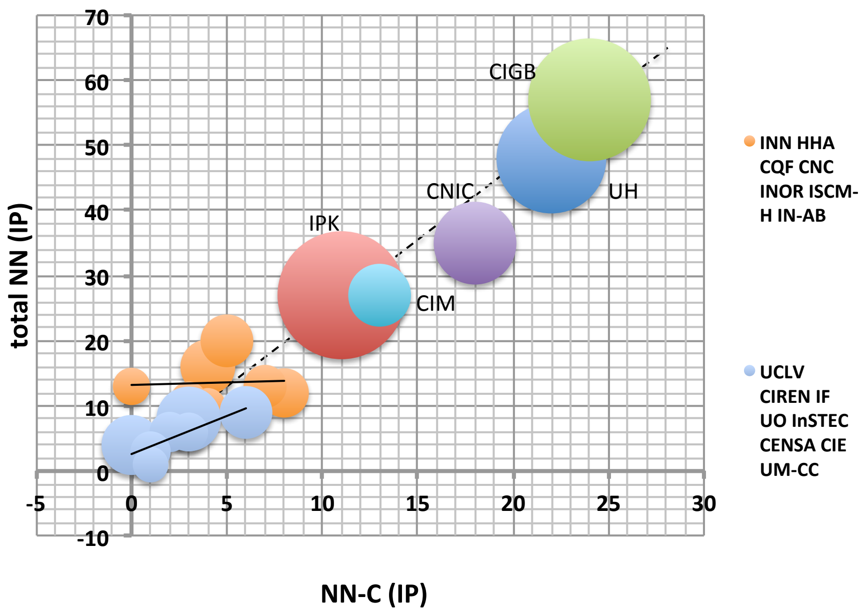
TNP: Total Net Publications (shaded in grey); TIP: Total Institutional Publications, N, NN, NI and NNI are types of collaborations (see text)

Institutional publications (IP) allow us to analyse the pattern of collaboration and the relationship among national institutions in which all participating institutions were accounted for their contributions to the article regardless of the position of the institution in the list of contributing authors. Collaborative articles both involving national or international co-authorships and counted by IPs represented 74% of 980 IPs. Articles with more than one Cuban institution (NNs) either national or international represented 75% of collaborative papers (only NI excluded from collaborative papers) indicating the strong relationship among Cuban institutions (Table 5.3), with Central group leading the cooperation (38.9%), followed by the Distal group with 22.3%.

### 5.2.2 *Cuban national collaboration*

The analysis of the national collaboration focuses on placing the Central group in the leading role when collaborating with other institutions in the Middle (M) and Distal (D) groups as well as the collaboration within the Central (C) group. The best approach for this purpose might be using IPs as a source of data. In general there is a linear relationship (y = 2.2 x and $R^2$= 0.899) between the amount of collaborative papers within the C group (NN-C) and the total amount of national collaborative papers (Figure 5.1), accounting for 50% of national collaboration. The top five institutions by the volume of their publications contribute more to the collaboration within the Central group, as most of them are part of the Scientific Park in the West Havana.

Figure 5.1 National collaboration of institutions in the Central group

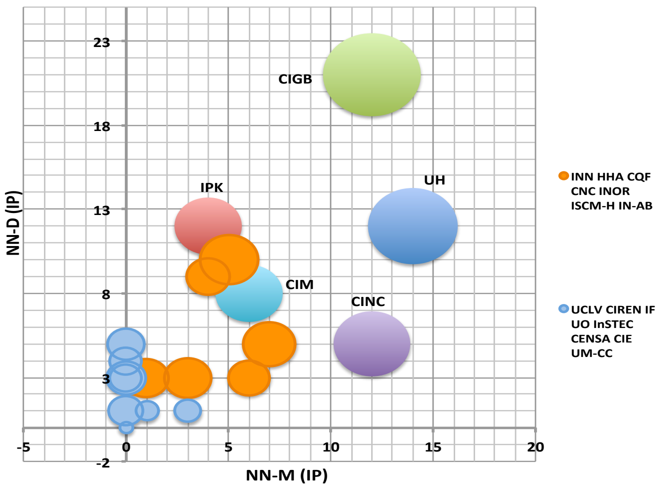



Total number of national collaboration in the Central group by their institutional publications (IP). The x-axis represents collaboration within Central group (NN-C) versus y-axis total collaboration. The sizes of the circles represent total publications of each institution.

Those institutions with higher volume of publications (larger diameter of the circles) are the Institute of Tropical Medicine Pedro Kourí (IPK) with 141 papers, the Centre of Genetic Engineering and Biotechnology (CIGB) with 130, University of Havana (UH) with 104, National Centre of Scientific Research (CNIC) with 59, University of Villa Clara (UCLV) with 36 and the Centre of Molecular Immunology (CIM) with 34. The next institutions of the Central group fitting less in the linear relationship of NN *versus* NN-C are the National Institute of Neurology and Neurosurgery (INN), Hospital 'Hermanos Amejeiras' (HHA), Centre of Pharmaceutical Chemistry (CQF), Cuban Neuroscience Centre (CNC), National Institute of Oncology and Radiology

(INOR), Higher Institute of Medical Sciences of Havana (ISCM-H) and Institute of Nephrology 'Abelardo Buch' (IN-AB). The last sub-group of institutions in the core group with the less contribution in terms of national collaborative papers are Central University of Las Villas (UCLV), International Centre for Neurological Restoration (CIREN), Finlay Institute (IF), University of Oriente (UO), Higher Institute of Technologies and Applied Sciences (InSTEC), Centre of Immunoassay (CIE), National Centre of Animal Health (CENSA) and University of Matanzas Camilo Cienfuegos (UM-CC).

Figure 5.2 National collaboration of Central group with Middle and Distal groups



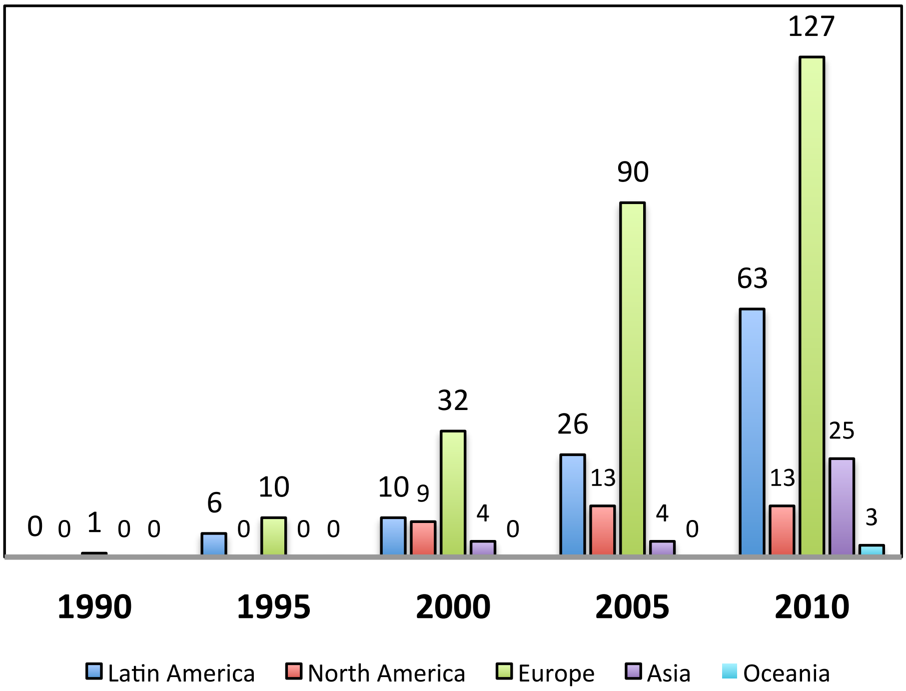

National collaboration of Central group (size of the circles) with Middle (NN-M) and Distal (NN-D) in x- and y-axis respectively.

The collaboration of the institutions of the C group with the ones of the M and D groups did not follow a linear relationship (Figure 5.2). The majority had stronger collaborations with institutions in D group, as the relation (M:D) shows for IPK (1:3), HHA (1:2), UO (0:4), CQF (1:3), CENSA (0:3) and IN-AB (4:9). Leading the institutions with stronger collaborations with those of the M group are the CNIC (12:5) and ISCM-H (3:1). The rest of the institutions collaborated almost equally with institutions in M and D groups. Interestingly, the strong collaboration of CNIC with M group might indicate the role of this institution as incubator of spin-off institutions (either research or state enterprises Chapter 2.5.4) with a defined profile of applied science and progressively incorporating production.

5.2.3 *Cuban International collaboration*

International collaboration of Cuban institutions has been increasing steadily since 2000 with European institutions sharing the highest presence in collaborative papers with Cuban institutions (Figure 5.3).

Figure 5.3. International collaboration of Cuban institutions



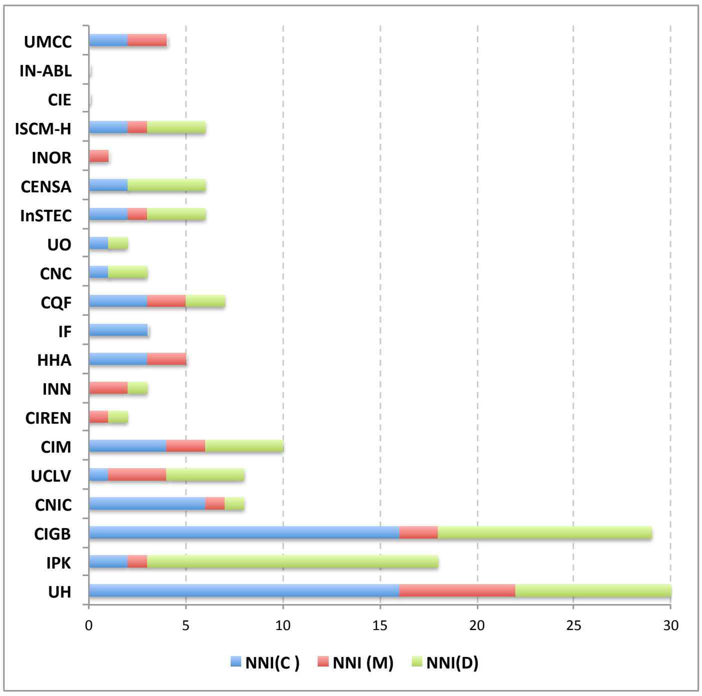

Number of international collaborative articles per world regions in the indicated years

Fourteen European countries have co-authored 249 articles with Cuban institutions when looking at the aggregate data of institutional publications; and in 2010 the European countries with more collaborative papers with Cuba were Spain (46; 36.2%), Belgium (17; 13.4%), Germany (16; 12.6%) and United Kingdom (14; 11%) out of 127 collaborative IP. Nine Latin America countries participated in collaborative papers in the period of study accounting for 100 IP and in 2010 the Latin American countries with the highest share were Brazil (25; 39.7%), Argentina (15; 23.8%) and Mexico (10; 15.9%) out of 63 collaborative IP. Japan is the individual country with highest share per region with 44% of collaborative papers in 2010. North America in spite of being the region of highest output in science, the share of collaborative papers with Cuban institutions has been relatively lower with only 35 collaborative IP; and in 2010 both Canada (6; 46%) and United States (7; 54%) were similarly represented for a total of 13 articles. In 2010 all regions except Africa were publishing in collaboration with Cuban institutions. International organizations such as WHO, UNESCO and PAHO have been represented through their experts co-authoring papers with Cuban institutions with 2 and 6 publications in 2000 and 2010 respectively. For the years included in this study, countries publishing with Cuban institutions were: Argentina, Brazil, Chile, Colombia, Mexico, Nicaragua, Paraguay, Peru, Puerto Rico, Canada, United States, Austria, Belgium, Finland, France, Germany, Italy, Portugal, Spain, Sweden, Switzerland, United Kingdom, Russia, Bangladesh, Cambodia, China, Iran, India, Japan, Korea, Malaya, Philippines, Singapore, Syria, Thailand, Vietnam, Uzbekistan, Australia and New Zealand.

Collaborative papers with international institutions represented 41% of the total net publications (266 out of 646). When analysing the contribution of each group of institutions to the total IPs in terms of publications with at least one international institution (NI+NNI), all institutions in the C group co-authored 261 papers (69%); 24 out of 25 institutions of the M group participated in 47 papers (12.4%) and only 51 out of 155 institutions of the D group contributed participating in 70 papers (18.5%) for a total of 378 IPs involving international collaboration (Table 5.3). For institutions in M and D groups national collaboration (NN) is stronger (50% and 53% respectively) versus international (33% and 34% respectively) in relation to their own institutional publications.

The contribution to the total international collaboration of individual institutions in the Central group publishing with one or more international institutions (NI) was 80.4% (for NI: 144 out of 179 IPs) and 58.8% (for NNI: 117 out of 199 IPs) when other Cuban institutions were participating in the collaborative articles (see table 5.3). The leading role of the Central group incorporating institutions in M and D groups is shown in Figure 5.4, with the Institute of Tropical Medicine Pedro Kourí (IPK) sharing almost 80% with D institutions in those articles including another Cuban institution. Another eleven institutions of the Central group share a third or more of their international collaboration with institutions of the Distal group.

Figure 5.4. Share of the international collaboration of the Central group with other Cuban institutions



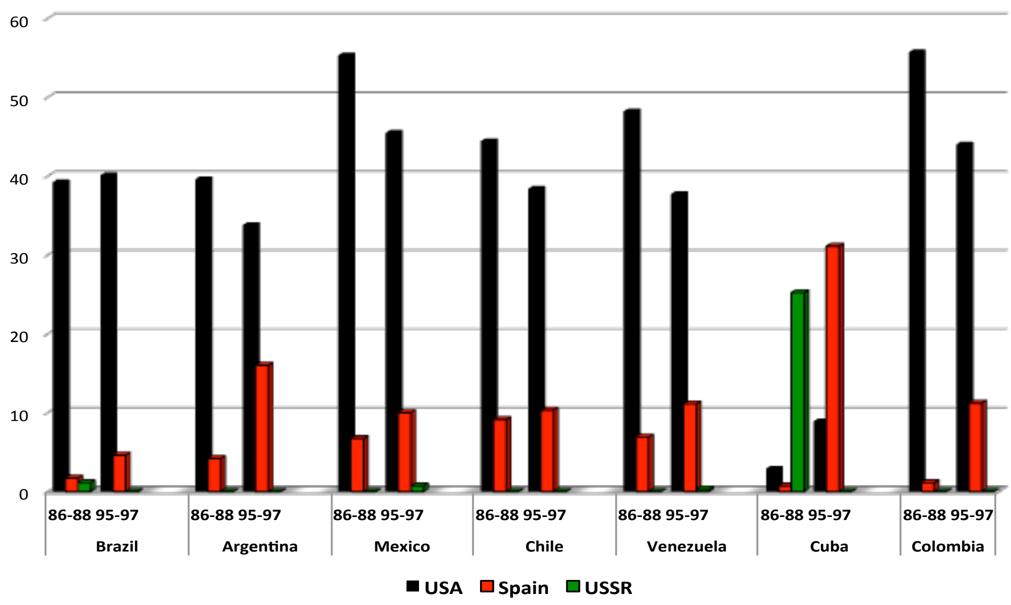

Institutions of the Central group and the composition of their international institutional publications (IPs) with another Cuban institution (NNI) in Middle (M), Distal (D) and within Central (C) groups

5.2.4 *Cuban Science, Technology and Innovation System: networks of institutions*

International collaboration between scientific institutions co-authoring articles in science and engineering (S&E) is one of the features strengthening the countries capabilities in scientific research and development. The global growth in international co-authored articles in S&E has increased by 133% from 90,867 articles in 1997 to 211,841 in 2012 and United States remains the strongest hub for scientific collaboration (NSF 2000 and 2014).

After the collapse of Soviet Union and socialist countries of Eastern Europe at the beginning of 1990, Cuba evolved in her pattern of international collaboration probably as the only way to maintain the commitment for the development of science initiated since the early 1960s. The Figure 5.5, generated from data of the National Science Foundation, science and engineering indicators (NSF 2000), show how different was the pattern of Cuban international collaboration from other countries of the region at the end of last century.

Figure 5.5 Partners in international scientific collaboration for top seven countries in Latin America



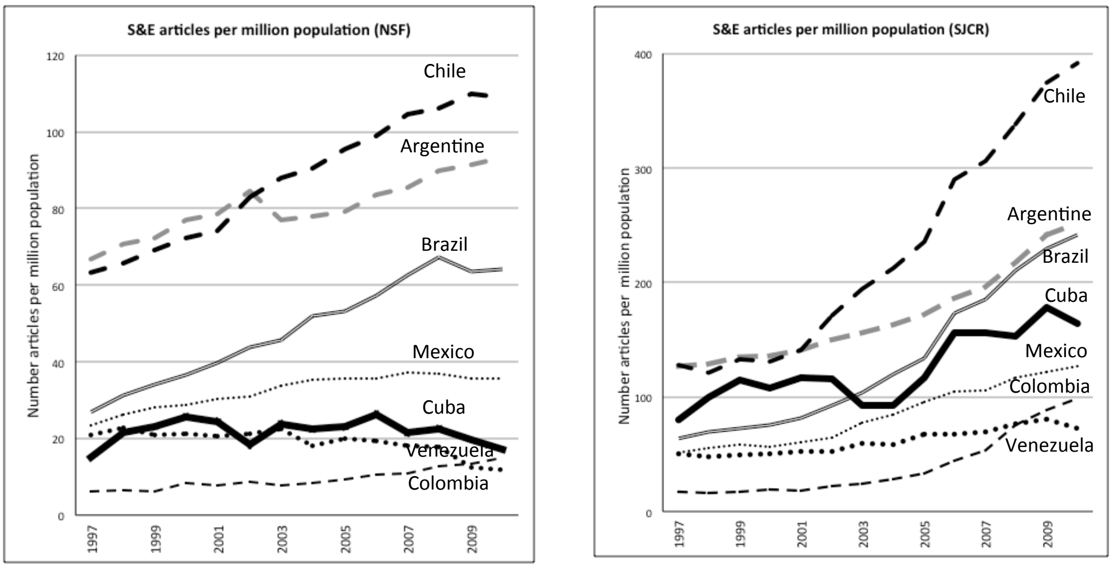

Graphic built using source of the data from NSF and *SJ&CR* for the period 1997-2010

Latin American countries as shown in the Figure 5.5, shared 32% - 55% of their internationally co-authored articles with U.S. in the period before and after 1990, while Cuba showed a distinctive turn in the pattern in which the collaboration with Soviet Union was substitute for Spain. Diversification of the international collaboration was also characteristic of this period by producing collaborative articles with countries such as Canada, Belgium, Denmark, Japan and Austria, as well as increasing the share of scientific collaborative articles with others such as United Kingdom, Switzerland and France among others (NSF, 2000). Even with United States, Cuba experienced an increase in scientific collaboration regardless the geopolitical distance between both countries.

At the beginning of this century Cuban scientific output measured by the number of articles published in international journals has been shown to be not far from the mean of the Latin American and the Caribbean scientific articles when normalized by population (Clark Arxer, 2010), being slightly higher in 2001 and lower in the following years up to 2007. In general, the scientific output for developing countries is not adequately represented in international databases (Gailland, 1992). The evaluation of scientific output changes depending on the sources used to obtain the science and technology indicators, as two different results might arise by counting scientific articles either from *Science Citation Index (SCI*), *Thomson and Reuters* or from *SCImago journals and country rank (SJ&CR)*, powered by *Scopus* database.

Latin American countries are better represented in *Scopus* than in *SCI* (*Science Citation Index*) and Cuba ranks in fifth (NSF, Figure 5.6) or fourth (*SJ&CR*, Figure 5.6) positions in the amount of scientific and engineering (S&E) articles for the region when normalized per million of population. Using *SJ&CR*[38] we found that more than a third of total publication in these top seven countries of the LAC correspond to international collaboration for the period 2000-2010 with Chile, the leading country in the table, having 52.5% of international collaboration, followed by Colombia (52.1%), Cuba (44.9%), Venezuela (43.5%), Mexico (40.2%), Argentina (40.5%) and Brazil (27.8%).

Figure 5.6 Scientific publications of seven Latin American countries by two different databases: National Science Foundation (US) and *Scopus* (Elsevier)




Graphics elaborated by the researchers using SCIMago data and NSF (S&E publications) in years indicated

The cross section of aggregated publications for the years 2000, 2005 and 2010 in which all author affiliations were recorded, shows as expected, that the disciplines contributing more to overall publications were immunology and microbiology (19.7%),

---

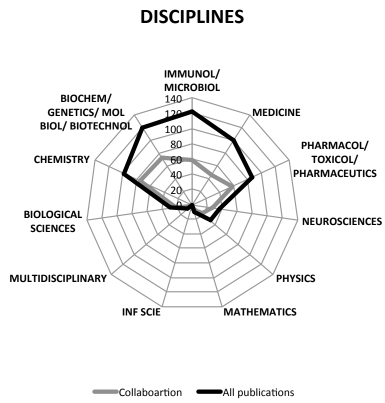
38 *SJ&CR: SCImago Journal and Country Rank*, powered by *Scopus*. Information accessed on 17th September 2014. http://www.scimagojr.com/countrysearch.php?country=EC

the group of biochemistry-molecular and biology-biotechnology (18.6%), medicine (15.6%) and the group of pharmacology-toxicology-pharmaceuticals (15.2%); interestingly the group of chemical sciences (16.1%) had strong representation, which denotes its role supporting biomedical research in structural and molecular biology (Figure 5.7).

Figure 5.7 Collaboration articles by disciplines

COLLABORATIVE ARTICLES BY DISCIPLINES
(Aggregate net publication of year 2000, 2005 and 2010)

| Group of related disciplines | Relevant discipline | All Net Publ (aggreagate) | Collaborative articles |
|---|---|---|---|
| IMMUNOL/ MICROBIOL | IMMUNOLOGY<br>MICROBIOLOGY/PARASITOLOGY | 127 | 58 |
| MEDICINE | CLINICAL MEDICINE<br>EPIDEMIOLOGY<br>DENTISTRY<br>PUBLIC HEALTH | 98 | 47 |
| BIOCHEM/ GENETICS/ MOL BIOL/ BIOTECHNOL | BIOCHEM/BIOPHYS/BIOINF<br>CELL BIOLOGY/MOL BIOLOGY<br>GENETICS<br>GENETIC ENGINEERING<br>BIOTECHNOLOGY | 119 | 72 |
| CHEMISTRY | ANALYTICAL CHEMISTRY<br>PHYS CHEMISTRY<br>MEDICINAL CHEMISTRY<br>CHEM ENGINEERING<br>COMPUTATIONAL CHEMISTRY | 104 | 76 |
| PHYSICS | MEDICAL PHYSICS/ENGINERING<br>PHYSICS | 27 | 18 |
| MATHEMATICS | BIOSTATISTC<br>MATHEMATICS | 11 | 7 |
| NEUROSCIENCES | NEUROSCIENCES | 37 | 32 |
| PHARMACOL/ TOXICOL/ PHARMACEUTICS | PHYSIOLOGY<br>PHARMACOLOGY/TOXICOLOGY<br>PHARMACEUTICAL/DRUG DEV | 91 | 54 |
| BIOLOGICAL SCIENCES | PLANT BIOLOGY/ AGRICUL SCI/ VET MED<br>MARINE BIOLOGY | 27 | 21 |
| INF SCIE | INFORMATION SCIENCE | 2 | 1 |
| MULTIDISCIPLINARY | MULTIDISCIPLINARY | 3 | 3 |
| | | 646 | 389 |



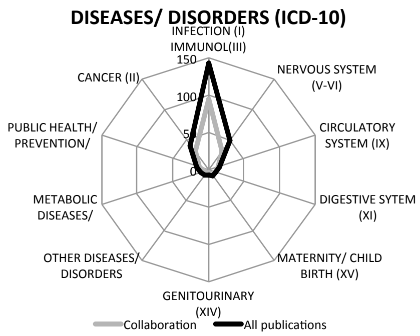

Number of aggregate of net publications (2000, 2005 and 2010) per disciplines in science

This result is an expression of national policies to advance science to improve the health of the Cuban population and to stimulate innovation in areas that can reach foreign market such as biotechnology. Immunology and microbiology are essential disciplines in the diagnostic, cure and prevention of transmissible diseases, including the development of new vaccines. Immunology is also a key discipline in Cuban approach to develop technologies of immunotherapy in the treatment of cancer. The groups with less collaborative articles are immunology-microbiology and medicine with 46% and 48% respectively compare to the total of 60%. In the case of immunology-microbiology seems to be consequence to the high representation of articles related with infectious diseases in *PubMed* since *Revista Cubana de Medicina Tropical* is the only Cuban journal indexed in this database. Indirectly it might suggest that disciplines other that immunology and microbiology only have a selected representation in *PubMed,* in which collaborative articles are strong candidates to be accepted in foreign journals. In the case of medicine the observed low collaboration has been attributed to the degree of specialisation of National Institutes of Health (Vega Almeida et al., 2007) and publications by departments in hospitals concerning their own casuistic. Low collaboration in the health sector has been also shown in other studies (Arencibia Jorge et al., 2013, Zacca González et al., 2015) and might be the reason why the outputs in the sector are less than the expected.

Not surprisingly, the classification of the articles by diseases and health disorders showed the same trend with more representation of scientific contribution in infectious diseases (46%), cancer (13%) and disorders of the nervous system (16%) as shown in figure 5.8. However, in general articles contributing explicitly to a particular disease or disorder account for 309 publications meaning that 62% of this output came from institutions that do not belong to the health sector, but their applied research addressed priorities of the national health system and consequently the proportion of scientific collaboration rose to 69%.

Figure 5.8 Cuban scientific publications according to the International Classification of Diseases (ICD-10)

| SUBJECT (ICD-10) | Collaborative publications | All publications |
|---|---|---|
| INFECTION (I) IMMUNOL(III) | 95 | 143 |
| CANCER (II) | 31 | 41 |
| NERVOUS SYSTEM (V-VI) | 31 | 49 |
| CIRCULATORY SYSTEM (IX) | 14 | 16 |
| METABOLIC DISEASES/ NUTRITION (IV) | 5 | 11 |
| DIGESTIVE SYTEM (XI) | 9 | 9 |
| MATERNITY/ CHILD BIRTH (XV) | 6 | 9 |
| GENITOURINARY (XIV) | 3 | 7 |
| OTHER DISEASES/ DISORDERS | 7 | 8 |
| PUBLIC HEALTH/ PREVENTION/ | 12 | 16 |
| | 213 | 309 |




Number of collaborative articles per group (aggregate values for years 2000, 2005 and 2010. International Classification of Diseases (ICD-10): (I) Certain infectious and parasitic diseases; (II) Neoplasms; (III) Diseases of the blood and blood-forming organs and certain disorders involving the immune mechanism (IV) Endocrine, nutritional and metabolic diseases; (V) Mental and behavioral disorders (VI) Diseases of the nervous system (VII) Diseases of the eye and adnexa; (VIII) Diseases of the ear and mastoid process; (IX) Diseases of the circulatory system; (X) Diseases of the respiratory system; (XI) Diseases of the digestive system; (XII) Diseases of the skin and subcutaneous tissue; (XIII) Diseases of the musculoskeletal system and connective tissue; (XIV) Diseases of the genitourinary system) Diseases of the genitourinary system; (XV) Pregnancy, childbirth and the puerperium; (XVI) Certain conditions originating in the perinatal period; etc. *Group of diseases with less than 5 publications were not included in the representation.*

An illustration reflecting Cuba's priorities in research is the case of '*dengue*', a tropical disease that attracts the interest of publishing only by 0.1% of the world entries in Medline (3,456 out of 3, 460,987). However because of the frequent outbreaks of this infectious disease in Cuba, research in dengue is one of the Cuba National Research

Programme in which different institutions participate. Therefore taking Cuba to the fourth in the world ranking of national interest among 79 countries with 4.6% of its total publications in this field and sharing 1.94% of international publications in dengue for the $14^{th}$ ranking (values calculated on $20^{th}$ June 2014 from the available search engine in *Medline/PubMed* developed by Corlan, 2012).

Multi-disciplinary teams generally support biosciences and biomedical research making difficult sometime to separate the boundaries between them, however in many cases, one discipline takes the centre of the contribution (Vega-Almeida et al., 2007).

## 5.3 LIMITATIONS OF THE STUDY

The key decision for further studies would be choosing the source of information among all available databases representing Cuban output in science. Previous studies evaluating the total scientific production of Latin America and the Caribbean region (Miguel, 2011) found that in the case of Cuba, 48.6% of Cuban journals (151) listed in *LATINDEX* were covered by *SciELO* (70.5%), *RedALyC* (37.3%) and *Scopus* (41.2%) as electronic databases with different platforms supporting the search and retrieval for bibliometric studies. Moreover, the study of Araujo Ruiz and collaborators (2005) showed that the Institute of Scientific Information Databases (ISI-DBs**)** indexed only 20.7% of Cuban articles when compared to the local database *CubaCiencias* during the period between 1988 and 2003.

In a macro level study of Cuban scientific output combining socioeconomic and bibliometric indicators, the authors concluded that *Scopus* was a better information source when it was compared to *WoS* (Arencibia Jorge and Moya Anegón, 2010). Obviously, studies addressing the visibility of Cuban science in which the databases provide the engine for analysing the citation of articles might still need to use those databases with less than 50% representation of Cuban outputs in science. However, searching nationally generated databases and documents will provide more information when focussing on how Cuban scientific and engineering outputs have contributed to build the scientific capacity of the country.

In spite of the limitations mentioned above, the results indicate that collaboration between scientifically advanced institutions (Central) and a wide range of national institutions is a consequence of the social character of science in Cuba in which cooperation rather competition prevail (López Mola et al., 2006). The conclusion comes from a search in the limited field of biomedical science in which Cuba has a recognised strength. The Cuban government has supported areas of biomedical research not only to improve the health of the Cuban population but also to strategically create sources of income out of the high performance in biotechnology research as well as expanding its capacity to effectively co-operate with developing countries and emerging economies (Sáenz et al., 2010; Keck and Reed, 2012).

# CHAPTER 6:  RESULTS - PART II

## CUBAN SCIENTISTS AND ENGINEERS IN EUROPE

### 6.1 INTRODUCTION

The theory underpinning the research for this chapter was discussed in chapter four. Briefly it covered the modern science, the rise of the scientists as a profession (Merton, 1957; Kuhn, 1970; Beaver and Rosen, 1979) and the beginning of their documented work through peer reviewed scientific journals (Price, 1961, 51; Price, 1963) making it possible to trace back their scientific contributions, patterns of their collaboration and places of work.

The creation of scientific knowledge in modern science has been the consequence of an increasing collaboration between scientists. Patterns of scientific collaboration have been studied through the new paradigm of scientometrics based on the quantitative analysis of the bibliographic records of publications in peer-review scientific journals. More recently the attention has been paid to international collaboration as the *new invisible college* in which scientific collaboration beyond geographical borders might provide opportunities for developing countries (Gailland, 1992; Wagner and Leydesdorff, 2005a; Wagner, 2008, Gaillard and Arvanitis, 2013).

Here the Cuban scientists working in European institutions of S&T are taken as a case study in the context of examining the existence or not of a scientific diaspora and the possibilities of collaborating with the scientists at home for the development of the country. The study as described in the previous chapter four is supported by the publishing patterns of this defined community of scientists (section 4.5.2).

## 6.2 DEMOGRAPHY OF CRiE AND OPPORTUNITIES IN THEIR DESTINATION COUNTRIES

### 6.2.1 *Size and distribution of Cuban scientists in Europe*

The empirical design to find the sample of Cuban scientists and engineers in Europe was described in chapter 4.5.2 and depicted in the Figure 4.4. The result of the evolution of the sample across the study is shown in Table 6.1. The original group of 150 Cubans working in European institutions of S&T found through the snow-ball and chain referral sampling methods supported by professional networks such as *LinkedIn* (Lk) and *ResearchGate* (RG) were further reviewed for their records of scientific publications listed in *Scopus* in order to select the active researchers for the final sample for the study. The use of the acronym CRiE in the rest of the thesis refers to active researchers.

Table 6.1 Cuban Researchers in Europe and active researchers (CRiE)

| COUNTRY | CODE | Lk/RG | ScopusID | ACTIVE RESEARCHER |
|---|---|---|---|---|
| BELGIUM | 201 | 15 | 15 | **10** |
| FRANCE | 202 | 10 | 8 | **7** |
| GERMANY | 203 | 18 | 16 | **11** |
| FINLAND | 204 | 3 | 3 | **3** |
| ITALY | 205 | 12 | 10 | **10** |
| PORTUGAL | 206 | 1 | 1 | **1** |
| SPAIN | 207 | 51 | 48 | **36** |
| SWITZERLAND | 208 | 9 | 5 | **4** |
| SWEDEN | 209 | 4 | 4 | **4** |
| UK | 210 | 24 | 22 | **17** |
| NETHERLANDS | 213 | 1 | 1 | **1** |
| DENMARK | 216 | 1 | 1 | **1** |
| LUXEMBURG | 225 | 1 | 1 | **1** |
| TOTAL | | 150 | 135 | **106** |

In a previous study evaluating scientific productivity of British researchers (Plume, 2012; discussed in 3.1.2) the proportion of active researchers was 14% in a sample of 2.5 million authors. The high percentage of active researchers in the sample of CRiE (106/135: 79%) might be due first, that only full articles in journals were considered as documents, whereas in the case of the Plume's study he also included conference papers and letters. Second, because the size of the sample was too small, every author was individually analysed in the database of *Scopus* using different combinations of the names and surnames (as one or two surnames are often used among Hispanic researchers when publishing) and additionally checking the field (discipline) of research in the publications. Table 6.2 shows the number of active researchers with two and three unique identification numbers (UIN) given by *Scopus* in the sample of CRiE. If the corrections were not in place, those authors with more than one UIN might not be classified as active researchers, because of splitting identities and therefore distorting the outcome of their scientific production. In the case of the cohort group CRiC inspecting the list of researchers per institutions showed 18 researchers with 2 UIN, 14 with 3 UIN and one with four UIN in the group of 121 researchers accounting for more than 48 publications each.

Table 6.2 Active researchers with more than one UIN by country

| COUNTRY | CRiE with UIN | 2 UIN | 3 UIN | Researchers by UIN |
|---|---|---|---|---|
| BELGIUM | 15 | 0 | 0 | 15 |
| DENMARK | 1 | 0 | 0 | 1 |
| FINLAND | 3 | 1 | 0 | 4 |
| FRANCE | 8 | 1 | 0 | 9 |
| GERMANY | 16 | 1 | 1 | 19 |
| ITALY | 10 | 3 | 1 | 15 |
| LUXEMBURG | 1 | 0 | 0 | 1 |
| NETHERLANDS | 1 | 0 | 0 | 1 |
| PORTUGAL | 1 | 0 | 0 | 1 |
| SPAIN | 48 | 11 | 0 | 59 |
| SWITZERLAND | 5 | 2 | 0 | 7 |
| SWEDEN | 4 | 0 | 0 | 4 |
| UK | 22 | 4 | 2 | 30 |
| TOTAL | 135 | 23 | 8 | 166 |

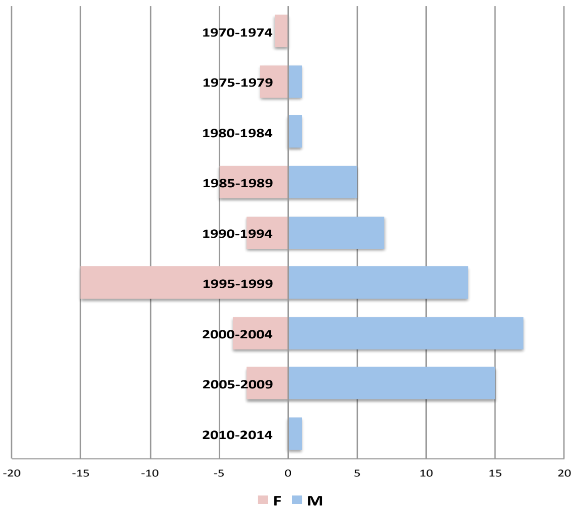
Another problem found when using the database of *Scopus* was the author's place of work, sometimes showing the last institution from which the scientists published. Therefore once classifying the CRiE as an active researcher their affiliation was checked again in their updated version of *LinkedIn* and *ResearchGate* by the end of 2014. If the last affiliation of active researcher was in Cuba (returning researchers in 2014 were 2) or if they were not able to publish as yet in Europe (another 2 active researchers) they were excluded from the study.

6.2.2 *Gender, place and year of higher education attainment and post graduate studies*

The study sample did not reflect the Cuban gender composition in research institutions with average 53.8% female researchers between 2005 and 2010 (ONE, 2014), although this percentage refers to the total composition and not specifically to active researchers. Female CRiE were only 34% (36 female out of 106 active researchers). Female CRiC were 25% (30 out of 120 CRiC) when selecting researchers with more than 48 publications in the period working in 14 different institutions out of 94 listed through the *Scopus* search (Table 4.3). The bigger group of female CRiE attained their HE in the years from 1995 to 1999 and for the male active researchers during the years 1995 to 2009, as shown in figure 6.1. Those years in which larger group of CRiE graduated from Cuban universities correspond to researchers between 30 and 40 years old, which is the age related group of the Cuban population with the highest proportion of migration (Sorolla Fernádez, 2013). Assuming those researchers did not have any interruption during their education, 67% (21 out of 33) of the females and 77% (46 out of 60) of the males were younger than 40 years old.

CRiE graduated from academic institutions in Havana represent 89% of those who stated their places of HE graduation in the public domain (98 researchers, Table 6.3). This is in agreement with previous findings of Havana as a sender city of tertiary educated (Martín Fernández, 2007) migrants. Other factors behind this high representation of Havana in the CRiE sample might be the density of HE institutions in Havana (seven out of twenty one universities in the Ministry of Higher Education, see appendix 6.1) holding more students than the rest of the country, and the quality of education attained in those institutions with high standards, allowing the graduates to secure places in European universities and research institutions. The quality of education in this case refers to the possibility of students being part of an environment with a long tradition of publishing in scientific journals as it is the case of University of Havana (Palacios-Callender et al., 2016) and with strong national and international collaboration.

Figure 6.1 CRiE: Gender and year of HE attained




Another characteristic of the CRiE is the low proportion of engineers with only 17% involved in research. This could be due to the filter applied for active researchers; publication pattern in science differs from engineering that might have patents as output rather than publications in scientific journals.

Table 6.3 Numbers of active CRiE with HE attainments in different Cuban institutions for HE

| HE inst. | Biol. | Pharm Food | Phys. | Math | Chem. | Med Sci. | Chem Eng. | Compt Eng. | Nucl. Phys. | Radio Chem. | nd | Total. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| UH | 29 | 4 | 15 | 4 | 15 | - | - | - | - | - | 2 | 69 |
| ISPJAE | - | - | - | - | - | - | 2 | 2 | - | - |  | 4 |
| InSTEC | - | - | - | - | - | - | 5 |  | 3 | 4 | 1 | 13 |
| UCLV | - | 2 | - | - | 1 | - | - | - | - | - | - | 3 |
| UOPL | - | - | 1 | - | - | - | - | - | - | - | - | 1 |
| USSJM | 1 | - | - | - | - | - | - | - | - | - | - | 1 |
| ISCM | - | - | - | - | - | 2 | - | - | - | - | - | 2 |
| USSR | - | - | 2 | 1 | 1 | - | - | - | - | - | - | 5 |

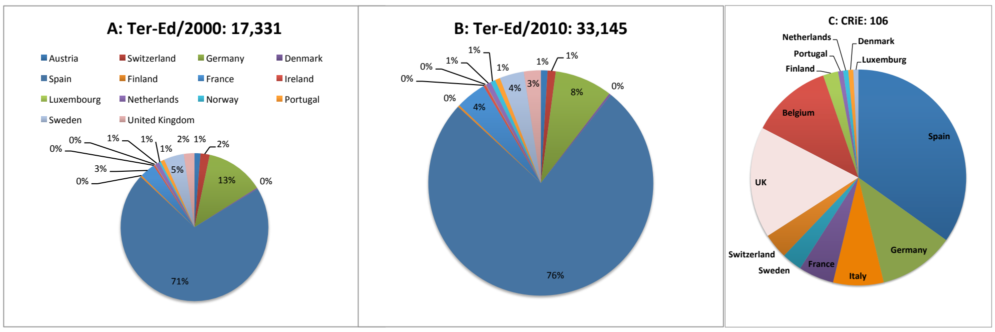
Data obtained from *LinkedIn*, *ResearchGate* and online curriculum vitae found through their institutions in Europe. Data completed for 98 out 106 CRiE. Three CRiE did not specifying the type of career (nd) and another nine did not mention where in Cuba they graduate from HE, but only the working experience in Cuban institutions.

### 6.2.3 *The Cuban scientists in Europe and their environment: describing the European science and technology institution*

There are 13 Cuban PhD students at different stages of completing their doctoral studies in the CRiE sample. They have been in Europe for more than two years and they are already publishing in scientific journals, however some of them might return back to Cuba after graduation. There were 2 PhD students who returned to Cuba and therefore they were excluded from the sample. However, others remained in Europe as the sample of CRiE have another 44 Cuban PhD graduated from European Institutions (see in Table 6.4).

There is a high mobility of Cuban researchers in Europe as expected since they seem to be in the early stage of their careers as PhD students and postdoctoral researchers. There are at least two factors determining such mobility in the early years of the researchers' careers: first the funding for the PhD studies are limited to three years (more years if it is part-time) and second, funding for research in Europe encourages movement within Europe. A third factor might be a consequence of shortage of funding in academia during the economic crisis of 2008 (Izsak et al., 2013), increasing the mobility of CRiE towards destinations in Europe with more resources for research (Germany, Sweden, Norway, etc.) or long tradition (United Kingdom, France, etc.) in S&T. Figure 6.2-C shows how Cuban researchers are more evenly distributed in countries of Europe where research and innovation is strong while the rest of the Cubans with tertiary education preferred Spain as the destination country.

Figure 6.2 Distribution in Europe of Cubans with tertiary education and CRiE

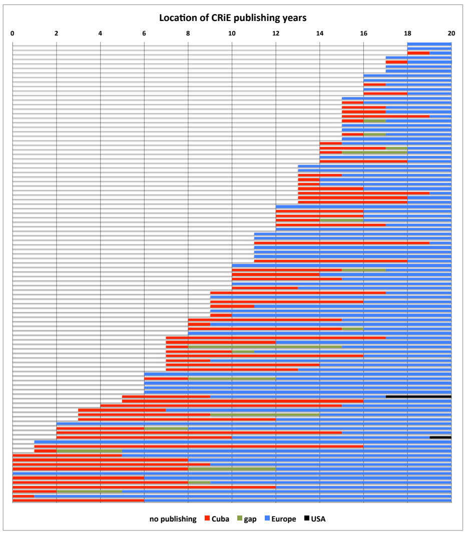



A and B: Cuban migrants with tertiary education (TerEd) in OECD countries data (source: Brücker et al., 2013). C: CRiE

Few CRiE remained in one place of work for more than five years; the majority has changed affiliation more than three times, and often they have been working in different countries within Europe. Three have been postdocs in United States and returned to do research in universities in Europe and another two remained in United States.

Sixty seven per cent of Cuban researchers have published first from Cuban affiliations at least once before moving to Europe and the remainder of thirty-three never published from Cuba. In general more than 50 % have published for more than 10 years including both groups: those publishing only from European addresses and those with Cuban and European addresses. In some cases there is a gap of one or more years between publishing in Cuba and later in Europe. In figure 6.3 the horizontal bars represent each Cuban researcher in the 20 years period of study (1995-2014). In red are the years when the Cuban researchers were publishing in Cuba, the green indicates the gap years, in blue the years they were publishing in Europe and in black those that moved to United States.

Figure 6.3 Pattern of CRiE publications according to their publishing location




CRiE have been publishing from one hundred and fourteen European institutions but only ninety-six were listed in *Scopus* as research entities. Institutions were mainly universities, research institutions and research organizations such as IMDEA (Instituto Madrileño de Estudios Avanzados), CSIC (Consejo Superior de Investigaciones Científicas) both in Spain; CNRS (Centre National de la Recherche

Scientifique) in France or Max Planck Institutes in Germany. Table 6.4 lists the European universities included in the 500 top *ARWU* in 2012 from where CRiE have been publishing, indicating the number of researchers per position.

Table 6.4 European institutions from where CRiE have been publishing

| | European Institutions (ARWU 2012) | Univ degree | PhD student | Doctorate | Posdoc | Senior Res | Princ invest | Director |
|---|---|---|---|---|---|---|---|---|
| 1 | University of Cambridge (5) UK | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 2 | University of Oxford (10), UK | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| 3 | University College London (21), UK | 0 | 1 | 3 | 3 | 3 | 0 | 0 |
| 4 | Swiss Federal Institute Technology Zurich (23) Switzerland | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 5 | Imperial College London (24) UK | 0 | 0 | 0 | 0 | 1 | 1 | 0 |
| 6 | Universite Paris Sud (41), France | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 7 | University of Manchester(40), UK | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 8 | Karolinska Institute (42), Sweden | 0 | 0 | 0 | 2 | 1 | 0 | 0 |
| 9 | University of Copenhagen (44) Denmark | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 10 | University of Edinburg (51), UK | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 11 | University of Zurich (59), Switzerland | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 12 | Oslo University (58), Norway | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 13 | King College London(68) , UK | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 14 | Upsala University (72)Sweden | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 15 | Helsinky University (70), Finland | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| 16 | Moscow State University (80), Russia Federation | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| 17 | Ghent University (89), Belgium | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 18 | University of Liverpool (101-150), UK | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 19 | Freigurg University (101-150), Germany | 0 | 0 | 1 | 1 | 0 | 0 | 0 |
| 20 | Katholic University of Leuven (101-150), Belgium | 0 | 1 | 1 | 2 | 2 | 2 | 0 |
| 21 | University of Strasbourg (101-150), France | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 22 | University Munster (101-150), Germany | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 23 | Ecola Polytechnique Federale de Lausanne (101-150), Switzerland | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 24 | University of Frankfurt (101-150), Germany | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| 25 | University Libre de Bruxels (101-150), Belgium | 0 | 0 | 2 | 0 | 1 | 0 | 0 |
| 26 | Cardif University (150-200), UK | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 27 | University of Bern, (150-200), Switzerland | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 28 | University of Milan, (150-200), Italy | 0 | 0 | 2 | 2 | 1 | 0 | 0 |
| 29 | University of Frankfurt (101-150), Germany | 0 | 0 | 0 | 0 | 1 | 1 | 0 |
| 30 | University of Paul Sabatier (Toulosse 3) (201-300), France | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 31 | University of Dusseldorf (201-300), Germany | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 32 | University of Reading (201-300), UK | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 33 | University of Durham (201-300), UK | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 34 | University of York (201-300), UK | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 35 | Royal Institute of Technology (201-300), Sweden | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 36 | Umea University (201-300), Sweden | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 37 | University of Bochum (201-300), Germany | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 38 | University of Barcelona (201-300), Spain | 0 | 0 | 4 | 0 | 0 | 0 | 0 |
| 39 | University of Erlangen-Nuremberg (201-300), Germany | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 40 | University of Marbourg (201-300), Germany | 0 | 0 | 1 | 1 | 0 | 0 | 0 |
| 41 | Queen Mary University of London (201-300), UK | 0 | 0 | 0 | 3 | 1 | 0 | 0 |
| 42 | Autonomus University of Madrid (201-300), Spain | 0 | 1 | 3 | 2 | 0 | 0 | 1 |
| 43 | Complutense University Madrid (201-300), Spain | 0 | 0 | 4 | 1 | 1 | 1 | 0 |
| 44 | University of Turku (300-400), Finland | 0 | 0 | 1 | 2 | 0 | 0 | 0 |
| 45 | Chalmers University of Technology (300-400), Sweden | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 46 | Autonomus University of Barcelona (300-400), Spain | 0 | 0 | 5 | 1 | 1 | 0 | 0 |
| 47 | University of Basque Country (300-400), Spain | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 48 | University of Porto (300-400), Portugal | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 49 | University of Genova (300-400), Italy | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 50 | University of Bourdoux (300-400), France | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 51 | University of Twente (300-400), Netherland | 0 | 0 | 1 | 1 | 1 | 1 | 0 |
| 52 | Ecola Polytechnique (301-400), France | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 53 | Polytechnic University of Valencia, (301-400), Spain | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 54 | University of Vigo (400-500), Spain | 0 | 1 | 1 | 2 | 0 | 0 | 0 |
| 55 | University of Pavia (400-500), Italy | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 56 | University of Bremen (400-500), Germany | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 57 | University Nice Sophia Antipolis (400-500), France | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 58 | University of Regensburg (401-500), Germany | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 59 | Vrije University of Brussels, (400-500) Belgium | 0 | 1 | 0 | 3 | 0 | 0 | 0 |
| 60 | University Pompeo-Fabra (401-500), Spain | 0 | 1 | 0 | 2 | 0 | 0 | 0 |
| | **Sub total CRiE in European Institutions (500 ARWU)** | 3 | 11 | 40 | 46 | 19 | 10 | 1 |

Note: The aggregate do not represent total number of researchers, but job positions

The numbers in the cells illustrate positions occupied by CRiE spanning the period of study; meaning that for a CRiE who reached the position of Director of an institute, the PhD and postdoc positions in other places were also counted. However not all positions were always counted.

Seventy-four out of 106 CRiE were in those top institutions in Europe and twelve are principal investigators or professors. Another twelve CRiE have moved to the industry sector after few years in postdoc positions in academia and four of them are group leaders.

Although there are few rankings evaluating worldwide research universities the *Annual Ranking for World Universities* (ARWU) was the first one created by the Institute of Higher Education of Shanghai Jiao Tong University, China in 2003 with the purpose of knowing how Chinese universities were performing in relation to other universities in the world. This system of ranking was referred to and used since then by universities, organizations and governments worldwide when assessing the quality of universities. *ARWU* uses six indicators for ranking the world universities including the number of alumni and staff winning Nobel Prizes and Fields Medals, number of highly cited researchers selected by *Thomson Reuters*, number of articles published in high impact journals such as *Nature* and *Science,* and the number of articles indexed in *Science Citation Index* (SCI). Overall the ranking is an indication of excellence in science and education; and these universities by being included in the 500 best, earn the prestige of ensuring funding from governments and organizations as they are large and research-intensive academic centres. Moreover those universities will also attract the best researchers and students to maintain the excellence attained. Holding a doctoral degree in those academic institutions is also a passport for new job opportunities and grant applications, ensuring longer periods in research. It also might explain why CRiE working in top universities are more represented in the sample of investigation because once the researcher gets in and manages to succeed, new opportunities will ensure progression in science and publishing as active researchers in the twenty year period of this study. Cuban researchers working in institutions of excellence in science are carrying out their research under the best available conditions, sharing knowledge and networking experience with top researchers worldwide. This fertile environment also generates opportunities that could be harnessed by the CRiE's networks through collaboration and cooperation.

Another system for evaluating academic and research institutions is the *SCIMago* institution ranking, which includes in the methodology two new indicators: excellence and leadership. The first one is a measurement of the visibility of the institution evaluating the frequency of cited articles of a given institution. The second indicator takes into account the affiliation of the corresponding author in the scientific publication of the given institution. The data source in *SCIMago* is *Scopus* and therefore Latin American countries are better represented. However the annual report of *SCIMago* includes all types of research organizations with more than 3,000 worldwide research institutes. Unfortunately the Internet option of selecting the academic institutions for their rankings is no longer available, making the data processing unnecessarily laborious. For the purpose of this study the *ARWU* ranking seems to provide an acceptable reference of the quality of the higher education institutions within the region where the majority of the CRiE are. In general all methodologies have been criticised and one of the reasons is the sources used to evaluate performance do not evenly weigh international publications. Nevertheless, those different ways of establishing the institution's place in the ranking might change the order in the top ranking places, but in general governments, funding agencies and wider type of organizations consult them extensively.

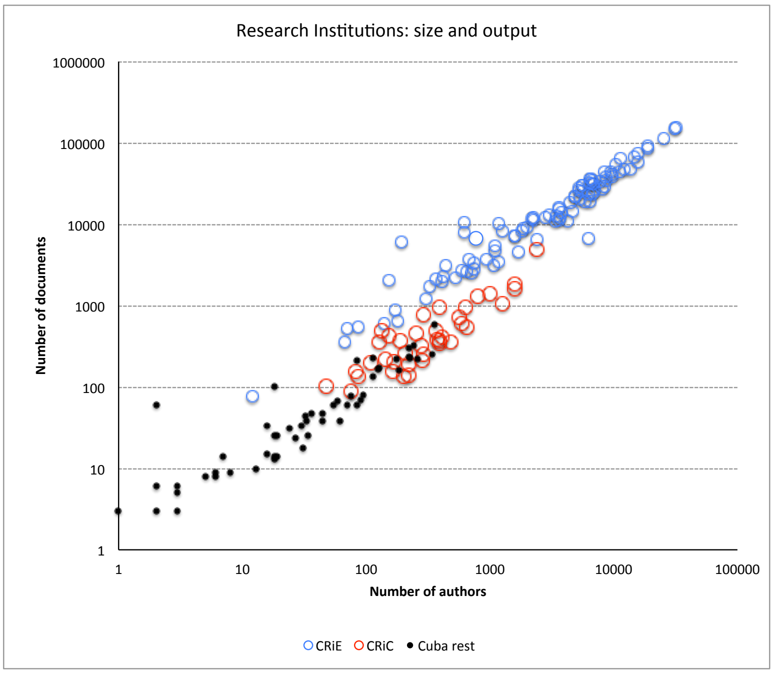
Interestingly those countries well represented in *AWRU* by number and ranking are also in the scientifically advanced countries according to the scientific capacity index, except Spain, which has been in the group of scientifically proficient countries (Wagner et al., 2001; Wagner, 2010, 88).

Regardless which system is chosen to evaluate the environment where Cuban researchers have been working, they show equally the enormous possibilities in those European institutions to foster the development of young Cuban researchers in terms of resources for basic research, the appropriate infra-structure, the institutional organization, the human capital for nurturing and being part of the creation of new knowledge. The challenge then is how to convert a segment of this potential into a tangible asset to the countries that provided their earlier education, even when their career development may have gone through personal effort.

The distribution of human resources (authors) versus scientific outputs (scientific publications) where the CRiE are currently working can gauge the potential of the environment for their further development, but also the potential of establishing scientific collaboration with the Cuban researcher in Cuba (CRiC). This information was obtained through the *Scopus* database, searching for the name of each individual institution in the case of CRiE. For institutions in Cuba the search was done using in the affiliation field, the name Cuba. A list of ninety-eight Cuban institutions was retrieved, of which four were split in two due to English translation of their institution names in Spanish. At least 317 Cuban institutions are in the affiliation field of publications indexed by *Scopus* but probably with less number of publications (Arencibia Jorge and Moya Anegón, 2010) to have an identification number. Figure 6.4 shows the size (number of authors corresponding to number of researchers) and output (documents published with the address of that institution) of the ninety-nine research institutions in Europe where the 103 CRiE are or have been publishing (blue circles); the thirty-eight research institutions where the 100 CRiC are currently publishing (red circles) and the rest of the Cuban institutions indexed with an identification number in *Scopus* (black dots). The sample of Cuban researchers in Cuba (CRiC) used as a cohort group (next section) were publishing in a group of institutions with a higher national productivity in terms of publications per author, being University of Havana the top institution with 4,889 publications contributed by 2,384 authors and therefore with a productivity of 2.1 documents per author. The overall productivity of Cuban institutions was 1.1 documents per author. On the other hand, fifteen affiliations shown in CRiE publications were not indexed by their names in *Scopus*. Among those having an identification number, three institutions have more than 100,000 articles: Centre National de la Recherche Scientifique de Paris, University College London and University of Manchester, with mean productivities of 4.8, 4.7 and 4.4 articles per researcher respectively. However the overall productivity of the ninety-nine European institutions listed in *Scopus* is 4.4 publications per author indicating that their high performances are more equally distributed.

Regardless of the limitation of representing the performances of the research institutes included in the study by just looking at productivity, those Cuban researchers in Europe are exposed in terms of resources and experiences from their peers to an environment that performs at least four time better than institutions in the home country.

Figure 6.4 Distribution of research institutions by number of authors and publication




Source: *Scopus* database institutions with identification number (2014). Graphic created using log-log scale. European institutions are in blue and Cuban institutions in red and black.

CRiE progressing their careers in those institutions are also acquiring organizational skills to lead research teams successfully and probably becoming influential in decision making regarding activities of their scientific communities such as organization of international meetings, editorial roles in scientific journals, consultancy, etc. Moreover they become highly collaborative researchers with influential networks.

## 6.3 BIBLIOMETRICS: PRODUCTIVITY AND SENIORITY (PERIOD 1995-2014)

The mobility of CRiE within Europe previously mentioned made difficult the counting of the publications of CRiE per each country as they move. The country code and a consecutive counting will always trace back the mobility of the researcher. When the mobility is between institutions in the same country the aggregate per country is not affected. Table 6.5 shows the total number of publications in Europe of active CRiE per country.

Table 6.5 Number of Publications per country of CRiE

| COUNTRY | CODE | ACTIVE RESEARCHER | NUMBER OF PUBLICATIONS 1995-2014 | IN EUROPE |
|---|---|---|---|---|
| BELGIUM | 201 | 10 | 225 | 200 |
| DENMARK | 216 | 1 | 3 | 2 |
| FINLAND | 294 | 3 | 71 | 59 |
| FRANCE | 202 | 7 | 126 | 41 |
| GERMANY | 203 | 11 | 179 | 136 |
| ITALY | 205 | 10 | 112 | 75 |
| LUXEMBURG | 225 | 1 | 15 | 13 |
| NETHERLANDS | 213 | 1 | 14 | 12 |
| PORTUGAL | 206 | 1 | 31 | 23 |
| SPAIN | 207 | 36 | 836 | 620 |
| SWITZERLAND | 208 | 4 | 35 | 25 |
| SWEDEN | 209 | 4 | 133 | 105 |
| UK | 210 | 17 | 625 | 541 |
| **TOTAL** | | **106** | 2405 | **1852** |

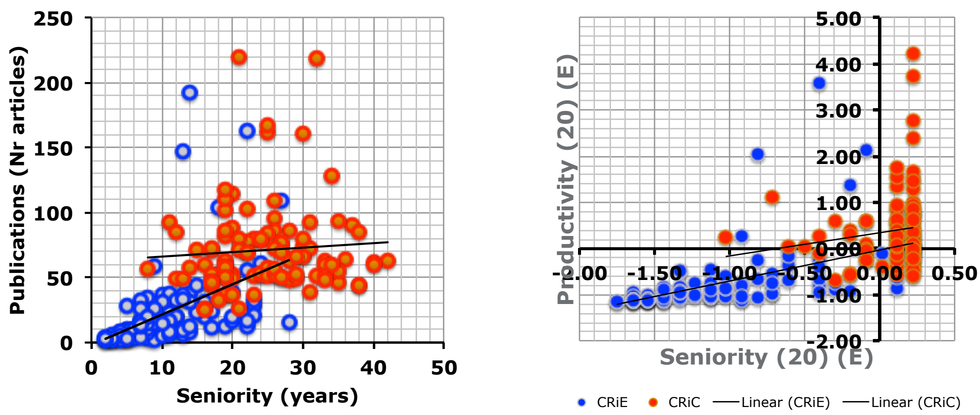
### 6.3.1 *Cuban scientists in Europe (CRiE) and in Cuba (CRiC)*

The bibliometric indicators used to investigate the Cuban researchers were productivity and seniority, described in section 3.2.2 (j). Productivity refers to the total number of publications per researcher and seniority refers to the length of time in years since the researcher published for the first time. They also refer to a specific period (1995-2014) and places (Cuba or Europe).

A cohort group of 100 Cuban researchers working in Cuban institutions (CRiC) was selected as described in section 3.2.2 (h) aiming to provide a referent for scientific production (productivity) and years of working experience (seniority) for the CRiE. A list of active CRiC per Cuban institutions was shown in chapter 4 (Table 4.3). This study does not aim to establish a quantitative comparison between both groups, but to have an indication of where CRiE stand in relation to the best performers in Cuba. Among the reasons why the quantitative comparison is not valid here are the differences of age groups, the type of research as applied or basic research, different fields of research within and between both groups, etc.

Choosing the most productive Cuban researchers in Cuba implies that they probably are the more senior as well. Indicators per researcher were normalized to account for the effect of seniority on productivity. In Figure 6.5 the distribution of both seniority and productivity for CRiE (blue) and CRiC (red) is shown with and without normalization.

Figure 6.5 Distribution of Productivity versus Seniority for CRiE and CRiC




The left side graphic in figure 6.5 shows for each researcher the total number of years of publishing versus the total number of articles during that number of years. The mean values ($x,y$ $or$ $s,p$) are for CRiE in blue: [11.1, 24.1] and for CRiC in red: [24.8, 71.3]. The general means and standard deviations of both indicators for Cuban Researchers (CR) were calculated in order to normalize the indicators for the analysis of the period 1995-2014 (20 years) and the place of publication: Cuba for CRiC and Europe for CRiE (in this case publications of CRiE in Cuba will not be taken into account).

Seniority $_{(CR)}$: *mean* ± standard deviation: *17.7* ± 9.6 years

Productivity $_{(CR)}$: *mean* ± standard deviation: *47.5* ± 40.3 articles

The graphic on the right is the dot-plot of normalized values x,y (seniority, productivity) for CRiC normalized for the 20 years (20) period 1995-2014 in red; and the normalized values for CRiE while in Europe (E). The origin 0,0 represents the means of $s$ and $p$ of CR. The mean and standard deviation for years publishing in Europe for CRiE is -1.1 ± 0.1 years, while the mean of productivity is -0.7±0.7 articles indicating that the group mainly in the negative zone of the graphic has less years publishing with less productivity than the CRiC, something expected from the criterion of selection of the cohort group CRiC. The main difference between both graphics is the separation of red and blue dots: in terms of seniority it is clear that CRiE who have been publishing in Europe mainly in the last few years and CRiC are more homogeneous in terms of publishing time over the total mean of both groups. However there are few outstanding CRiE in term of productivity reaching positive values for the number of articles in a relatively short period of time. The means and standard deviations of normalized values for CRiC in 20 years publishing were 0.1 ± 0.1 years and 0.6 ± 0.8 scientific articles both in the positive area of the graphic. The high values of the standard deviations in both groups for the number of articles indicates the heterogeneity of both samples due to different areas and fields of research as well as the stages in their careers. Researchers in some academic institutions have teaching as a priority compared with those in research institution and therefore publishing less. Group leaders also get the benefit of the contribution of the team members to science. Table 6.6 shows means and standard deviations for seniority and productivity of CRiE and CRiC according to time and places.

Table 6.6 Means and standard deviations of indicators for Cuban Researchers

| | SENIORITY (years) | | | PRODUCTIVITY (articles) | | | |
|---|---|---|---|---|---|---|---|
| Groups of CR | $S$ | $S_{(20)}$ | $S_{(E)}$ | $P$ | $P_{(20)}$ | $P_{(E)}$ | $P_{(5)}$ |
| CRiE | 11.1±6.2 | 10.1±5.7 | 7.7±5.0 | 24.1±31.4 | 22.9±31.3 | 17.7±28.3 | 11.2 ±15.4 |
| CRiC | 24.8±7.3 | 18.8±2.2 | - | 71.3±34 | 63.4±32.5 | - | 18.3±13.0 |

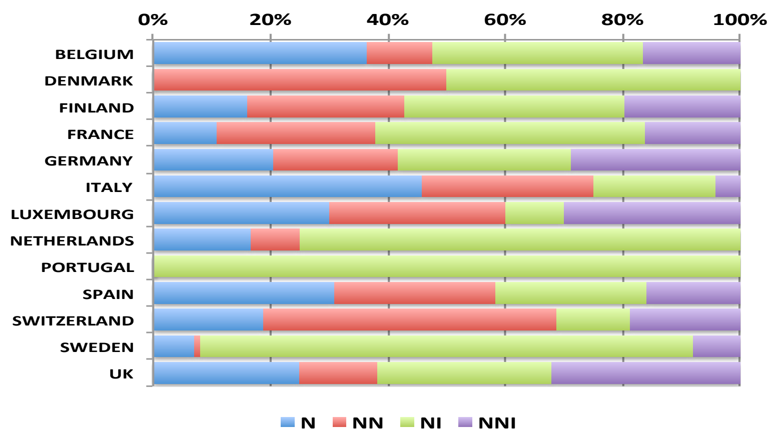
The total publishing years of CRiE is less than half of those for CRiC but with only one year difference for the period of study (1995-2014) indicating that CRiE are younger researchers as seen in the previous section 6.2.2 (Figure 6.1), publishing a third of the cohort group in general and for the period of study; and even if counting their publications while working in Cuba ($P_{(20)}$). The difference is less dramatic in the last five years as CRiE is gaining in seniority.

The standard deviations for *Productivity* are high in all groups as researchers come from fields of research with different patterns of publications.  Although there is not a CRiE - CRiC matching for each researcher the multidisciplinary subjects in both groups are similar, reflecting the strength of Cuban science (biotechnology, bioinformatics, theoretical chemistry, physics, immunology, etc.). Choosing CRiCs from 31 Cuban institutions might have contributed to improving the groups' similarities in terms of fields of research.

## 6.4 PATTERNS OF SCIENTIFIC COLLABORATION OF CRiE

This part of the study was set to explore the potential of those Cuban researchers working in European institutions regarding their scientific collaboration in general and with the country of origin in particular. The previous chapter described the patterns of scientific collaboration of Cuban institutions both national and international. The same classification for types of collaboration was used here. When only one institution was referred in the authors' affiliation regardless of the number of departments participating in, it was classified as one institution: N; more than two national institutions: NN, regarding the CRiE affiliation in Europe; collaboration of one national institution with one or more international institutions: NI and more than one national institution with one or more international centres: NNI. Figure 6.6 shows the patterns of collaboration associated with the work of CRiE.

Figure 6.6. Types of scientific collaboration associated to CRiE

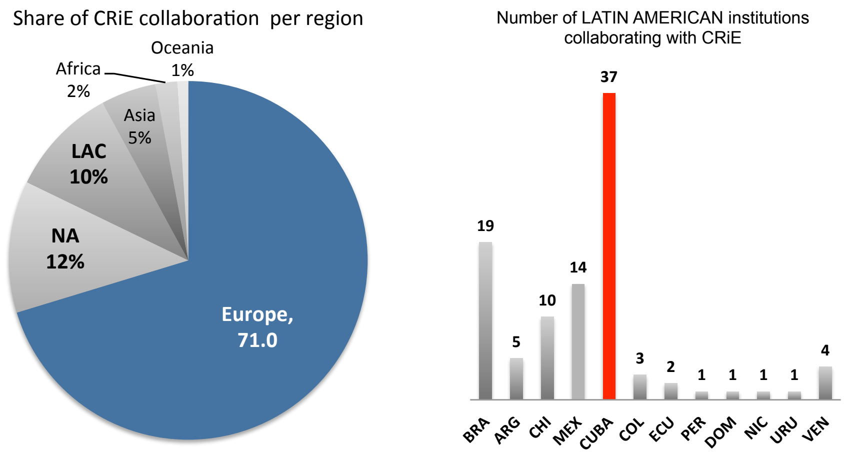


In general CRiE scientific production is very collaborative representing 74% of total publication (NN+NI+NNI) and 54% are with other countries different from where they work (NI+NNI). The original data suggests that CRiE keep collaborating with the previous institution where they were working before and the mobility within Europe increases their collaboration.

### 6.4.1 *Evidence of scientific collaboration between CRiE and Cuban institutions*

As expected the international collaboration within Europe dominates over other regions and countries. CRiE have collaborated with 985 institutions from 57 different countries, of these 697 were European institutions as seen in figure 6.7

Figure 6.7 Number of worldwide institutions in collaborative articles with CRiE




European institutions sharing Latin roots are highly represented among the institutions of the region in which Spain shares 24% of collaborating European institutions, followed by Italy (15%), France (14%) and Germany (11%). This characteristic of cultural ties in scientific collaboration was also observed in other studies (Luukkonen et al., 1992; Franzoni et al., 2012).

CRiEs seem to have a distinctive pattern of preferential collaboration for Latin American institutions with 46% share of collaborating institutions in the Americas (98/215) compared with North America 54% (117/215) in as much as the world share of Latin American scientific papers is still very low compared to other world regions.

European Union and North America remain leaders in scientific output with the world share of 36.5% and 31.1% of scientific publications respectively in 2008 while the world share of scientific publication for Latin America was only 3.9% in the same year (Hollanders and Soete, 2010) as shown in the *UNESCO Science* report of 2010.

More interesting is the favourable share in scientific collaboration that Cuba had as the result of participating in the network of scientific collaboration of CRiE, with 38% of Cuban institutions participating out of the total of Latin American ones. Cuban scientific publication represents only 2% of the region share in which Brazil dominates with 51.1% (Albornoz et al., 2010) as shown in the *UNESCO Science* report of 2010.

## 6.5 NETWORK ANALYSIS OF THE SCIENTIFIC COLLABORATION OF CRiEs

Mapping the international scientific collaboration has been a subject of recent interest to follow the properties and evolution of the network as new players are emerging in science (Wagner, 2005c; Wagner and Leydesdorff, 2005a; Wagner and Leydesdorff, 2005b; Kozak et al., 2015).

In the previous section it was shown that more than 70% of scientific articles published by CRiE were collaborative and 54% were international collaboration. For the purpose of visualizing the networks created by CRiE using the network theory, the institutions shown in the CRiE author affiliation were designated as type I and all the other affiliations of their co-authors were designated as type II institutions. Details of the design and codes used are in chapter 4, section 4.5.2 (I).

The general matrix of collaboration between all the type I institutions in Europe where CRiE have been publishing and the type II institutions with whom they collaborate has generated the dense network shown in Figure 6.8.

The CRiE network as shown in Figure 6.8 has 985 nodes (institutions) and 3140 undirected ties (links of collaboration) which were then reduced to 614 when only counting the links with the frequencies > 3, revealing only the strongest connections as in Figure 6.9.

Figure 6.8 Network of scientific collaboration of CRiE

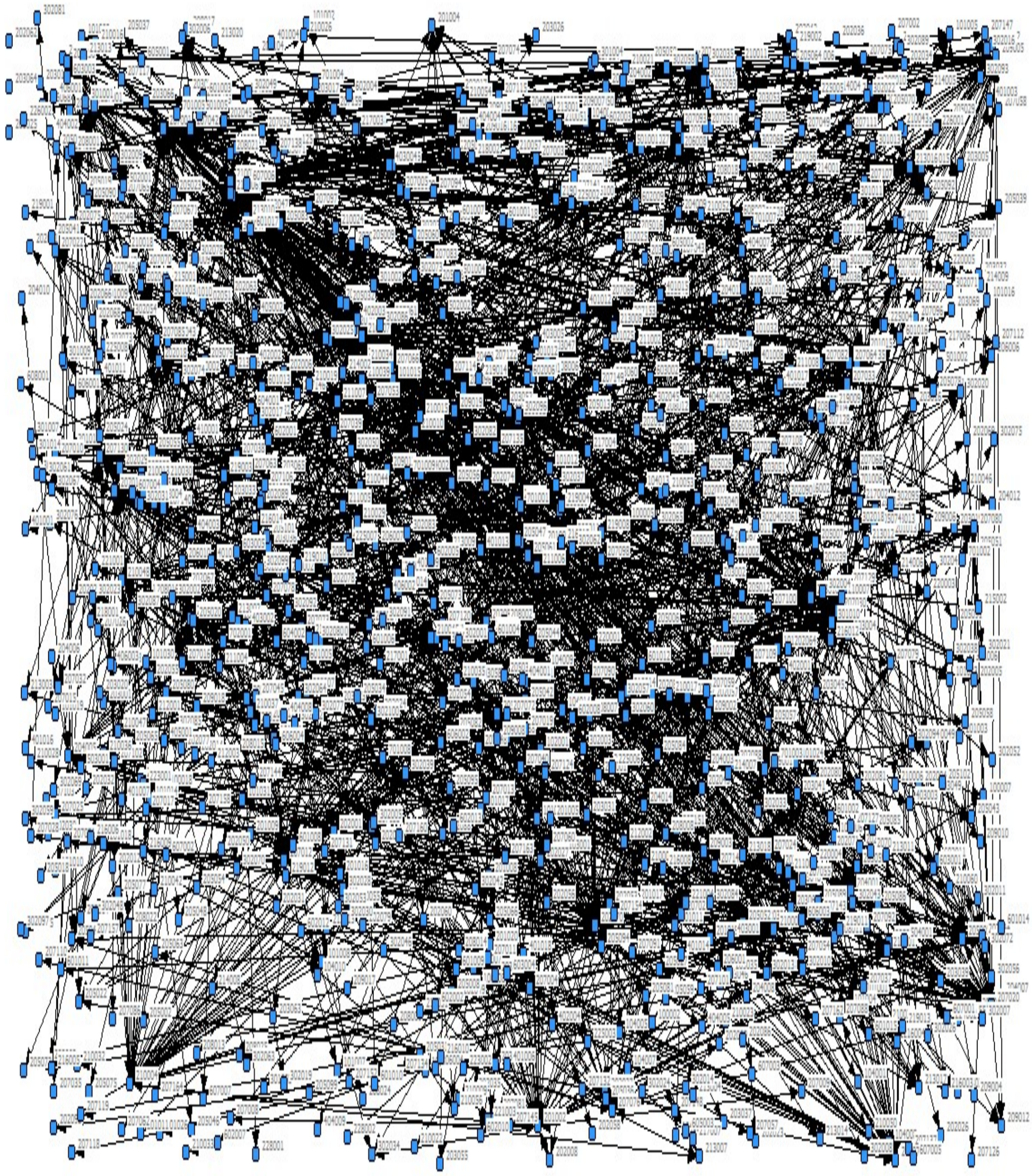
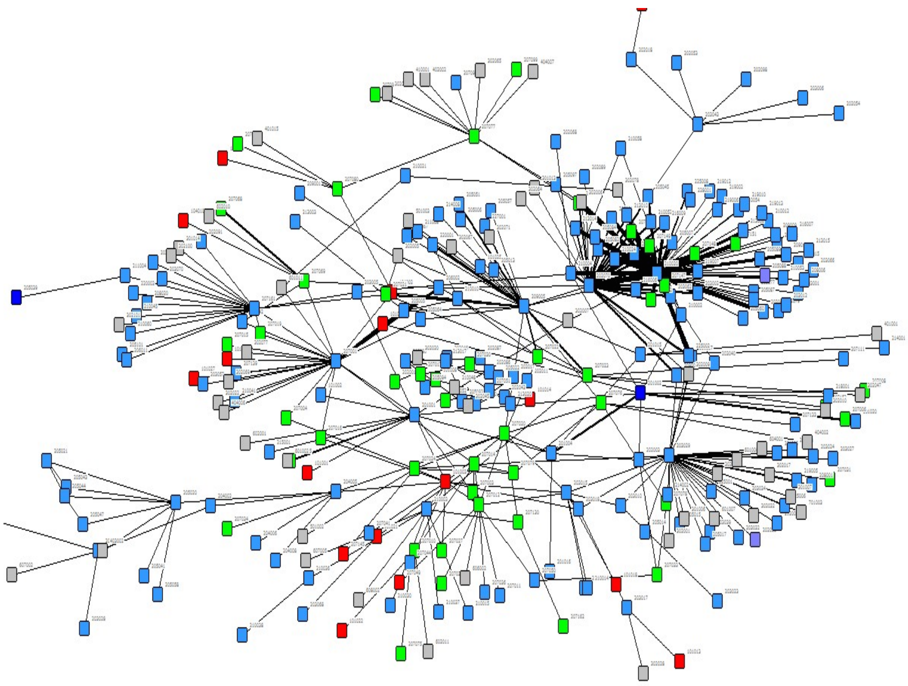


Figure 6.9 Network of CRiE with strong ties in collaboration



In red squares are Cuban institutions and in blue and green are European institutions while the rest of the world are in grey squares. Green squares represent Spanish institutions. The higher numbers of CRiE are or have been working in Spain and the mobility towards countries in Europe with more resources might have contributed to the connectivity of Spain with the rest of Europe and with Cuba, as it will be discussed next (6.5.2).

### 6.5.1 *Viewing CRiE networks of collaboration in relevant European countries*

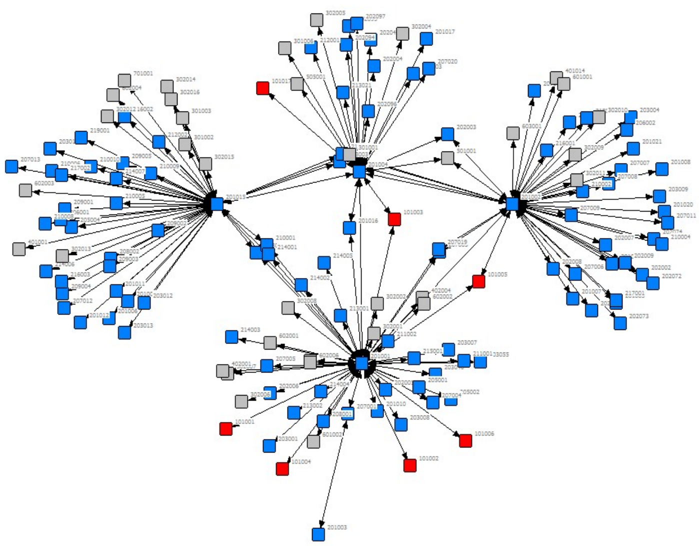
Breaking down the total network of scientific collaboration created by CRiE according to their demographic distribution will allow a further analysis of the characteristics of such networks at a meso-level. European countries with higher density of CRiE show bigger networks in terms of numbers of nodes. The number of ties or links per nodes and the complexity of the network depend on the collaboration established by each CRiE and their mobility patterns. Those CRiE moving to another country different from the one being represented will also appear in the network with the number of the nodes corresponding to the new country.

*CRiE working in Belgian institutions of S&T*

The scientific network of Cuban researchers working in Belgian institutions related with biosciences is probably strong because is shaped by the integration of research groups in the Flanders Institute of Biotechnology (Vlaams Institut voor Biotechnologie, VIB). Created in 1996 by the Flemish government to ensure excellence in scientific research, VIB harbours researchers from four Flemish universities: Ghent University, Katholieke Universiteit Leuven, Antwerp University and Vrije Universiteit Brussels. The Cuban researchers working in Flemish universities are part of the strong research network created by the VIB as shown in Figure 6.10. The only node without connection with Cuban institutions is the Ghent University Hospital.

Cuban institutions in the network are shown in red either in collaborating with one Belgian institution, or with two of them simultaneously giving more strength to the network. These institutions are Institute of Cardiology and Cardiovascular Surgery (ICCC from Spanish name) with the code 101002 in the network and 5 publications; University of Havana, with the code 101003 and 5 publications; Centre of Pharmaceutical Chemistry, code 101001, with 1 publication; University of Villa Clara (UCLV) with code 101005 and 4 publications; the Finlay Institute, with code 101006 and 1 publication and the Higher Polytechnic Institute Jose Antonio Echevarria (IPSJAE) code 101017 with one collaborative article.

Figure 6.10 Network of CRiE from Belgian institutions



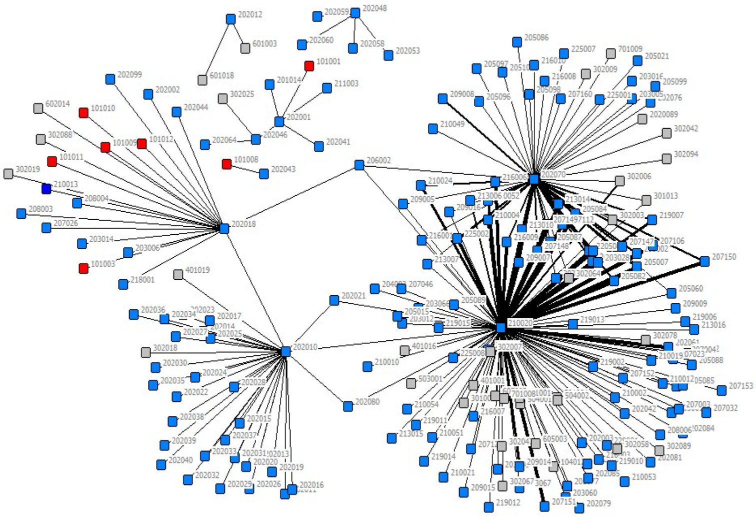
The network of CRiE working in Belgium institutions of S&T comprises 152 institutions with 332 links or ties among each other. Belgium academic institutions from which CRiEs established their collaboration are: Katholieke Universiteit Leuven (201001); Vrije Universiteit Brussel (201002); Ghent University (201015); Universite Libre de Bruxelles (201004), and all of them are also in the top 500 universities in the *ARWU* with two Ghent University and Katholieke Universiteit Leuven in the top fifty of Europe.

The UCINET k-core analysis showed sixteen institutions (nodes) in the inner core out of 152 nodes in the CRiE network in Belgium, of which six were national institutions. Among those nodes were institutions from Spain (2), Germany (2) and Cuba (2). Other countries with one institution were France, Poland, UK and Canada.

*CRiE working in French institutions of S&T*

The network of CRiE working in French institutions of S&T has 131 nodes and 252 links representing the number of collaborations. Two institutions (202070 and 210020) share significant number of collaborators as the CRiE generating such publications moved from the International Agency for Research on Cancer in Lyon, France to the Imperial College London, in England as shown in Figure 6.11. These two institutions are also in the inner core obtained with the UCINET k-core analysis with another thirty-five European institutions and three from North America. Moreover there are three small loose networks and two isolated nodes (institutions) with less scientific collaboration. The French institutions with more scientific collaboration are the International Agency for Research in Cancer (IARC), University of Nice-Sophia Antipolis and Montpellier Cancer Research Institute (IRCM).

Figure 6.11 Network of CRiE from French institutions

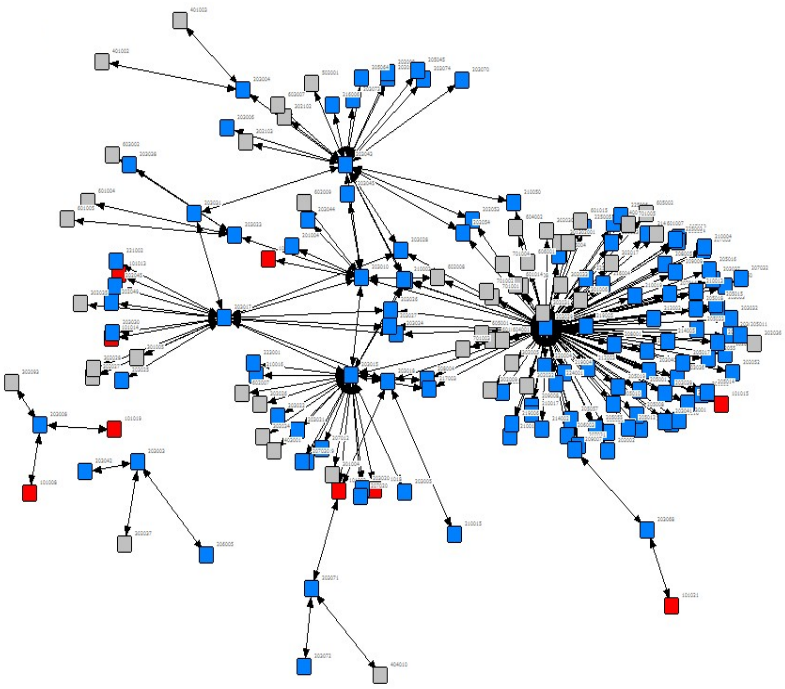


The French institutions of the CRiE network participating in collaborative publications with Cuban institutions are University of Nice-Sophia Antipolis (code 202018), Centre National de la Recherche Scientifique (code 202001) and University of Bordeaux 1 (code 202043). Cuban institutions connected to those nodes are: Centre of Pharmaceutical Chemistry (101001), University of Havana (101003), Higher Institute for Advanced and Applied Science (InSTEC, code 101008), Research Institute of Food Industry (IIIA, code 101010), Institute of Tropical Medicine Pedro Kouri (IPK, code 101011), Labiofam Centre (code 101012) and Centre of Marine Bio-products (CEBIMAR, code 101009). All Cuban institutions have only one publication each. French research institutions have been a temporary location for four out of seven CRiE who later moved to other countries in Europe or United States, one of them has published with Cuban institutions while in the United Kingdom.

*CRiE working in German institutions of S&T*

Eleven Cuban researchers have been collaborating as co-authors while working in eighteen German institutions of S&T of which five are in the inner K-core group of 21 institutions. These five highly connected institutions are: University of Regensburg, University of Muenster, J.W. Goethe Frankfurt University, Max Planck Institute for Coal Research and Heinrich-Heine University of Dusseldorf all of them in the 500 top universities of *ARWU* or in the *SCIMago* top ranking institutions.

Figure 6.12 Network of CRiE from German institutions



The majority of institutions in the inner core of the K-core analysis are German (67%) and other European institutions are in United Kingdom (2), Austria (1), France (1) and Switzerland (1); among other institutions in the next shell of the K-core analysis are the University of Havana and the Chinese University of Hong Kong.

Seven German institutions have been participating in collaborative work with Cuba through the CRiE network publishing from German institutions. The Max Planck Institutes (203015 and 202071) have collaborated with University of Havana (101003) eight times and twice with the Higher Institute of Basic and Pre-clinical Sciences Victoria de Girón (101018). The VTI-Institute for Wood Technology and Wood Biology (203068) has been in four publications with University of Matanzas (101021). The Ruhr University of Bochum (203018) has published five collaborative articles with University of Havana (101003) and University of Heinrich-Heine (203017) has collaborated with Hospital Lenin (101013) in two articles and with the Centre of Genetic Engineering and Biotechnology (101014) one. The University of Erlangen-Nuremberg (203008) has collaborated with Higher Institute for Science and Nuclear Technology (101019) and Higher Institute for Advanced Technology (InSTEC, 101008) with one publication each. Other institutions are University of Muenster

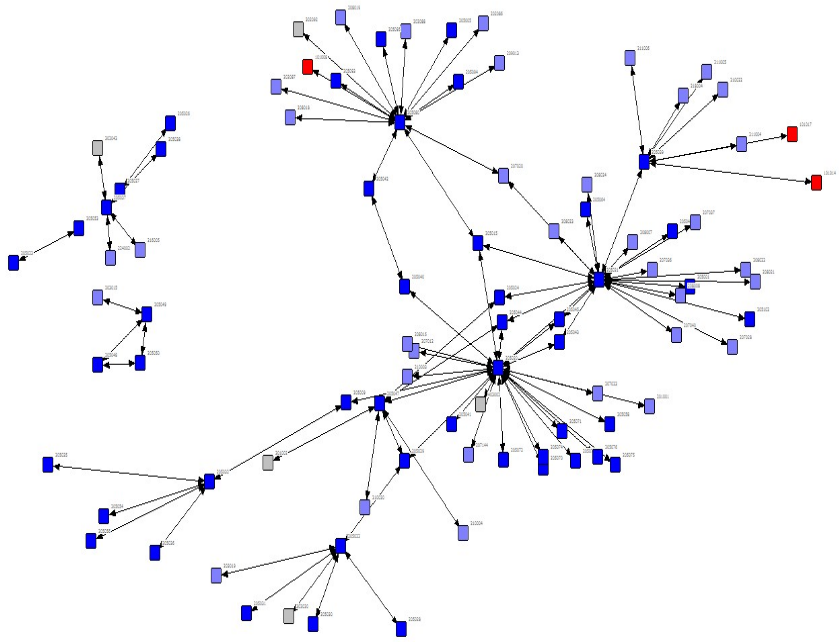
(203010) and J.W. Goethe University of Frankfurt publishing through the CRiE network of collaboration with Centre of Advanced Studies in Cuba (101016) and Centre for the Investigation of Hereditary Ataxias (CIRAH, 101015). Interestingly, one of the CRiE has been publishing with Cuban institutions from three different German institutions in this period, and also institutions with more than one CRiE publishing independently with Cuban institutions. Both situations are also present in other countries of the CRiE network.

*CRiE working in Italian institutions of S&T*

Ten Cuban researchers have been working in twenty Italian institutions of S&T of which five were part of the eleven nodes of the K-core group. The two institutions more connected within the CRiE-Italy network are the University of Milan and Institute of Research in Pharmacology Mario Negri. The institutions in the inner K-core group are mainly Italian (15) of which six are in the 500 top universities of *ARWU*. Five CRiE were working in three of these institutions: University of Milan, University of Genova and University of Pavia. The only other country included in the CRiE-Italy inner K-core group of institutions was Spain with one institution: Autonomous University of Barcelona, also in the top 200 universities of the *ARWU* ranking. Figure 6.13 represents the CRiE-Italy network of scientific collaboration (ties or edges) between research institutions (nodes). Nodes in blue are European institutions (83 of which 49 are Italian), in red (3) and grey (5) are the Cuban and worldwide institutions.

Only two Italian institutions (International Centre for Genetics Engineering and Biotechnology, Trieste and University of Pavia) have six collaborative articles with three Cuban institutions through two CRiE: the International Centre for Genetic Engineering and Biotechnology (CIGB, 101014) and the Higher Polytechnic Institute Jose Antonio Echevarria (ISPJAE, 101017) with two publications each and the University of Pavia (205080) with the Higher Institute of Technology and Applied Sciences (205080). Interestingly, CRiE in Italy and in Switzerland have the lower proportion of international collaborative articles (see Figure 6.6). Italian institutions in the network are represented by 91% and the other two countries with more presence in the network are Spain and Switzerland.

Figure 6.13 Network of CRiE from Italian institutions



*CRiE working in Spanish institutions of S&T*

Thirty-six Cuban researchers have been working through seventy research positions in thirty-seven Spanish institutions of S&T between 1995 and 2014 indicating their mobility within the country. Collaborative interactions of CRiE in Spain have generated a network of 406 nodes or institutions collaborating through 1058 links. In Figure 6.14 (a) and (b) are the institutions with more frequency of collaboration (links>2).

In the Spain-CRiE network, only a third are Spanish institutions with 138 centres out of 406 (34%), another 153 from the rest of Europe (38%) and 115 worldwide (28%), of which 20 are Cuban institutions.

Figure 6.14 Network of CRiE from Spanish institutions (a. 529 and b. 194 ties)

Figure 6.14.a (529 ties)

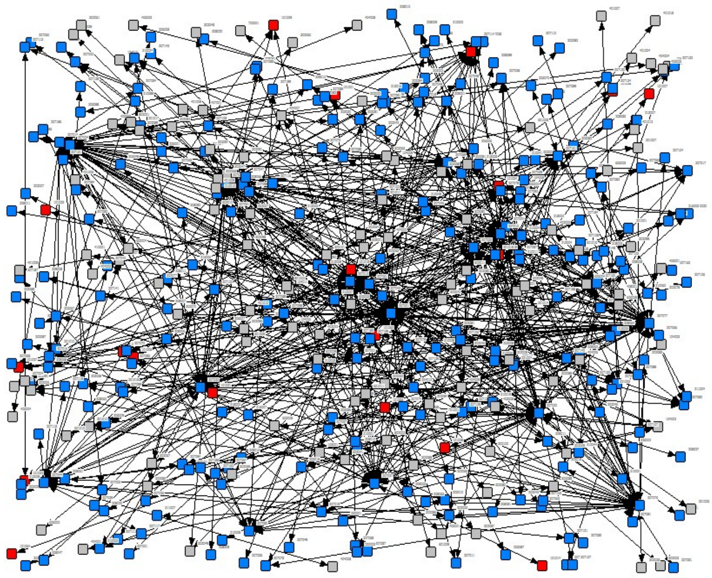
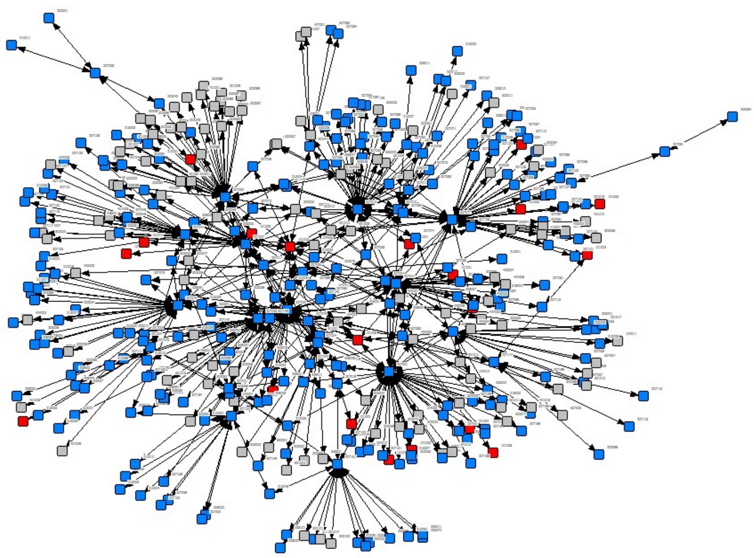


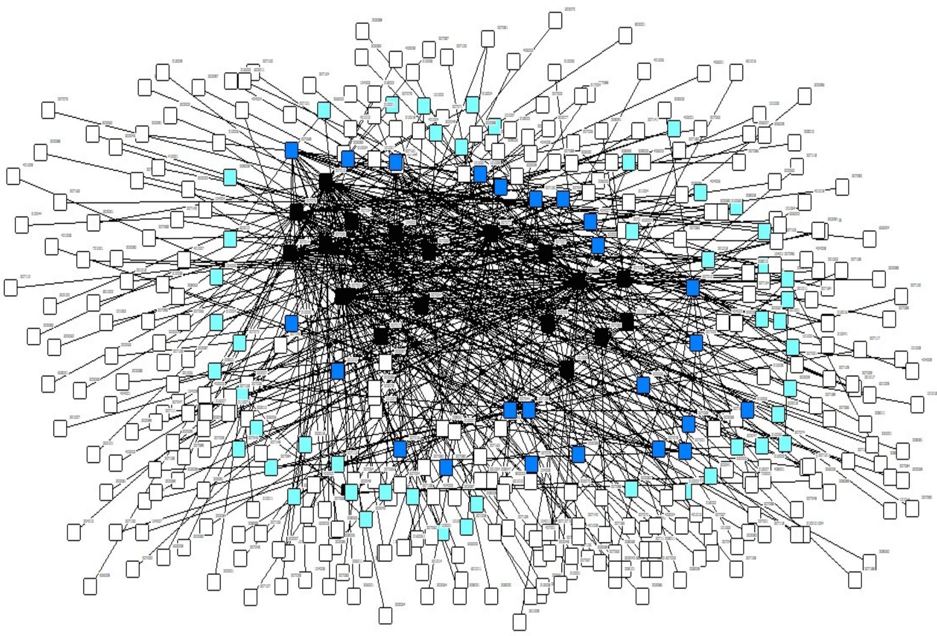
Figure 6.14.b (194 ties)



Eighteen Cuban institutions (red nodes in Figure 6.14) were collaborating with the following Spanish centres: Instituto de Fisica Fundamental, CSIC (207025), University of Santiago de Compostela (207001), Universidad de Vigo (207016), Spanish National Cancer Research Centre, CNIO (207027), Universidad Autonoma de Madrid (207012), Universidad Autonoma de Barcelona (207020), Institucion Catalana de Recerca i Estudis Avanats, ICREA (207017), Universidad de Cadiz

(207041), Universitat Politecnica de Valencia (207075), Institute for Research in Biomedicine, Science Park (207024), Complutense University of Madrid (207014), Centro Nacional de Biotecnologia, CSIC (207113), Institute of Physical Chemistry Rocasolano, CSIC (207114), Universidad de Oviedo (207044), Centro de Investigaciones Biologicas, CSIC (207010), Universitat Pompeu Fabra (207030), Instituto de Quimica Organica General, CSIC (2070129), Centro Nacional Del Hidrogeno 2 (207029), Euskal Heriko Univertsitatea, IKERBASQUE (207069), University of Valencia, (207019), University of La Laguna (207077). The Cuban and Spanish institutions generated 118 collaboration links out of 1058 (11%) within the CRiE-Spain network.

Figure 6.15 K-core analysis in CRiE-Spain network



The Cuban institutions were: Centre of Pharmaceutical Chemistry (101001), University of Havana (101003), Central University of Las Villas (101005), Center of Molecular Immunology (101007), Instituto Superior de Tecnologias y Ciencias Aplicadas, InSTEC (101008), Parque Nacional Alejandro de Humboldt, CITMA (101009), National Bioinformatics Center, CITMA (101009), Center for Genetic Engineering and Biotechnology (101014), University of Matanzas (101021), Centro de Estudios Avanzados de Cuba, CITMA (101022), University of Granma (101023), Provincial Center for Human Genetics, , Las Tunas (101024), National Centre of

Neurosciences (101025), University of Camaguey (101027), Centro Provincial de Higiene, Epidemiología y Microbiología de Villa Clara (101062), Unidad Provincial de Vigilancia y Lucha Antivectorial (101063) and Unidad Municipal de Higiene y Epidemiología de Camagüey, (101064).

The k-core analysis obtained through the UCINET software showed four cores in the CRiE-Spain network. The inner fourth core (in black) has 18 institutions, the third core (blue) has 20; the second core (in light blue) has 56 institutions and the in outer shell (white empty squares) has the rest of less connected institutions (figure 6.15). Fifteen institutions out of eighteen in the inner core fourth are Spanish, two Cuban (University of Havana and the Central University of Villa Clara, UCLV), another Latin American (Autonomous National University of Mexico, UNAM) and one of United States (Harvard University). Cuban researchers have been working in twelve of the Spanish universities in the inner core with six of them in the top 500 universities of the AUWR ranking. There are no Cuban institutions in the third core (blue) of twenty nodes, European institutions represent (85%) of which the Spanish are the majority (13 out of 17). In the next core (light blue) comprising 56 nodes there are six Cuban institutions and another four Latin American and eight North American institutions.

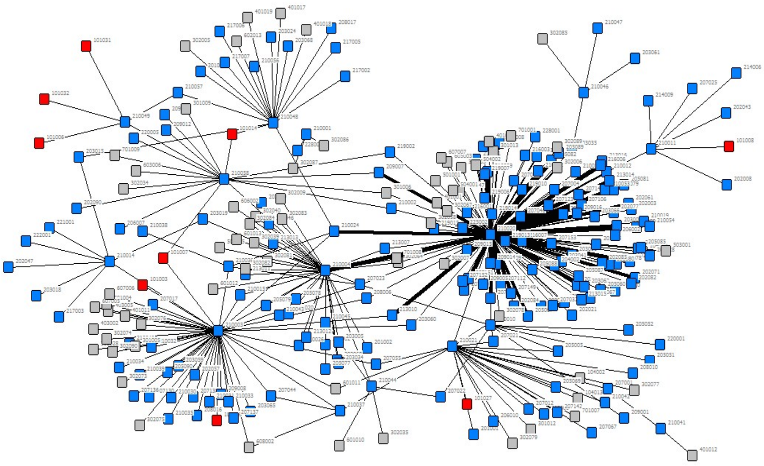
The k-core analysis suggests that Cuban researchers might have a preference for Cuban collaborators in Cuba (CRiC) keeping their links once moving to Spain as a first port in Europe. If this is the case, the analysis in the CRiE-UK network might confirm the hypothesis since a second move to United Kingdom from Spain and other European countries took place.

*CRiE working in British institutions of S&T*

The sample of Cuban researchers currently in British institutions of S&T has seventeen researchers of which four came from Spain, two from Italy, another two from France and one from Germany. However only the publications from British institutions were processed to create the network shown in Figure 6.16.

The total number of collaborating institutions or nodes was 274 with 608 ties or collaboration links with the following composition: 195 European institutions, of which forty-one were British (21%), thirty were Spanish (15.4%), twenty-five French (13%), twenty-one German (11%) and twenty Italian (10%). The fifteen European countries were also represented in the network with Sweden and The Netherlands with ten institutions each one (5%), the rest with less institutions. In the Figure 6.16 red nodes are Cuban institutions (9), in blue and grey are European and worldwide institutions (70).

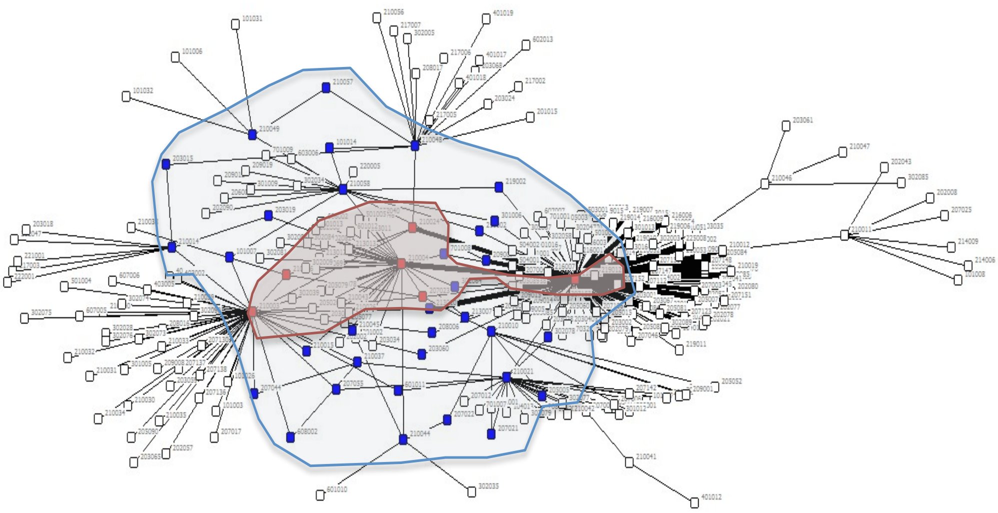
Figure 6.16 Network of CRiE from British institutions



Six British institutions are part of the nodes of CRiE connected to Cuban institutions. They are: University of Durham (code 210011), University College London (210003), Safety Environment Assurance Centre, SEAC (210041), European Molecular Biology Laboratories, EMBL, Cambridge (210048), University of Glasgow (210049), University of York (210058) and University of Strathclyde (210021). Nine Cuban institutions participated in seventeen collaborative links with the six British institutions through the CRiE network: Teaching Hospital Vedado (101031), Paediatric Hospital Juan Manuel Márquez (101032), National Aquarium of Cuba (101026) and Finlay Institute (101006) all with one publication each; Centre of Molecular Immunology (101007); the Higher Institute for Advanced and Applied Science, InSTEC (101008) and University of Camagüey (101027) with two publications each; University of Havana (101003) with four publications and Centre of Genetic Engineering and Biotechnology (101014) with five publications.

In the particular case of the United Kingdom, more than 50% of the researchers currently working in British institutions have published first in other countries of the region and their previous collaborators might continue publishing with them. Indeed Spain, France, German and Italy share the highest per cent of institutions in the CRiE-UK network. The K-core analysis using UCINET showed three shells involving 35 cliques-like structures as shown in Figure 6.17.

Figure 6.17 K-cores in CRiE-British network



Cores obtained by K-core analysis (UCINET): core 1 in white, core 2 in blue and core 3 in red

Six institutions form the inner core 3: five British (83%) and one Spanish (17%). Another twenty-nine institutions form the next core 2 with twelve British institutions (41%), next country with more institutions is Spain (15%) and then four other countries share 7% each: Germany, The Netherlands, Cuba and the United States.

The topology of the network revealed by the K-core analysis suggests that the mobility of the CRiE might increase the connectivity of the network pulling in the countries in which they have been previously publishing to the core of the network as part of the strongest loops with more clique-like structures.

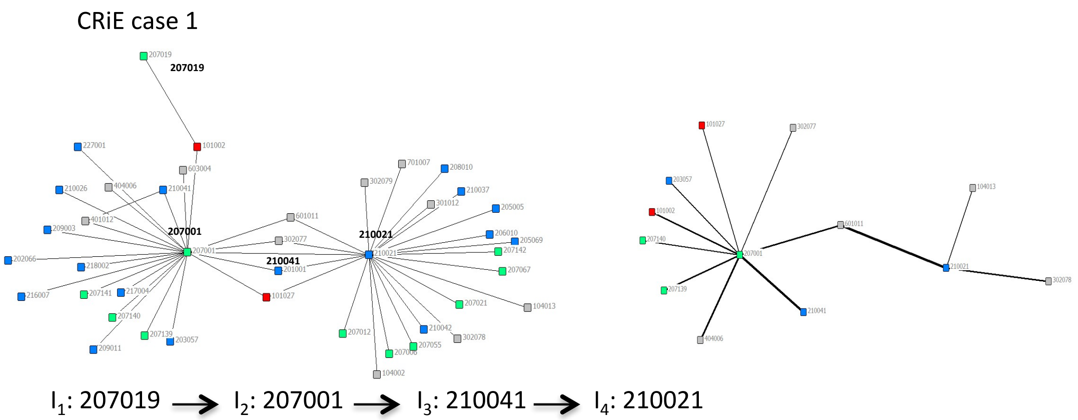
### 6.5.2 *CRiE as carriers of scientific collaboration*

The previous observation could be illustrated by following the trail of five Cuban researchers moving across institutions in Europe. Although it will require a different experimental design it was an important feature observed in the sample that might support the hypothesis that nomad researchers carry with them their best collaborators wherever they move. It might also indicate that a collaborator from a stronger institution might pull another collaborator to work within his or her team and that might or might not be involving another country.

*Case one: Mobility Cuba-Spain-UK*

A Cuban researcher published with a Spanish affiliation (207019), returning to Cuba for a while and continued publishing with her/ his Cuban affiliation then moving towards the institution in Spain of one of her or his collaborators (207001). After four years publishing more than twenty articles the Cuban researcher moved to the United Kingdom to work with one of her/his collaborators (210041) publishing with this affiliation seven articles but returning back to the stronger Spanish institution (207001) after two years in UK.

Figure 6.18. CRiE case 1: Cuba-Spain-UK



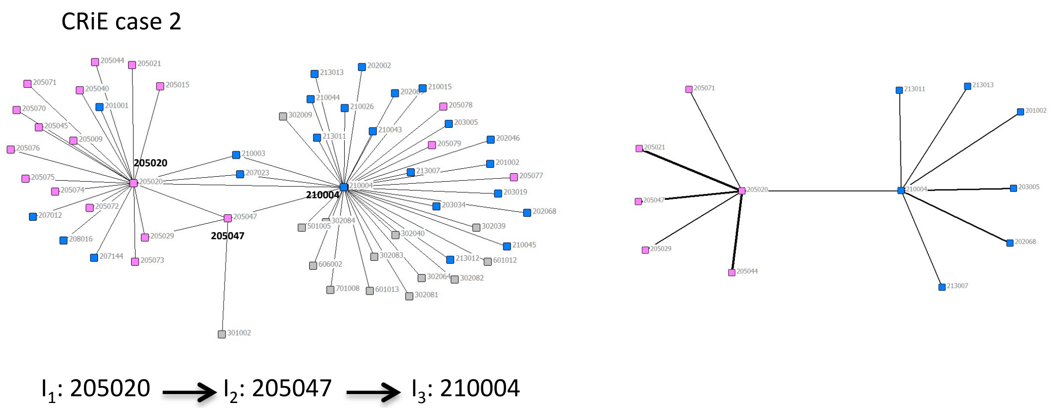

The link to the new place in UK (210021) is through one of the collaborators and for the following years the researcher while in UK, continued publishing with another five Spanish institutions, as well as keeping the worldwide collaborators including one

Cuban institution. Figure 6.18 is the network of the trail of the case 1 researcher, in green Spanish institutions, in blue, red and grey the European, Cuban and worldwide collaborating institutions. On the right side of the figure the network was limited to a higher frequency of publications showing the stronger collaboration. In time the earlier collaboration with Cuban and Spanish institutions gets diluted.

*Case 2: Mobility Italy-UK*

The Cuban researcher in this case never worked in Cuba moving to Italy for her/his doctoral studies. Probably the earlier collaboration was already in place in the University of Milan where he worked and the pattern is mainly national collaboration as shown in Figure 6.19 with pink nodes. Three collaborators were taken for a while when moving to UK including the last institute where the researcher worked. Collaboration in the UK diversified with more European and worldwide institutions in the researcher network. On the right side of the figure the stronger links showing the total loss of Italian collaborators, except the previous Italian institution.

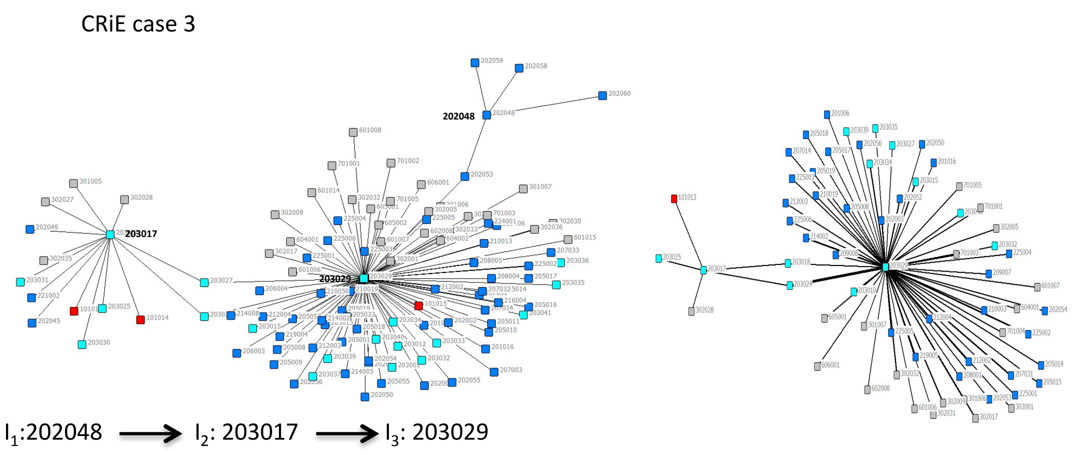
Figure 6.19 CRiE case 2 Italy-UK




Case 3: Mobility Cuba- France- Germany

A researcher started collaboration from Cuban institutions (not included in the network) and then signed with German and Portuguese institutions but returning back to work in Cuba. The first institution shown in the network is in France (202048) working there for a short period, and then moving to Germany to work in two different institutions. Once in Germany the researcher spent two years in the United States publishing two articles of high impact but collaborators were from the same institute and therefore not shown in the network. The researcher returned to Germany and the collaboration with Cuban institutions (shown in red nodes) was maintained in both German institutions. Collaboration has been mainly within Europe (75%) of which 25% between German institutions. Three Cuban institutions were in the researcher network although only one remained with a stronger link (more articles published) as shown in the right side of the Figure 6.20. Two of the institutions collaborating in the earlier institution (203017) continued publishing later with the researcher case 2 in the new place (203029).

Figure 6.20 CRiE case 3 Cuba-France-Germany

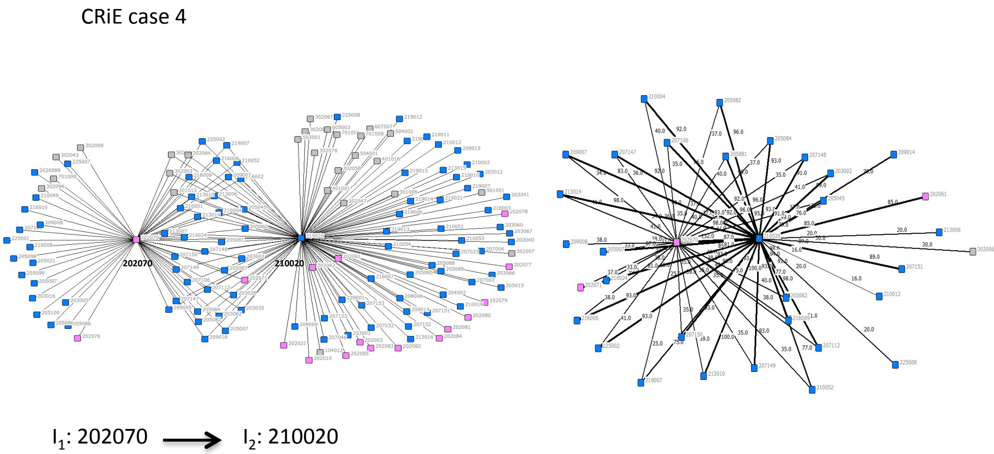



Interestingly the mobility of the researcher involved an improvement in her career from University of Dusseldorf among the 301-400 in the *ARWU* ranking to the University of Frankfurt in the top 150 best universities of the world.

*Case 4: Mobility France-UK*

The researcher in case 4 is a member of a global research project, however the majority of collaborators are in Europe (82%). The network started in France (institution 202070) and forty institutions continued publishing systematically in collaborative articles with the new institution now in United Kingdom (210020). This strong cloud of collaborators represents 48% of the nodes of this researcher network. It seems that also through the network new collaborators from France became part of the network of the institution in United Kingdom representing 22% of the European collaboration while British institutions only represented 8%. The research institution in United Kingdom is in the twenty-third position of the best world university ranking in 2014 (*ARWU*).

Figure 6.21 CRiE case 4: France-United Kingdom



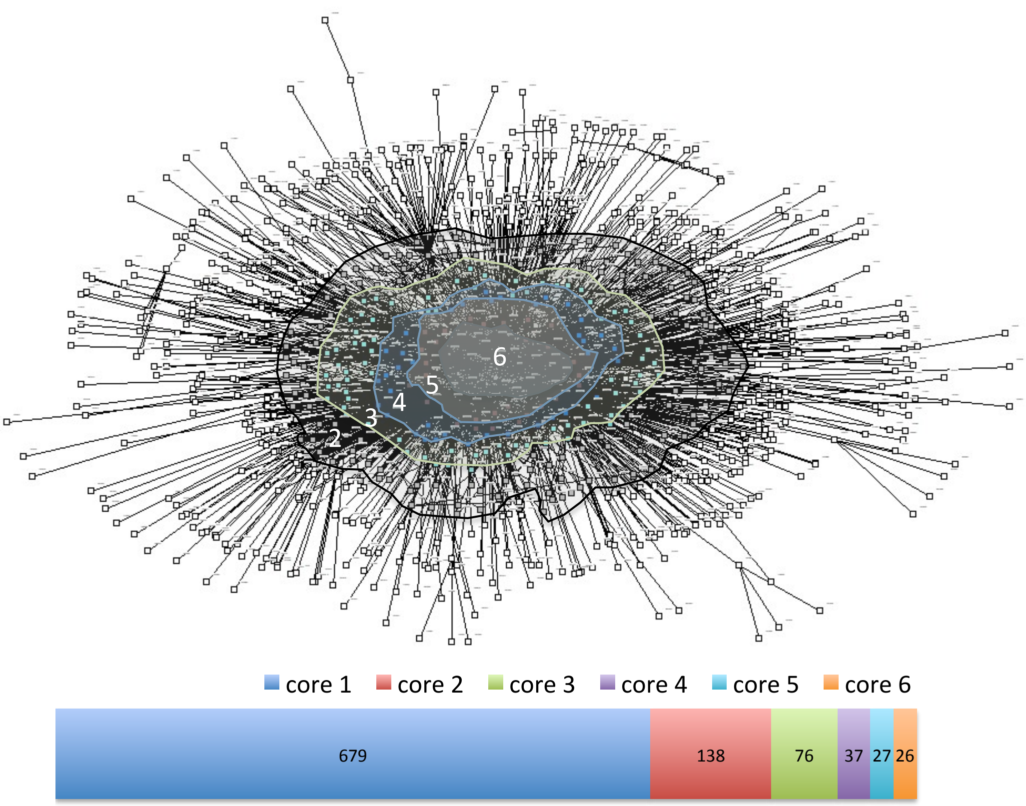

The four cases analysed illustrate how part of the collaborators of a given researcher continue publishing with him/her in the new institution that may or may not be in the same country.  These cases also show how the researchers might move toward the institution of one of his/her collaborators with a better outcome in science as part of their career prospect. Nevertheless pursuing the hypothesis that the mobile researchers might increase the presence of her home institution in the destination country (or region) will require a different experimental design.

6.5.3 *Cuban institutions in the CRiE network: the role of collaborators*

The K-core analysis of the networks in those countries with higher density of CRiE (Belgium, Germany, Italy, Spain and United Kingdom) showed that in two of them (Belgium and Spain) the University of Havana and the Central University of Villa Clara were among the institutions in the inner core, while the University of Havana was the only Cuban institution in the inner core of Germany.

The fragmentation of the network per country although given local information, breaks connections due to the mobility of CRiE within the region. The whole network of CRiE on the other hand, takes into account the movement of researchers within Europe. The whole CRiE network comprises 985 nodes (institutions) and 3,140 links of collaboration. The results of the K-core analysis of this network showed 6 cores or shells (Figure 6.22) with a distribution from the inner core six of 26, 27, 37, 76 and 138 institutions.

Figure 6.22 Cores and number of institutions per core in the CRiE network




Cores of the CRiE network and the number of institutions per core indicated in the bar graph

Cuban institutions are distributed through the shells as follow: in the inner core 6 two institutions: the University of Havana and the Central University of Las Villas; in core 4 another two institutions: the Centre of Biotechnology and Genetic Engineering and the Centre of Marine Bioproducts (CEBIMAR); in core 3 five institutions: Institute of Cardiology and Cardiovascular Surgery, Centre of Pharmaceutical Chemistry, the Centre of Molecular Immunology, the University of Matanzas and University of Camaguey and in core 2 another five institutions: Finlay Institute, the Polytechnic University Jose E. Echeverria (ISPJAE), the Cuban Centre of Neurosciences, the Higher Institute of Basic and Pre-clinical Science “Victoria de Giron” and the Experimental Sugar Cane Station Villa Clara-Cienfuegos.

These fourteen Cuban institutions are part of those three hundred and four institutions shaping the connectivity of the network of Cuban researchers in Europe representing 4.6% of the total. The share per country with more presence in the central cores 6 and 5 shows Spain as the strongest country with 39.6% of institutions, followed by Germany (13.2%), United Kingdom (11.3%), France and Italy (7.5%), the United States (5.7%), Belgium (3.8) and Cuba (3.8%).

## 6.6 LIMITATIONS AND FURTHER STUDIES

The characteristic of the experimental design restricting the sample to active researchers publishing systematically in peer review journals is also a filter for successful researchers. Therefore the study excludes those who started their careers in European institutions of S&T and did not succeed, or those who after a period of postdoc positions moved to places from which they did not continue publishing; and those who might never had the opportunity to work for what they have been trained (brain waste).

The study did not include the analysis of citations that provided impact and visibility of the scientific publications of study. However the information was collected in the datasets of both CRiE and CRiC for further studies.

The dataset collected through this study will support further investigations such as the study of visibility of the CRiE collaboration through their citation patterns.

## 6.7 SUMMARY OF THE FINDINGS

The results of this chapter show the characteristics and potential of a group of one hundred and six Cuban scientists actively publishing in European institutions of S&T (CRiE).

Gender composition of the CRiE sample corresponds to 34% female versus 25% in the cohort group of CRiC. CRiE are younger than the cohort group shown by both the number of years publishing (11 versus 25 years for CRiC) and the high proportion of them graduated after 1995, indicating that the 77% are younger than 40 years old.

CRiE are mainly graduated from academic institutions in Havana and the higher proportions are from the faculties of Biology (30%), Physics (15%) and Chemistry (15%).

Eighty six per cent of the CRiE are concentrated in six European countries: Spain (36), United Kingdom (17), Germany (11), Belgium (10), Italy (10) and France (7). They have published more than 1,800 articles in the whole period and 50% of them have published in the last ten years. 52.8% CRiE have published at least once with Cuban institutions.

CRiE were mainly PhD students and post-doctoral researchers who moved to Europe to further their careers although 67% published at least once from a Cuban institution before moving to Europe. They are very mobile and highly collaborative with more than 75% of their publications with national and international co-authors. Fifty six CRiE (52.8%) have published at least once with Cuban institutions from their European affiliations.

The design to explore the network of scientific collaboration of the CRiE showed a network with more than 985 institutions from fifty-three countries generating more than 3,000 links of collaborations. Twenty-four Cuban institutions were part of this network and fourteen of them were actively connected through the cores of the network. University of Havana and the Central University of Villa Clara were among the 26 institutions in the inner core of the network with higher number of links, among them University of Oxford, Imperial College London, University College London, University Pompeo Fabra, University of Barcelona, Karolinska Institute, the National Autonomous University of Mexico (UNAM) among others of international prestige.

This chapter has provided strong evidence of the potential of Cuban researchers working in institutions of S&T in Europe, with a particular pattern of preferential collaboration with Cuban scientists among Latin American counterparts. Evidence suggests that this collaboration is self-organized by the researchers themselves. To further explore the potential of this network a qualitative study should follow.

# CHAPTER 7: RESULTS - PART III

## CUBAN SCIENTISTS OF THE REVOLUTION

> *…'unprecedented in the history of mankind Cubans have witnessed [...] the construction of the science in a country in the lapse of human life and from very little. For younger people, the Cuban science is a natural event; many seniors cannot understand what has happened, because they did not have the opportunity to be educated for it'.*
>
> *Luis Alberto Montero Cabrera (2012)*

## 7.1 INTRODUCTION

This chapter takes the challenge of analysing the Cuban scientific community as a whole regardless of their geographical dispersion and the diversity of the scientific fields of research. The work described here summarises qualitative evidence of how Cuban researchers relate to scientific collaboration using semi-structured interviews. The questions and subjects of further investigation were elaborated after the bibliometric analysis of how scientific collaboration operates in Cuba (Chapter 5), how Cuban researchers in Europe (CRiE) stand in relation to top Cuban researchers in Cuba (CRiC) in terms of seniority and productivity, and featuring the collaboration of CRiE through the network analysis (Chapter 6).

In reporting data in this chapter for comparative analysis, it is useful to make a distinction between CRiE and CRiC in the overall population whose publications were studied in the bibliometric analyses (chapters 5 and 6), and those who were interviewed and discussed in this present chapter 7. In this discussion, those interviewed are referred to as **iCRiE** and **iCRiC** and are highlighted in **bold** so as to clearly differentiate commentary, which compares the interview sample with the larger sample (CRiE and CRiC).

Therefore this section aims to give the opportunity to the researchers themselves to express their views and experiences in scientific collaboration in general and in particular the collaboration between Cuban researchers in Cuba and abroad. Through the interviews the lens will be placed on the points making Cuban researchers one community of scientists with universal goals and how the current distance between Cuban researchers in Cuba and abroad could be shortened for the benefit of the home country and society in general, including the destination countries in Europe.

By definition this fieldwork is not interventional but observational and limitations are analysed at the end of the chapter. Methodologically it follows the general rules of naturalistic enquires (Robson, 1993, 57) which are normally used in exploratory case studies before establishing the variables of the main research. However in this case the lines of enquiry come after the quantitative study as previously described as well as from the studies of international scientific collaboration (Beaver, 2001; Wagner, 2004).

## 7.2 GENERAL INFORMATION ABOUT THE INTERVIEWS AND INTERVIEWEES

### 7.2.1 *Interview process*

The interviews started in Cuba with the purpose of gathering relevant information from Cuban researchers at home to which the interviews of the researchers in Europe might relate to regarding scientific collaboration and possibilities of future developments.

The interviews in the cohort group of Cuban scientists working in Cuban institutions (**iCRiC**) were carried out in two visits to the country ($29^{th}$ January to $18^{th}$ February, 2015 and $22^{nd}$ June to $12^{th}$ July, 2015). Interviews were all taken face-to face after receiving the scientist's consent by e-mail or by phone call and signed before initiating the interview. Contacting the researchers was by phone, emails or face-to-face and locations were chosen by the interviewees either in their workplace or in their home addresses or public spaces (room facilities during international conferences). Interviews were carried out in Spanish and notes were transcribed later into English. The most relevant researchers were not always available and alternatively active Cuban researchers were chosen reflecting their leadership in Cuban science.

The English versions of the transcriptions were sent by email to the interviewees for approval giving them the chance to correct the content, however not all interviewees replied with corrections, and specific phrases were not taken from those cases although it was assumed they agreed with the transcriptions. Due to the small number of interviewees all transcriptions were used even if they were incomplete (this option was given in the consent letter to the researcher aiming to gain more participants otherwise reluctant to be interviewed). Table 7.1 shows the records of CRiC contacted and or interviewed (**iCRiC**) during the two visits to Cuba in 2015 for the sample of this qualitative study.

Table 7.1 CRiC contacted for interviews

| Cuban Institution | Code | CRiC sample | Field | Total Publications | Invited for Interview | Available | Date interview |
|---|---|---|---|---|---|---|---|
| **UH** | 101003-01 | X | Chemistry | 72 | X | X | 31/01/2015 |
| **UH** | 101003-02 | X | Mathematics | 87 | X | X | 09/02/2015 |
| **UH** | 101003-03 | X | Mathematics | 96 | X | X | 10/02/2015 |
| **UH** | 101003-17 | X | Mathematics | 83 | X | X | 09/02/2015 |
| **UH** | 101003-24 | NO | Microbiology | 8 | X | X | 09/02/2015 |
| **UH** | 101003-25 | NO | Mathematics | 8 | X | X | 09/02/2015 |
| **UH** | 101003-18 | NO | Biology | 37 | X | X | 26/06/2015 |
| **CIM** | 101007-07 | X | Biochemistry | 19 | X | X | 07/02/2015 |
| **CIM** | 101007-01 | X | Biology | 52 | X | NO | NO |
| **InSTEC** | 101008-01 | X | Engineering | 37 | X | X | 23/06/2015 |
| **CIDEM** | 101029-01 | X | Biochemistry | 80 | X | X | 23/06/2015 |
| **FCM-H** | 101060-01 | X | Biochemistry | 112 | X | X | 25/06/2015 |
| **UMCC** | 101030-01 | X | Chemistry | 26 | X | X | 12/02/2015 |
| **UMCC** | 101030-02 | NO | Biochemistry | 7 | X | X | 12/02/2015 |
| **UCLV** | 101005-01 | X | Mathematics | 130 | X | NO | NO |
| **CIGB** | 101014-05 | X | Chemistry | 80 | X | NO | NO |
| **IPK** | 101011-02 | X | Medicine | 219 | X | NO | NO |
| **IPK** | 101011-03 | X | Medicine | 62 | X | NO | NO |
| **CNIC** | 101004-01 | X | Biochemistry | 167 | NO | NO | NO |
| **CNC** | 101025-01 | X | Medicine | 64 | NO | NO | NO |
| **ICCC** | 101002-01 | X | Medicine | 65 | X | NO | NO |
| **IIIA** | 101010-01 | X | Chemistry | 222 | NO | NO | NO |
| **CIGB** | 101014-07 | X | Chemistry | 53 | NO | NO | NO |

Thirteen Cuban researchers were interviewed from which only nine were included in the cohort group of **iCRiC**. However, four other available Cuban researchers were interviewed who were academics with more than twenty-five years of research experience in academia; two of them had participated in academic exchanges and teaching experience in Africa and another had worked in two different Cuban research institutions besides University of Havana. Although these four Cuban researchers were not among the highly productive ones, they all are currently in senior positions as professors (professor titular). One interview was not completed as the researcher had to attend to a planned meeting and the previous interview took more time than expected.

The interviews with the Cuban scientists in Europe (**iCRiE**) took place over a longer period of time from September 2015 to January 2016. Invitations to participate as well as the consent form was sent to twenty-seven CRiEs out of twenty-nine selected by their scientific productivity with a cut-off of 2.4 articles per year published using the European affiliation on 7th September 2015 and a gentle reminder three weeks later. The addresses of two of the twenty-nine researchers included in the list were not found in their publications indicating that they were not corresponding authors but collaborators. The interviews (n = 11) were carried out mainly by video link using Skype as a platform. CRiE were often travelling to scientific meetings and this was the best way of communication. Travelling to the country in Europe for the interviews was expensive and not effective (unexpected cancellations) and did not add any advantage to the interviews. Table 7.2 shows those CRiE with the highest productivity included in this sample for the qualitative study and those agreeing to participate in the interview.

Table 7.2 CRiE contacted for interviews

| European Institution | Current Country | CRiE Code | Field | Total Publ. | Years in Europe | Reply to invitation | Date of Interview |
|---|---|---|---|---|---|---|---|
| KUL | Belgium | 201001-06 | Physiology | 45 | 14 | NO | NO |
| VUB | | 201004-07 | Biochemistry | 37 | 10 | NO | NO |
| UG | | 201007-08 | Medicine | 38 | 14 | NO | NO |
| KUL | | 201001-10 | Biology | 14 | 4 | NO | NO |
| RIC-M | France | 202010-02 | Mathematics | 12 | 4 | NO | NO |
| MPI-K | Germany | 203015-01 | Chemistry | 16 | 6 | NO | NO |
| MPI-K | | 201015-03 | Chemistry | 32 | 12 | DECLINE | NO |
| GUF | | 203032-04 | Neurobiology | 48 | 20 | DECLINE | NO |
| MPI-K | | 201015-09 | Chemistry | 9 | 2 | NO | NO |
| UH | Finland | 204001-01 | Biochemistry | 41 | 7 | YES | 13/10/2015 |
| UP | Portugal | 206006-01 | Chemistry | 61 | 13 | YES | 21/09/2015 |
| UPF | Spain | 207030-03 | Bioinformatics | 14 | 4 | YES | 04/01/2016 |
| CNIO | | 207027-05 | Biochemistry | 12 | 4 | YES | Cancelled |
| UA (1) | | 207051-09 | Chemistry | 8 | 2 | YES | 02/10/2015 |
| EHU | | 207069-12 | Chemistry | 51 | 12 | YES | 18/09/2015 |
| UHE | | 207069-33 | Chemistry | 130 | 9 | NO | NO |
| CSIC-IC | | 207076-15 | Neuroscience | 39 | 20 | NO | NO |
| UCM | | 207014-22 | Biochemistry | 27 | 5 | NO | NO |
| ULL | | 207077-23 | Mathematics | 99 | 16 | YES | 08/09/2015 |
| UB | | 207023-39 | Biology | 17 | 15 | YES | 21/09/2015 |
| ETH-Z | Switzerland | 208011-03 | Physics | 13 | 5 | NO | NO |
| KI | Sweden | 209005-01 | Biochemistry | 59 | 9 | YES | 10/09/2015 |
| KI | | 209005-03 | Biochemistry | 30 | 5 | NO | NO |
| UCL | UK | 210003-02 | Chemistry | 41 | 11 | YES | 13/10/2015 |
| UoS | | 210021-03 | Chemistry | 133 | 16 | YES | No available |
| ICL | | 210020-09 | Biology | 188 | 14 | YES | 11/01/2016 |
| UL | | 210056-15 | Chemistry | 41 | 7 | YES | 14/09/2015 |

Transcriptions of the interviews into English were sent to the interviewed CRiEs for corrections and some of them attached additionally their curriculum vitae indicating their willingness and openness to be part of the study. Two CRiEs opted for sending the answers by e-mail due to their limited time and were equally valuable in content. The face-to-face or video link interviews allowed additional rapport for further interactions concerning the current research project.

7.2.2 *General information about the interviewed Cuban researchers*

All scientists interviewed were Cubans graduated after 1959 either in Cuba or in socialist countries as part as the national programme in higher education of the revolutionary Cuba.  In the sample of the top hundred CRiC, one Cuban finished medicine in Mexico in 1962 and returned to Cuba in 1970; an Argentinian doctor arrived to work in Cuba in 1962 and a graduated Mathematician from the University of Havana was born in Uruguay, another two were born in U.S. but completed their education in Cuba. Science in Cuba did not exist previous to 1959 (Clark-Arxer, 2010) to the degree of supporting relevant international scientific publications, with the exception of individual cases (Montero-Cabrera, 2012). In the case of CRiE, as described in chapter four, their education and year of graduation from the Cuban higher education system was found mainly using social-professional networks, the webpage created for this project, published curriculum vitae from their current academic positions in Europe and in few cases personal contact through e-mail.

In both groups researchers are mainly from faculties of science rather than engineering, and faculty of physics is missing in the sample of interviewed CRiC, although 10 physics researchers working in the University of Havana and ICIMAF (Institute of Cybernetic, Mathematics and Physics) were included in the quantitative study.

Students graduated from universities in the Soviet Union, now Russian Federation and Ukraine in chemistry, physics and mathematics are represented in both samples, indicating the cooperation in higher education between Cuba and the former USSR.

Tables 7.3 and 7.4 summarises general information about the interviewees (**iCRiC** and **iCRiE**).

There is an under representation of the female gender among the interviewed researchers in both groups. In the previous chapter (6.2.2) it was shown that only 25% of top CRiC by number of publications were female while the proportion in all Cuban researchers is 53% (ONE, 2015b); and in the interviewed sample only one out of 12 (8.3%) was a female researcher.

Tables 7.3 General information about interviewed **iCRiC**

| Code | Faculty | Gender | Place of HE Graduation | Year of Graduation | Year of PhD graduation | |
|---|---|---|---|---|---|---|
| | | | | | In Cuba | Abroad |
| 101003-01 | Chemistry | M | UH | 1969 | | 1980 |
| 101003-02 | Mathematics | M | UCPEJV, UH | 1979 | | 1991 |
| 101003-03 | Mathematics | M | UCPEJV, UH | 1983 | 1998 | |
| 101003-24 | Biology | F | UH | 1976 | 1988 | |
| 101003-25 | Mathematics | M | UH | 1973 | | 1988 |
| 101003-18 | Biology | M | UH | 1978 | 1987 | |
| 101007-07 | Biology | M | UH | 1998 | 2007 | |
| 101008-01 | Chem. Eng. | M | DMUCTR | 1987 | 2002 | 2002 |
| 101029-01 | Biology | M | UCPEJV, UH | 1987 | 1996 | |
| 101030-01 | Chemistry | M | UH | 1996 | 2008 | |
| 101030-02 | Biology | M | UH | 1975 | | 1981 |
| 101060-01 | Biology | M | UH | 1975 | 2004 | |

UH: University of Havana, Cuba; UCPEJV: Pedagogical University Enrique Jose Varona, Cuba; DMUCTR: D. Mendeleyev University of Chemical Technology of Russia, Russia Federation (then USSR)

Tables 7.4 General information about interviewed **iCRiE**

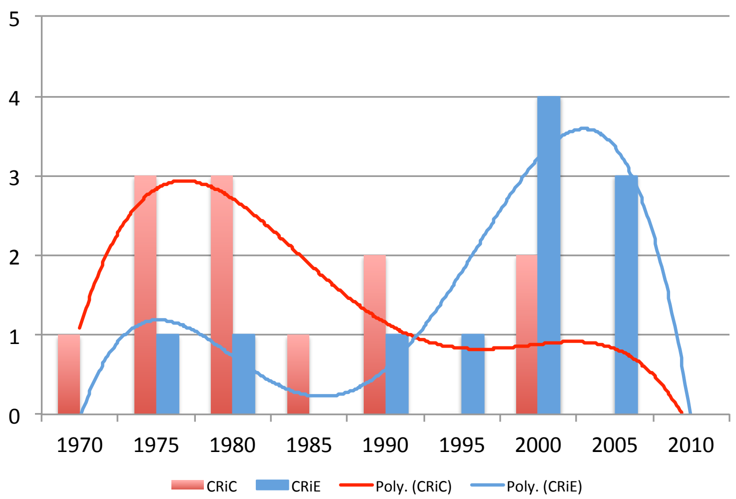
| Code | Faculty | Gender | Place of HE Graduation | Year of Graduation | Year of PhD graduation | |
|---|---|---|---|---|---|---|
| | | | | | In Cuba | Abroad |
| 204-01 | Biology | F | UH | 1998 | 2004 | |
| 206-01 | Pharm. Sci. | M | UCLV | 2004 | 2009 | 2010 |
| 207-03 | Biology | M | UH | 1998 | 2006 | 2006 |
| 207-09 | Chemistry | M | UH | 2003 | 2009 | 2010 |
| 207-12 | Math. Phys. | M | MSU | 1988 | 1997 | |
| 207-23 | Mathematics | M | ONU | 1977 | 1980 | |
| 207-39 | Biology | F | UH | 1993 | | 2001 |
| 209-01 | Biology | M | UH | 2003 | | 2008 |
| 210-02 | Physics | M | UH | 1998 | | 2006 |
| 210-15 | Radio-chem. | M | InSTEC | 1996 | | 2012 |
| 210-09 | Biology | F | UH | 1979 | | 2007 |

UH: University of Havana, Cuba; UCLV: Central University of Las Villas, Cuba; InSTEC: Higher Institute of Technology and Applied Science, Cuba; MSU: Moscow State University, Russia Federation (USSR); ONU: Odessa National University I.I. Mechnikov, Ukraine (then USSR).

The difference between the proportions of female CRiE (34%) as a whole compared to the interviewed sample (27.3%) was less dramatic. Nevertheless one possibility to improve those proportions would have been to continue the interviews before publishing the results (but time constraints limited this option).

In terms of the age representation per group, the interviewed **iCRiC** are older researchers with almost 50% graduated between1975 to 1980 while in the group of **iCRiE** 50% are between 1998 and 2005 (Figure 7.1). The generation gap between both groups was expected from the quantitative evaluation of their scientific performances (Figure 6.4).

Figure 7.1 Distribution by year of graduation of interviewed iCRiC and iCRiE groups



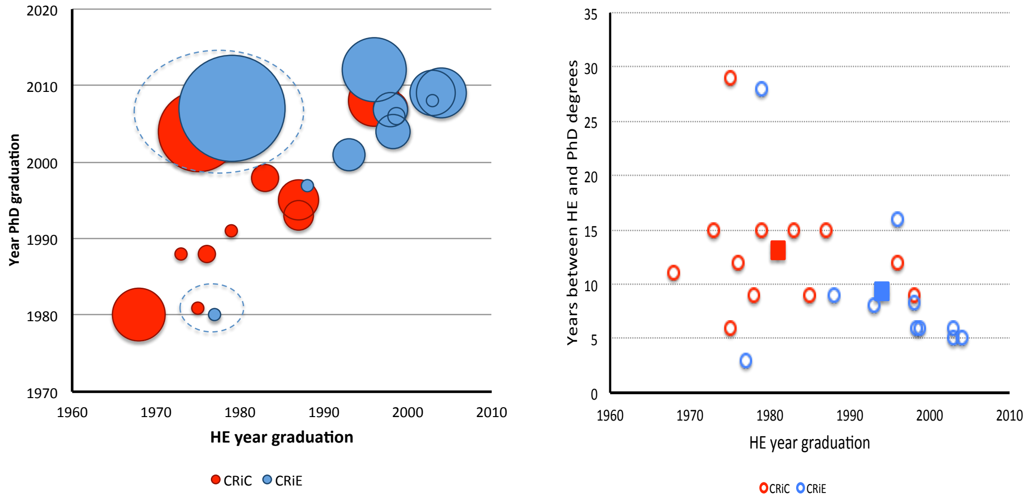

In terms of doctoral degrees both groups have different patterns although the same number graduated abroad. In **iCRiE** three doctoral students had their title recognised in Cuba (University of Havana) and in the partner institution abroad through bilateral agreements (Alonso-Becerra and Rodriguez, 2014), characteristic of the current internationalization of higher education.  This is also observed in one of the **iCRiC** with a doctoral degree obtained in 2002. Places of the attained doctoral degree are also different. In the **iCRiC** group: University of Havana is the main institution awarding the doctorates (four doctoral degrees) and other institutions with one doctoral degree each are: the Higher Institute of Medical Sciences of Havana, the National Centre of Scientific Research in Havana and including those of the former socialist countries the Technical University of Dresden, then East Germany; Visoka

Skola Chemika Technologika in Prague, then Czechoslovak Republic and Moscow State University, then USSR. As the doctoral graduates in the **iCRiE** group obtained their degree after 1991, academic places are mainly in Western Europe with the exception of one case graduated from the Moscow State University in 1980. The academic institutions awarding the doctoral degree, in no particular order are: Institut National Agronomique de Paris-Grignon, France; University of Pavia, Italy; Birkbeck College University of London, United Kingdom; Polytechnic University of Catalonia, Spain; Autonomous University of Madrid, Spain; University of Barcelona, Spain; University of Helsinki, Finland and University of Porto. Cuban institutions co-awarding doctoral degrees are University of Havana (five) and Central University of Villa Clara (one).

The patterns of years between graduation of higher education (HE) and the year of being awarded a doctoral degree (PhD) in both **iCRiE** and **iCRiC** seems to have similar characteristics including the number of publications up to the end of the PhD. In the Figure 7.2, the left panel shows the years of HE graduation (x axis) versus the year of PhD graduation (y axis) and the diameter of the circle indicates the number of publications since HE graduation up to the year in which they were awarded a PhD. The extreme situation is marked with a dotted circle in which either the researcher is awarded with a doctorate earlier with almost no publications and the opposite, they were awarded after years of experience in their research supported by the number of publications.

Although the interviewed researchers were not chosen for this particular characteristic, both **iCRiE** (blue) and **iCRiC** (red) shared the same features. It seems that it was typical of the 70s and 80s decades either starting the doctoral studies early (mainly in socialist countries) or working in research institutions and gaining experience before the doctoral degree. The right panel of the Figure 7.2 is the scatterplot of the year of finishing the HE degree (axis x) versus the gap years between HE and PhD graduations (y axis) for each researcher. There is a general trend of doctorates being awarded earlier after HE graduation in recent years but the fit for linear correlation is poor in both CRiE ($R^2$=0.205) and CRiC ($R^2$=0.038) samples. Nevertheless the means of the gap years between HE and PhD graduations seem to be another consequence of the age difference between CRiE and CRiC.

Figure 7.2 Doctoral degrees in CRiE and CRiC




Left panel: years of HE graduation (x axis) versus the year of PhD graduation (y axis) and the diameter of the circle represents the number of publications per researcher before and during PhD. Right panel: years of HE graduation (x axis) versus the gap years between HE and PhD graduations (y axis) for each researcher

## 7.3 RESEARCHER'S EXPERIENCES AND VIEWS ABOUT SCIENTFIC COLLABORATION

All subjects were explored through specific questions to **iCRiE** and the control group **iCRiC**. Some open questions were designed to obtain maximum information on the researchers' experiences and others to gauge the answer to a specific topic. As described in methodology, before conducting the interviews a summary of the individual patterns of research collaboration was obtained from the bibliometric study for those approached for participating in the interviews. Having the knowledge of the researcher's scientific production in terms of their field of investigation as well as their records and type of collaboration was essential previous to the interviews and contributed to the openness shown in the process. Table 7.5 shows the typical pattern of research collaboration in only those Cuban researchers who were interviewed and therefore included in the groups of study.

Table 7.5. Scientific collaboration of Cuban researchers

| Group | Researchers per group (n) | Total publications | | Publ w/o collaboration | Type of Collaboration (%) | | Average Affiliation per publication |
|---|---|---|---|---|---|---|---|
| | | Cuban affilation | Europe Affiliation | | International (NI+NNI) | National (NN+NNI) | |
| **CRiE** | 11 | 80 | 584 | 120 | 60% | 49% | 4.8 |
| **CRiC** | 12 | 566 | 0 | 130 | 68% | 30% | 2.4 |

Aggregate and mean values obtained from the datasets of **iCRiE** and **iCRiC** created for the bibliometric study [chapter six].

The total number of articles published by interviewed **iCRiE** using their European affiliations is 584 and although the number is larger than the total publications of interviewed **iCRiC** of 566 papers, the t-test comparing the mean of publications per researcher showed there is no difference between the groups[39]. The percentage of collaborative articles are 79% for **iCRiE** and 77% for **iCRiC**: of those, international collaboration represented 60% and 68% of the total number of publications for **iCRiE** and **iCRiC** respectively. National collaboration in which at least two national affiliations are listed in a given publication represented 49% and 30% of the total number of publications.

The heterogeneity of the samples (age and fields of research) will not support any further assumption in terms of quantitative analysis beyond the general finding that in both groups more than 75% of their scientific outputs come from collaborative research.

### 7.3.1 *Scientific collaboration in general*

The first open question asked to both **iCRiE** and **iCRiC** groups was:

a) How scientific collaboration has evolved since your early days as a PhD student or researcher?

Then more specific questions were designed to be precise about the researcher's motivation behind collaboration and the way it was carried out, although sometimes they were answered in the previous open question.

[39] Means of publications per researcher are: $X_{CRiE}$= 60.4 and $X_{CRiC}$= 47.2; and the standard deviations are: $s_{CRiE}$ = 51.8 and $s_{CRiC}$= 37.8; t-test= 0.12

b) Please mark with an X your motivation behind collaboration:
*Complementarity in terms of knowledge, manpower and ideas:*
*Access to resources not available in your institution:*
*Multidisciplinary expertise or different skills:*
*Access to international (or national) funding:*
c) How did you meet your collaborators?
*International meetings:*
*Through the literature in the field of research:*
*Being asked to be a collaborator:*
d) How do you keep the communication with your collaborators during the course of the project? *For instance, exchange of data, or results, discussion, writing the manuscript, etc. In terms of type of communication: through e-mails? face-to-face? Tele-conference? Other Internet platforms, such as video-links?*

Questions were not exactly designed to quantify the responses but to have an idea of how collaboration evolves and what can facilitate or limit its progression in both groups. The interview aims for a wide description of their experiences as researchers.

*7.3.1.1 The beginning of the scientific collaboration and the research environment*

The first question showed in both groups that during the early days of their working life, the researchers are not in charge of making the collaboration, which is generally already established by the research leaders of the institutions. Situations and settings vary as it happens elsewhere but it seems that the older generation particularly in **iCRiC** were aware of their role in building the future of science in Cuba since the earlier days in scientific research. Sometimes the need for other skills, made them, as young researchers, to look out for help, which sometimes ended as collaboration, depending on the degree of contribution. Eight out of eleven **iCRiE** published their first scientific article with Cuban affiliations of which one listed both affiliations (Cuba and the European country) and another has added the Cuban publications not listed in *Scopus* after the interview. Only one **iCRiE** of the sample never worked in Cuban scientific institutions although receiving advanced training as a student in top research institutions before deciding to further his education in Europe. Those **iCRiE** who started as researchers in Cuba participated in projects involving international collaboration and were able to interact with visiting international researchers by participating in international conferences or research projects. One of the interviewees summarizes his experience from his days as an undergraduate student at the University of Havana (UH):

> *" By being exposed to this environment of experienced researchers, my education was immediately up-graded to international standard of performing scientific research…those programmes encourage and develop research qualities" and also referring to UH he added "teachers were outstanding I believe their way of teaching came from the German and Russian schools of teaching that have prepared me as an independent mind in science"*

Institutional environment plays an important role providing exchanges of knowledge, skills and exposure to other experienced researchers both national and international. Some institutions in Cuba go even further as a young **iCRiC** described:

> *"At the end of each event (international) a process called 'Meeting harvest' takes place as an inventory of all ideas and opportunities as well as a list of contacts from which the international collaboration emerges"*

Some institutions in Cuba are better equipped than others enjoying excellent conditions for researchers while others had to rely on cooperation and collaboration to advance science and education. Again Cuban researchers confront these realities differently as it might be related to their generation. One **iCRiE** with a doctoral degree awarded in Europe (although publishing first from Cuban institutions) had different views about resources in some parts of academia, and the precarious state of some facilities for teaching (Faculty of Physics):

> *"The Faculty has been in disarray almost in ruins, for a long time and it seems that nothing is happening to reconstruct the place: students have to attend classes outside the faculty, which affects the quality of teaching"*

Indeed some outstanding CRiCs have run the extra mile confronting the lack of resources, as Richard Stone a senior editor of *Science* magazine (2015a) highlighted days after the re-establishment of U.S.- Cuba relations in the words of one of them:

> *"My strategy to survive, as an experimental physicist was to violate the boundaries of safe science invading zone where I was not a specialist, looking around for new phenomena with wider eyes, seeing scientific instruments in daily life objects, attacking and retreating from serendipitous findings like a guerrilla"*

By analysing the views of these two groups of Cuban researchers (**iCRiE** and **iCRiC**) it is possible to see their passion for excellence in science, the need to create knowledge and how the same circumstances prompted opposite decisions, however convergent in many senses as the next comments about how collaboration started from two **iCRiEs** who agreed that good ideas are not limited to an "ivory tower":

> *"The concept of research then was excellent [in Cuba] although my decision was opting to further my knowledge in Europe. Here I found that research ideas and collaboration can emerge from different settings: the obvious are the seminars especially those given by worldwide prestigious scientists in the field invited by the university, but social life outside the workplace, in a pub, in a summer garden party are unexpectedly the environment where new ideas take shape and a new collaboration takes-off"*

Another **iCRiE** almost joking referring to where collaboration starts said:

> *"Scientists even use a napkin to draw and discuss their ideas during the dinner in a restaurant because they cannot stop thinking about their ideas"*

However his/her views about how the system works in United Kingdom are different, which is an indication of how personal is the perception and experience of each CRiE:

*"It is contradictory that United Kingdom having perhaps one of best resources in the world, the environment for the scientists to create knowledge is not the best. Coming from Cuba you appreciate how much they have in Europe, but the competition is counter-productive and is based on money. You spend more time looking for money than doing research or looking for new ideas or new knowledge. There are no permanent positions and when they offer a temporary position, it is conditioned to find a grant by the researcher and most of the time the field is crowded and competitive. It is hard to work in science for a living. Big and prestigious universities are more demanding and therefore it is more difficult to succeed. You might end up in a less relevant place to survive."*

Similarly, another two **iCRiE** in Spain with the Ramon y Cajal fellowship as Principal Investigators might not achieve the permanent position originally expected from this sort of funding supporting young talented researchers. Both have experienced mobility through more than two countries in their earlier careers, one of them in Europe and the other within Latin America.

One of the **iCRiE** currently working in Spain reflected on those early days as a researcher in Cuba:

*"Although I worked in Cuba for a while, I don't think I can offer a critical view on many things. I was very young and probably the information I had at the time is the same that any PhD student in Europe has, which is very little knowledge about how scientific collaboration behind the project works. The experience of the young scientist is limited to carry out research."*

All interviewed **iCRiE** in one way or the other recognized the contribution of Cuban education to their lives as solid foundation over which they built their successful careers. Some even acknowledge those days from primary school that one of them insisted as *"formal education and different from instruction"* from which he/she will be always grateful to his family and country. Many **iCRiE** attended those academically selective boarding schools such as the Special Institutes V.I Lenin in Havana or in provinces, and the School for talented students in mathematics, physics and chemistry "Mártires de Humboldt 7". Interestingly, it can be sensed in those young scientists who were interviewed, the degree of self-confidence and the need to challenge themselves in the search for excellence that might come from their earlier experience in those special schools. It has been suggested that those schools promoted not only social mobility but also spatial mobility when students were breaking their family ties and enjoying an environment of intense learning (Berg, 2015). Moreover during those days away from home they were building new and strong relationships, generational ties that became important later in their life outside Cuba (Berg, 2015).

There were such students in the **iCRiC** group as well, with the same attitude towards challenges and the self-confidence as scientists but somehow their expectations did not dissent from the bigger goal of contributing to Cuban science even having the opportunity of leaving the country during the worst economic period. One of the older **iCRiC** explained how in one of his scientific exchanges with United States, giving lectures in Chicago and New York, he was granted permanent residency in the U.S. even without asking for it and yet he returned to Cuba.

*7.3.1.2 Institutions in science*

Scientists carry out their research in different types of institutions, which operate with public funds such academia or with private funds more typical of the industry. All the interviewed Cuban researchers were currently working in the academia (11 **iCRiE** and 10 **iCRiC**) or in research institutes (2 **iCRiC**). The questionnaire did not include any particular question addressing the role of the institution however some Cuban researchers pointed out how the reputation of the team and the institution are also a crucial magnet for international collaboration and for receiving funding.

An **iCRiE** mentioned as a third factor why he was chosen as a collaborator:

> *"…and third, I work in an institute with an international reputation for good science and ethics, moreover because the leader of the group I work with, is an outstanding researcher with an international network built through many years".*

However the international reputation of the institution might not necessarily determine if the researcher will be awarded a grant as the same **iCRiE** expressed:

> *" I have received a lot of money in a grant that I was not even encourage to participate, however I won half a million Euros to carry out the research…. on another occasion I have developed better ideas in science and failed to receive the grant. Therefore there is no absolute correspondence in terms of good ideas and the money you might receive for taking the ideas forward."*

*7.3.1.3 Collaborators in science*

All **iCRiE** and **iCRiC** valued their collaborators in terms of knowledge and skills complementarity and to share workload when reducing the time for publications. However the dynamic of this relationship changes in time: at an early stage young researchers look for the best to collaborate with, later on the balance changes and they are the ones who have been asked to collaborate because of the quality of their publications. Generally as one young **iCRiE** expressed, the encounter with the best is not by chance:

> *"In my early days in Europe I searched for the best scientists in the field and tried to attend those meeting in which they were announced as key speakers. Once there I approached them to exchange ideas. You need to know them well, what they are doing, their main contribution to science in which you are interested and through the face-to-face exchange try to establish the bases of collaboration. Nothing is casual."*

In the views of this **iCRiE** the researcher's freedom to travel is also essential, implying the availability of funds supporting the attendance at international meetings as well. The take-off from a junior researcher to an experienced one requires enormous effort and personal dedication of the researcher building the curriculum of publications in good international journals. Participating in international meetings of the field is also essential in building the researcher's network: those opportunities are used by the researchers to organize further events, cooperative consortia, co-ordination of exchange visits, regional agreements and even encounter agencies and firms related to or interested in their research outputs.

Prestige comes from the quality and the quantity of the researcher's publications and prestige attracts more collaborators and even third party-collaborators. All interviewed **iCRiE** have been asked to collaborate by fellow researchers and overall reasons are a consequence of their publications, skills, expertise, their valuable database, sharing funding, productivity and efficiency (necessary to accelerate the publication, called by others manpower). One of the **iCRiE** mentioned the *honesty of the collaborator* as another reason when choosing them, which was not in the list of choices, but due to his particular experience he values highly an honest and trusted collaborator, especially now that false results are becoming a disease (Horton, 2015).

Another **iCRiE** mentioned that his strength as *"a collaborator"* comes from the versatile formation he received in Cuba making him [**iCRiE**] able to understand and work with two professionals that have little in common and might never collaborate:

> *"In other words I became the so-called T-shape researcher, essential for the breakthrough of new ideas"*

**iCRiE** of this particular group seem to be well connected to their networks of international researchers of their particular fields, they enjoy although in different degrees (some more than others), the prestige of being members of scientific committees or editorial boards of journals, organizers of international meetings, consultants for international agencies and governments and overall they have been very active in science and education.

Motivations for collaboration in **iCRiC** did not differ in general from those described earlier in **iCRiE**, however in all **iCRiC** interviewed one reason was always given: to reduce the isolation (Beaver, 2001) in which they felt the country was suffering due to the U.S. blockade. This reason also implies that through international collaboration they could gain access to financial sources still limited in their academic institutions. As one **iCRiC** summarized:

> *"Scientific exchanges of ideas, experience and results are vital for the development of science in general, however it does not exclude the additional motivation for seeking external financial support to carry out projects, otherwise collapsing due to the lack of resources, for instance hardware in computing. Through the exchanges we offer expertise, hardworking researchers committed to develop and complete any project for the benefit of the parts involved".*

Mobility was equally important for **iCRiC** and it is linked to international collaboration. Members of the **iCRiC** sample are top researchers in their field leading departments, research groups, representing the association of scientists in their field nationally and regionally (Latin America), they are members of scientific committees or editorial board of journals, organizers of international meetings, consultants for international agencies and governments, they are highly collaborative with some of them involved in international aids in education in African countries. They have been active in science and education for more than twenty years.

In terms of how **iCRiE** and **iCRiC** conduct research projects with their distant collaborators it seems that all means of communications are used and the advances in information and communication technology have been constantly facilitating and accelerating the exchanges. Electronic e-mails were used by all of them (**iCRiE** and **iCRiC**) on a regular basis exchanging information from original data to drafting documents for publication. Moreover under the umbrella of collaboration relevant scientific articles limited to the purchasing capacity of the stronger universities were shared among collaborators and it seems that it is not only limited to the needs of **iCRiC,** but a natural behaviour among researchers all over the world, included developed countries. **iCRiE** also enjoy new advances in communication when is needed such as teleconferences. One **iCRiE** remembered how many times she/he used to travel to the countries of collaborators:

*“Originally the research carried out through international collaboration required many working meetings all over Europe. Advances in ICT and digital technology have changed the pattern from face-to-face to video-links when two parties were involved or teleconferences for more than two centres. Those teleconferences are well organized and the host institution is in charge of organizing and running the expenses using the project grants. In general it is much cheaper and as equally effective as face-to-face and facilitate the participation of those who cannot travel. Web-seminars are excellent for exchanges as well as eLearning.”*

Researchers in Cuba (CRiC) might not have full access to the latest advances in ICT and modernization of the communication is not always possible, affecting the access to the Internet for instance in submitting articles because the connection to the journal webpage is slow, or paying the fees to attend international meetings when American banks were involved (affecting as well the visa process of CRiC attending international meeting). Problems of not having access to all options that the Internet offers also affects the way of communication through video-link, as it happened in the present research project in which the only alternative of interviewing **iCRiC** was face-to-face, while in the case of **iCRiE** video-link was used with nine of eleven researcher in Europe, some of them were even out of the country where they work.

One **iCRiC,** regarding the problems with the Internet, commented about accessing the journal webpage:

*“When the submission of articles were by post it was paradoxically easier for us. Now it has become a problem not a solution”*

The resilience of CRiC overcoming these situations find solutions in cooperation: the solidarity of a fellow researcher working abroad, not necessary a collaborator, but a friend or a member of their network who can help.

Interestingly evaluating motivations and how collaboration progresses in Europe, another **iCRiE** identifies the impact of publishing:

*"Publishing has been the main asset establishing collaboration in general and in the case of French researchers in cancer (NACRe)[40], the European Prospective Investigation into Nutrition and Cancer (EPIC)[41] has been the most relevant. This collaboration was strong enough to continue after moving to another country in Europe and we continue publishing, exchanging data and training PhD students from French institutions"*

The last remark brings the next key subject observed in many **iCRiE** while moving across European countries taking with them not only the knowledge and expertise acquired as their own "passport", but more essentially their collaborators, and in this way transforming the institutional and national collaboration into a network of researchers collaborating internationally. The study of the evolution of the individual patterns of collaboration of mobile researchers through social network analysis might be another strong evidence of the role of knowledge nomads in contemporary science (Day and Stilgoe, 2009) described in the new invisible college of self-organized networks by Caroline Wagner (Wagner, 2008).

7.3.2 *International collaboration*

The subject was explored through three specific questions to **iCRiE** and the control group **iCRiC**:

a) How is your rating (from 1 to 10) of International collaboration in institutions in Europe where you have been doing research? Do you have any experience that you can compare to how it was in Cuba? (**iCRiE**)

b) In your particular case, how did the international collaboration evolve since you started as a scientist? Did foreign trends or national need, or both shape it? (**iCRiC**)

---

[40] NACRe: A network of French researchers from different institutions and with complementary expertise coordinated by the Nutrition and Food Safety Laboratory (INRA) aiming to find the food and nutritional determinants operating as protective factors in helping to prevent cancer.

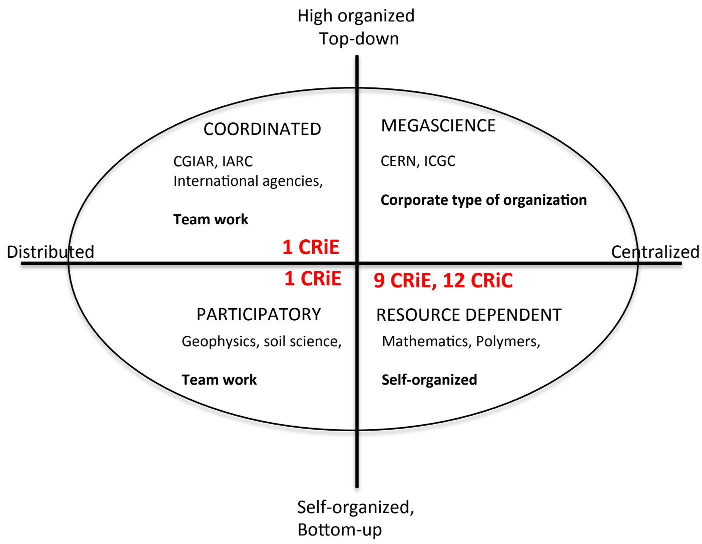
[41] EPIC: The European Prospective Investigation into Cancer and Nutrition study is one of the largest cohort studies in the world, with more than half a million participants (521,000) recruited across 10 European countries and followed for almost 15 years. Important contributions in the field of nutritional epidemiology were made using biomarkers analysis, questionnaire information, genetic and life style investigations.

c) On scale 1 to 10 where would you place international collaboration for its input to Cuban scientific development? Could you explain its evolution in time? Any relevant experience? (**iCRiC**)

The high proportion of European institutions in the collaboration network of CRiE accounting for more than 70% of the total was shown in the previous chapter six. All **iCRiE** interviewed also identified the *"Access to European funding"* as an important factor promoting scientific collaboration and one of the motivations behind researchers' choice. Europe as a region has strengthened its global position in science and innovation by creating programmes that encourage more than two countries participating in research projects, as well as fellowship for candidates with work experience in research institutions of a second or third country. In the first twenty years after the creation of the Framework Programs of research and technology in the early 1980s, the European Union funded more than 17,000 multinational projects in different fields in which some 85,000 collaborators in laboratories of member states were involved (Gusmão, 2001). However, not all members of the European Union have benefited equally from such programs and core centres of excellence remain dominating the scientific international collaboration in the region (Hoekman et al., 2010).

The **iCRiEs** participating in the interviews are currently working in top academic institutions in Europe and have been always moving within those elite universities. This fact gives them an advantage of participating in big international projects linked to the reputation of the elite institutions where they work and that advantage might be reflected in their experience in international collaboration. In terms of motivation (the researcher or institutional or government) for participating in international collaboration, Caroline Wagner (2006) proposed a schematic representation of two factors involved in the type of the international collaboration: one was related to funding and the other representing the location of the research. In Figure 7.3 the y-axis relates to funding from those international research organizations requiring a large budget to run them in the top, to research organized by researchers themselves sharing the cost of their projects. The x-axis represents from left to right the distribution of participants from more distributed to more centralized. Some of the examples given by Wagner (2006) in each quadrant represent some typical research projects. In the figure also are, in red, the interviewed **iCRiE** and **iCRiC** according to this classification of international collaboration in which they participate.

Figure 7.3 Representation of the factors involved in the organization of international collaboration




CERN: European Organization for Nuclear Research; ICGC: International Cancer Genome Consortium; CGIAR: Consultative Group for Agricultural Research, IARC: International Agency for Research in Cancer. Source: Wagner, C.S. (2006). In red are the type of research in which the samples of CRiE and CRiC are currently involved.

One **iCRiE** is part of an international research group with more than 30 articles involving more than 20 different affiliations in each one, but the majority of those affiliations are always the same. In *Scopus* this author showed more than 150 collaborators and this **iCRiE** is in the upper-left quadrant of the Wagner's diagram. A second **iCRiE** placed in the lower-left quadrant has a mixture of collaborative papers of 3 publications with more than 20 affiliations in a global genomic project (ICGC), however his job-position is supported by a national-European fellowship and therefore national collaboration seems to be stronger (see Appendix 7.1). All twelve **iCRiCs** were placed in the lower-right quadrant with the remaining of 9 **iCRiEs**. This quadrant according to the research of Caroline Wagner is where the vast majority of international research collaboration takes place and it is self-organized, motivated by the interest of particular communities of researchers called *"the new invisible college"* (Wagner, 2008).

The distribution of participating **iCRiE** and **iCRiC** in the diagram should also be considered in the diverse answers given by them.

When referring to international collaboration one of the **iCRiE** who has worked in academic institutions in three European countries gave a lower rating to Italy (8-9/10) and Sweden (9/10) placing United Kingdom in the top with 10/10:

> *"The laboratory conditions are the best you can aspire (referring to UK) including the excellence for research and innovation, optimal multidisciplinary interaction through consortium projects among others, the only thing I found is limiting discoveries and innovation is myself…because the place is a hub of excellence, you are expose to more collaboration and interaction with the best in the world".*

Interestingly the same **iCRiE**, as well as others, have mentioned their perceptions about cultural affinities and difference among the countries in Europe, which might hinder their full integration and success in collaboration.

When referring to Cuba for international collaboration the rate was 6/10 explaining:

> *"There was little time for research and collaboration; teaching was the main duty as an academic lecturer. Visiting international research laboratories was not always understood to be as important as teaching. Economic problems and lack of resources were also affecting research, as well as domestic life."*

Another **iCRiE** rating Cuba international collaboration as 7/10 observed:

> *"International collaboration in basic research is vital to advance science in Cuba and the researchers having some sort of support from the institution did most of the contacts. There are not enough resources or money, then collaboration is complementation".*

Motivation for collaboration beyond the borders also aims at accessing expensive resources, and researchers in Europe also experience this need, such as outsourcing for the large-scale facilities having the synchrotron and neutron sources in the Swiss Light Source at Paul Scherrer Institute, mentioned by one of the **iCRiE** as an example.

Researchers need to discuss and exchange other views and experiences in the process of creating knowledge, the motivation of pursuing excellence drives them to meet and exchange with the best researchers in the field, as expressed by another young **iCRiE**:

> *"Working with international experts allowed me to evaluate and rate my own contribution to science and therefore improving the quality of our research"*

Interestingly this remark could be achieved anywhere in the world, including Cuba, but the probabilities of working with top researchers in a particular field are higher in international centres of knowledge and excellence. In this view as in many other responses of the interviewed **iCRiE**, the sense of searching for excellence outside Cuba is, in one way or the other present as an individual aspiration of the young Cuban scientists in Europe. There is another motivation: this is a curiosity in researchers to meet face-to-face with those internationally acknowledged as the best, to have the opportunity to exchange ideas and promote their own work and ideas. One of the **iCRiC** although having as well as a strong motivation for international exchanges of ideas with the best, also projected his commitment with society in his role in education. Invited as a visiting professor to two Universities in France, the researcher remembered how when he was walking along the corridors and encountering those international figures he knew from literature, even the pictures of the famous researchers on the walls give anyone the sense of the strong tradition in science in those institutions, and he continues:

> *"Exchange of ideas and discussion coming from different background always make a positive impact. As a researcher you need to listen and to be listened, to challenge and to be challenged, and in this way you build your confidence.*

*The international collaboration, already established when I joined the group has a positive impact in the quality of teaching as well."*

Some researchers work in a specific theoretical field with few experts worldwide and exchanges of ideas to advance the field of research might be found in geographically distant places. This is the case of an **iCRiE** with the highest number of articles with either one author or one institution since the publication involves his own contribution to science explaining how collaboration works in his case:

*"I enjoy the challenges and risk of working in theories of quantum physics, but at the same time not many researchers work on it and finding the right collaborators to share ideas is not easy…I prefer to collaborate with the best, normally international well known researchers, but I also keep exchanges of ideas at national level, especially in the scientific park where I work".*

This type of basic and complex research in theoretical physics requires the input of the scientific community found in international meetings in which discussion takes place as the opportunity to go beyond the written article and from which collaboration develops, he continues:

*"The majority of collaboration develops through discussions when I present in international meetings ... other researchers ask to apply my model in their research and that leads to a new publication in collaboration".*

Another **iCRiC** (from an engineering background) valued highly the international collaboration as the platform for improving science in a country (Cuba) with high commitment but without a long tradition in science:

*"Multinational teams promote enrichment of ideas and diversity in the way you see things and solve problems: fifteen minutes discussion save months of work"*

In all **iCRiC** interviewed when asking for international collaboration they always involved the social dimension in their motivation as another **iCRiC** offered his views on international collaboration with France reflecting on his experience:

> *"France supports financially the mobility of researchers towards their facilities, but they don't offer financial support to further the research back in the country of origin, generating frustration in those researchers coming back to their home country. Nevertheless international collaboration with developed countries also provides opportunities to collaborate with third countries in the developing world, as it was the case with one of the ex-colonies of France confronting problems of corrosion in the tropical Caribbean environment. Through this path a new successful collaboration started and further developed"*

This was not an isolated case of international South-North collaboration developing into South-South collaboration; another interviewed **iCRiC** experienced almost the same situation. This time his expertise studying the immunological bases of some infectious diseases affecting the nervous system especially children in Cuba, prompted the interest of a German colleague and an international leader in neuro-immunology, to call the CRiC for collaboration in Africa where German expert was contacted from an international agency to assist in one of the tropical diseases transmitted by the Tsetse flies.

The interesting point here is how sometimes the international network of scientists grows with problems concerning countries of the South through the bridging role of the North, the latter also providing some sort of financial support, but essentially the source of knowledge and innovation might only be available in the South for the South. CRiCs are aware of these opportunities and they make the most of them as they consciously try to strengthen science in the South through collaboration especially in those emerging economies. As another **iCRiC** pointed out, the *"quality of Cuban scientists is one of the strengths of Cuban science"* and in this sense he was also referring to other qualities beyond the skills and expertise that will be discussed in the section 7.3.4.

Coming back to the role that the scientific institutions in the North might play, another principal investigator (**iCRiC**) and head of the research department in one of the Cuban institutions, explained from his personal experience coordinating international projects:

> *"A better approach is offered by the University of Antwerp, Belgium. Through the VLIR-UOS South Programmes this international cooperation not only helps Cuba with long term fellowships for PhD students in top Belgium institutions, but it provides the financial support when the post-doc returns back home, ensuring the post-doc can start creating laboratory conditions for research. Through these schemes the programmes aim to promote South-South exchanges, cooperation and collaboration; and Cuban scientists have participated in projects with Vietnam, Ecuador, Chile and Colombia ".*

*7.3.2.1 Mobility during PhD training and their contribution to science*

Countries and regions aware of the role of science in the knowledge society invest in the formation of new generation of researchers through research programmes abroad ensuring the access to the best centres of knowledge. The challenge however lies on maximising the brain circulation needed for competitiveness and avoids brain drain. The risk of losing talent definitively remains higher for countries in the South, as the following account of one CRiC reveals:

> *"Through international collaboration I completed my formation as a researcher in one of the top institutes in Europe in my field of research and as a result few articles were published. Combining resources and facilities in the Scientific Park in the East of Havana new research were carried out when I came back. However the training in Europe did not cover additional support back in Cuba. The situation faced by the young researcher trained abroad when coming back home could be very frustrating due to the lack of resources and some choose to remain abroad".*

An **iCRiE** in a senior position in Finland pointed out another difference between foreign-born PhD students related to their country of origin when explaining how for a small country as Finland the movement of talents has become essential for advancing science, allowing the exchanges of knowledge and networking:

> *"… in general foreign-born PhD students from developed countries are part of the international collaboration and a powerful element for developing science, remaining in close contact with the institution in the origin country. However, PhD students from the developing world come to learn under a personal basis".*

Concerning the role of the foreign-born PhD students as part or not of the international collaboration is not that simple and the previously described situation could only be circumstantial evidence. As a result of interviewing foreign-born researchers from other nationalities it was found that both situations do exist in countries of Latin America and in Europe. One PhD from the University Arturo Prat, Iquique, Chile was undertaking the research in the Autonomous University of Madrid through a successful long-term international collaboration between both academic institutions. Another PhD student from Mexico who had already migrated to Spain joined the doctoral program through a Mexican national scheme created to connect doctoral students abroad with local universities back in Mexico. The process of guiding the graduated nationals abroad to further their education was supported in this particular case by the Mexican consulate, which also coordinates, according to the interviewed PhD student regular meeting of exchanges among Mexican researchers in Madrid. Moreover the social network of students of the Autonomous University of Sinaloa, Mexico where the student graduated also played an important role guiding the graduates abroad with essential information and support. Interestingly, one of the differences between the two previously described cases is in their commitment to the country of origin after finishing the doctoral degree in the Autonomous University of Madrid: the first case is committed to the institution in which the PhD research project was part of the long-term international collaboration, the second sees the future wherever the opportunity might be, but ideally in the industry. The third interviewed was a Spanish researcher who returned home after a long period of post doc in the University of Pennsylvania, United States. The decision to accept a post doc position in United States, the researcher argued, came from the experience in previous visits to the University of Pennsylvania:

*"…Excellent conditions for research, infrastructure, international environment of top researchers working in frontline topics…they trained you to be independent and critic even to your senior researchers…you feel that the scientists are highly appreciated by colleagues and by the society in general, something I did not have back in Spain, where I always thought that no one was interested in my commitment for working in science".*

Priorities change over time. The reason that motivated this researcher enjoying the best anyone can ask in science in her years as a young PhD and post doc did not stand later when family came first and she decided to return home.

*"The excellence comes with a price… family life did not exist…your everyday life revolves around work, and colleagues are almost your only family. I remember the case of a mother that was not treated different from anybody else in terms of research duties and workload…My live changed when thinking of becoming a mother and how much I would like to spend more time with my family, deciding then to come back home [Spain]".*

This case also illustrates how some centres of knowledge and excellence benefit from hard-working foreign-born scientists and many times high impact articles in science might have only one institutional affiliation, but the authors contributing to the breakthrough are all of different nationalities. The resources might not be international, but the contribution of diversity in views, intellectual formation and previous experience comes from worldwide background and cultures (Levin and Stephan, 1999; Corley and Sabharwal, 2007).

*7.3.2.2 International collaboration with the United States*

The United States is a magnet for scientific collaboration. Although the global influence in science has been shifting away from the United States, still the country accrues a significant quality in their human capital having the best universities of the world attracting international collaborators. Seventeen universities in the U.S are in the top twenty (85%) and fifty-seven in the top hundred (57%) in the

Academic Ranking of World Universities (ARWU, 2012) and 20% of the world full-time researchers works in the U.S. research institutions[42]. Moreover U.S. is the single country with the highest GERD (GDP expenditure in Research and Development) of more than 270 billion in 2007, representing the 41% of the total of OECD countries (UNESCO, 2010). In terms of scientific outputs the U.S. was the top country contributing with 29% and 21% to the global publications in the periods 1999-2003 and 2004-2008 years respectively (The Royal Society, 2011, 17).

In chapter five, evaluating the patterns of Cuban scientific collaboration it was noticed that the United States, differing from the rest of Latin American countries, has less co-authored papers with Cuban scientists. Cuban researchers in Europe as shown in chapter six showed the strongest collaboration within European countries, followed by North America and Latin America as regions. However individual countries with more institutions collaborating in the network of CRiE are Spain (164), Italy (104) and France (99) in Europe, then United States (103). Those European countries also have hosted CRiE in their mobility through the region reflecting ties as seen in other studies (Luukkonen et al., 1992; Franzoni et al., 2012).

One particular question in both questionnaires (**iCRiC** and **iCRiE)** addressed the collaboration with specific regions as:

*Q.9 In terms of international collaboration would you comment on the relevance of collaborating with European institutions versus those in Latin American or U.S. (**iCRiC**)*

*Q.10 To what extent do you think your publications reflected the degree of knowledge exchange within Europe and with the U.S. Did you have any experience while working in Cuba that you might compare? Do you think that you have facilitated the collaboration between your European institutions and the ones in Latin America because of your cultural background? (**iCRiE**)*

[42] Estimation from reported values of 7.1 million researchers in global science (The Royal Society, 2011) and 1,425,550 full-time researchers in United States (UNESCO, 2010) both calculated in 2007

One of the problems conducting the interviews to the **iCRiC** was that researchers referred to this subject earlier in their comments, then the interviewer in those cases omitted asking again, but by doing that more precise answers were missed. Similarly it happened when **iCRiE** was interviewed, this time by making the question longer willing to have more information, made the interviewed researcher overlook the subject of interest when answering. Nevertheless the following observations can be made integrating key information derived from the overall interviews:

Researchers focused on the excellence of the collaborators regardless of their country of origin. They aimed for the best trying to meet them initially face-to-face in international meetings, hoping to integrate them to their network of collaborators. Cultural affinities help establishing the collaboration and funding opportunities increasing the likelihood of success. Hubs of science such as top universities and scientific parks also increase the number and quality of the collaboration. CRiE felt they enjoyed more freedom of travelling and meeting their collaborators (no border restrictions, or visa delays and affordable travel mobility), and CRiC on the other hand, sensed they depend on international collaboration to boost and in some places to decisively support their research, however they experienced difficulties to travel due to the national shortage of funding limiting participation in international meetings or short visits abroad, visa delays or suspected political interference with science.

The **iCRiE** did not particularly refer to the collaboration with the U.S. as different to any other country. The **iCRiC**, probably because the question was better formulated, offered detailed stories in how the collaboration started and developed with the U.S. in spite of the hostility of the government of the U.S. towards Cuba. Interestingly face-to-face links between Cuban and American scientists have often taken place in a third country while participating in international conferences and collaboration followed. In another case the collaboration was established indirectly through a Cuban researcher working in U.S. (CRiUS) as the **iCRiC** expressed:

> *"I realised that the supervisor of this CRiUS had the experimental data that could be used in my theoretical model, then I wrote an email explaining my ideas to this researcher in U.S. and he sent his experimental data. We published together and everything was through e-mail".*

This researcher in the U.S. might or might not be American born but it was the scientific problem itself that determined the collaboration between these two researchers and this time politics did not interfere. This is a classic example of self-organized collaboration behind the increasing number of international collaborations (Wagner, 2004).

Another **iCRiC** gave more details about how Cuban researchers can visit top American institutions and use the opportunity for international collaboration:

> *"I was awarded as a visiting scholar in Harvard School of Public Health. The origin of those fellowships is the creation of the David Rockefeller Centre for Latin America[43] in 1994 allowing Cuban scientists to participate (before it was only for social scientists). However the visits were for such a short time making it impossible to generate a scientific publication, but in the next visit I took samples with me and coordinated everything in advance and I managed to produce a top scientific article in a high impact factor journal, but the ideas, the samples and essentially the whole work were originated in Cuba and the contribution from overseas was mainly equipment and the operational expertise working with such equipment".*

The CRiC have a strong sense of maximising the opportunities when going abroad, aware of using high technologies and other resources not available in Cuba, including publishing in high impact factor journals because of the involvement of the institutions and researchers of the developed world. CRiE don't take opportunities for granted and in a similar way adopt the same attitude of CRiC towards maximising chances for collaboration.

### 7.3.3 National collaboration

To explore the views of **iCRiE** and the control group **iCRiC** about national collaboration the following questions were asked:

[43] CRiE explained Cuban can participate because the visit was not covered by U.S. budget

d) How is your rating from 1 to 10 of the national collaboration in those institutions in Europe where you have been doing research? Do you have any experience that you can compare in how it was in Cuba? Can you comment on the collaboration triple helix model of Academia-Government-Industry? (**iCRiE**)

e) On scale 1 to 10 where will you place the national collaboration and its relevance to Cuban scientific development? Can you comment on the collaboration triple helix model of Academia-Government-Industry? (**iCRiC**)

Ten out of eleven interviewed **iCRiEs** had worked in Cuban research institutions or in academia mainly in their early days as researchers. Those institutions in Cuba included a variety of areas of research and organizations such as University of Havana (UH), Central University of Villa Clara (UCLV), Ministry of Public Health (MINSAP), Ministry of the Basic Industries[44] (MINBAS) and Ministry of Science, Technology and Environment (CITMA). The twelve interviewed CRiC work in UH, University of Matanzas (UMCC), Higher Institute of Science and Advanced Technology (InSTEC) and MINSAP.

Although the main questions asking the interviewee to rate the collaboration was designed to have a semi-quantitative evaluation of the topic, it was found, similarly to the previous subjects of international collaboration, that any sort of process quantifying the answers could lead to wrong conclusions. The reason is related to the heterogeneity of the sample in terms of kind of research, and more importantly the size of the sample. Sometimes the rating alone was not enough to gauge the situation while the narrative using the researchers own words offered valuable qualitative information.

Illustrating the above-mentioned point an **iCRiE** with research experience in Cuba and in Europe rated Cuban national collaboration as 6/10 while giving to Europe 10/10. The interviewee's account might otherwise suggest a different rate, but the

[44] MINBAS, Ministerio de la Industria Básica have changed in 2012 to Ministry of Energy and Mines

most important point considered by the **iCRiE** was the efficiency in the process of publishing the results:

> *"Research was orientated to improve production in the Cuban Oil industry and basic researchers (working in computer simulations) worked in co-ordination with the experimentalists, who then worked with engineers making the scale-up for the production and optimization of catalysts of natural sources (Zeolites) to improve the cracking and refinery process. The interaction of researchers continued until the end of the cycle with the marketing, in this case also including Latin America. The triple helix academia-government-industry was working in Cuba in this field"*

When referring to the national collaboration in the academic institution where the **iCRiE** now works the explanation for the difference in the ratings became clear:

> *"In Europe* (referring to places where the iCRiE has worked) *national collaboration is among researchers working in basic research only, but exchanging expertise and resources to reach a world-class publication".*

A view from another **iCRiE** in a different country of Europe reveals similar observations regarding the priority for applied science and little for basic research, when rating Cuban national collaboration 1/10:

> *"Although some institutions have developed some expertise in Bioinformatics, the approach remains in applied science, which defines different tools, methodologies and philosophy when identifying research problems. Because of the nature of the applied research is linked to drug design, institutions in Cuba with the capacity to interact, do not particularly promote external interaction due to the type of information involved [intellectual property]".*

But rating comes from the individual experiences and the field of the researchers as another **iCRiE** working in the field of public health with more years of experience in research both in Cuba and in Europe rated Cuba with 8/10 while France (5/10) and UK (5/10) received half of the rating. The **iCRiE** explained that applying the scale to

Cuba was not comparable to European institutions in terms of output; noteworthy the collaboration within Cuban scientists was stronger. When discussing the triple helix academia-government-industry structure in collaboration, the **iCRiE** explained:

> *"The research has always been either in an international agency or in the academia [European institutions] involving the study of parameters in the population [or a segment of it] in collaboration with researchers in governmental institutions, but always avoiding working with or receiving funding from the industry, which might otherwise affect the credibility of our results".*

Coming from the field of Public Health her explanation for the lack of collaboration with the industry stressed the essence of research designed to support a better understanding of the population, in this case about health in which no intellectual property is involved, and by definition the research should be considered a *public good*'. Even more interesting it also offers the explanation of the kind of collaboration of Cuban institutions described in chapter five (Palacios-Callender et al., 2016) and the discrepancy with the classification using the triple helix approach given by others (Arencibia-Jorge et al., 2015).

One **iCRiC** working in the public health sector, also explained how in addition to the national programmes of research organized from the top down, Cuban scientists themselves search for cooperation and collaboration within national institutions to strengthen the output and in this regard he, as many other **iCRiC** described the consequences of the American Embargo (called by Cubans Blockade) and the Helms-Burton and Torricelli Laws[45]. Sharing equipment and facilities to overcome the limitations imposed by the economic situation might have stimulated, at least in part, the self-organized national collaboration.

[45] **Torricelli Law**. The officially named Cuban Democracy Act was a bill presented by US Congressman Robert Torricelli and passed in 1992, which prohibited foreign-based subsidiaries of US companies from trading with Cuba, travel to Cuba by US citizens, and family remittances to Cuba. This was therefore a major piece of legislation that extended the blockade beyond US territory and meant that if subsidiaries of US companies did trade with Cuba they would be subjected to various sanctions. **Helms-Burton Act**. The officially named Cuban Liberty and Democratic Solidarity Act was passed on 12th March, 1996 and acted to strengthen and continue the blockade against Cuba and added to the already in place Torricelli Law.

Interestingly the two **iCRiCs** in which national collaboration exceeds the international one are or have been working in the public health sector.

All **iCRiC** gave a lower score to national collaboration when comparing to the international one. International collaboration beyond the recognition for advancing science is also seen as a "*breath for external resources*" in a country struggling under economic restrictions. One **iCRiC** said that:

> *"…if a PhD student working in a Cuban institution has the option to carry out her project of choosing between another Cuban institution or an international one, even with less scientific reputation, the decision will be in favour of the one abroad because that will also mean a benefit for her family"*

The extent of how the everyday life in Cuba hinders the potential in the human capital committed to the country's development during this particular period of study might not be fully studied. Interestingly the subject did not arise as a complaint but with anger as the **iCRiC** said:

> *"I could combine more efficiently my duties as a senior member of the scientific committees and as a researcher if I had better mobility between places"*

Scientific collaboration involving more than three institutions requires efficient communication including domestic transport in addition to the Internet and other mobile technologies, all affected as a consequence of the economic restrictions of the post 1990s era and the threat to the sovereignty that the Cuban socialist government perceived[46]. The mean of number of institutions per article in the publications of **iCRiE** (4.8) is twice the number of those published by **iCRiC** (2.4), but it is the involvement of two **iCRiE** participating in global projects that is the main reason for this significant difference (Table 7.5).

[46] Chronological history of the Internet in Cuba and accounts related to of U.S policies towards ICT in Cuba in: Valdes and Rivera, 1999; Moreno Ginarte, 2008; Press, 2011 and RAND reports 1992, 1994 and 1996 by Gonzalez,and Rondeldt, 1992, 1994 and 1996

The specific question about the triple helix structure academia-government-industry (A-G-I) was asked in relation to national collaboration; assuming that the model should be the backbone of the national economies ensuring that innovation played a role in economic growth. However interviewed researchers in both groups gave little or no evidence of being part of such interconnected sectors vital for the national economies and it seems they were not aware of it with the exception of one **iCRiE** working in physical chemistry in the U.K. However, there is a mode of collaboration involving more than one national institution collaborating with at least one international partner, (identified in this research as NNI), which is offering a new insight into how countries harness the advances in science for economic growth.

To illustrate this case of national-international collaboration and the triple helix A-G-I model a case of an **iCRiE** working in a global project with strong national collaboration is discussed. First the triple helix model has extraterritorial boundaries and only in one country has the whole A-G-I link emerged, which is the United States with 20 universities, 8 government or non-profit research institutions and 5 in the industry sector with a mix of small-medium enterprises. Only two European countries were included in this NNI collaboration through three universities and one non-profit institute, the other non-European partners were five universities and another government agency for health from Canada, China and Brazil.

This example brings another key issue, which is science and foreign policy, called once by Caroline Wagner (2002), the *'elusive partnership'* and will be discussed in the next chapter. As this case shows the generation of knowledge from scientists in twenty-eight academic institutions are advancing science in the global sense, but the applications for commercial use might only be translated in one country. Nevertheless, such global projects pursuing excellence in research often declare their ethical principles ensuring that the results are made available to the entire scientific community (ICGC, 2010).

7.3.4 *General and specific ethos of Cuban scientists of the revolution through scientific collaboration and cooperation*

Some aspects concerning the ethos of the Cuban scientists educated in the Cuban revolution have emerged in the accounts given by all Cuban researchers through the interviews focusing on scientific collaboration.

Chapter one (section1.3) mentioned the principles used by Robert Merton (1957) portraying the scientists in the process of generating knowledge and how the principles of communalism, universalism, disinterestedness and organized scepticism have been challenged many times. For Hagstrom (1965, as referred by Diana Crane, 1972, 7) competition is at the centre of the scientific community in a process of creating knowledge and for that reason he proposed that the nature of scientific disciplines should be also taken into account.

According to Hagstrom, competition increases in a scientific field when '*a) the agreement about the relative importance of a scientific problem increase, b) the number of specialists able to solve the problem increase, c) the degree of precision achieve in a particular research increase'.* These two visions embody opposite and almost extreme behaviour in the scientist, Merton's view portraying the researcher sharing and generating knowledge is linked to the collective trust and cooperation, while Hagstrom's view relies on the competitive environment created by the advances of science and technology, giving no need for collaboration.

Other theories trying to explain how scientific knowledge grows and accumulates were proposed in the same period such as the '*Structure of scientific revolutions'* by Thomas Kuhn (1962) arguing that growth and development of scientific knowledge evolve as a result of the development of a paradigm or model of scientific achievement *'that for a time provides model problems and solutions to a community of practitioners'.* Simultaneously another theory based on the exponential growth of scientific literature was developed by Derek de Solla Price (1961 and 1963) explaining the transition from the slow growth of scientific production of the '*Little science'* to the collaborative mode in which science was increasingly evolving and giving way to the '*Big science'*, as discussed in chapter five.

Through all these theories it can be agreed that the scientist belongs to a community of practitioners in a defined field of scientific research and relates to this community through competitiveness and cooperation that ultimately translates into scientific collaboration. The latter, understood as co-authoring a scientific paper, and it is the natural and more efficient way to generate new knowledge in contemporary science. The norms and conduct of the practitioners in science of a specific field of research do not depend on a scientist's nationality, culture or religion.

However the background of the researchers of this study, formed through their early days of formal and instructive education at home and in the socialist society might foster qualities which might give, additionally to their scientific talents, an advantage establishing collaboration by earning the trust from their collaborators because they are hard workers, collaborative, honest and fairly share duties within the team. Those are not unique characteristics of Cubans but were systematically encouraged as social values in the national education (Kapcia, 2005) and in the ethics of the Cuban scientists (Nuñez Jover and López Cerezo, 2008; Reid-Henry, 2008). Because of the struggle due to economic restrictions, the Cuban population have endured historically, and the role model figures of Jose Marti, Ernesto (Ché) Guevara and Fidel Castro, have been adopted by Cubans as part of their moral values, along with *'voluntarism'* (Kapcia, 2005) as well as the endurance, perseverance and the resilience necessary in everyday life of the scientists (Reid-Henry, 2008; 2010, 6, 74).

Some expression of this ethos in **iCRiE** are present in the two following views when they were asked the reason why they were chosen as collaborators:

> *" Because I valued collaboration and helping others in tasks I know well, might be highly appreciated by colleagues and collaborators"*

And another expressed:

> *"First for working hard, for my commitment to finish in time and to provide the quality of the work I agreed to contribute, and that has given me a*

*reputation of a collaborator who can be trusted; second, because of my productivity in science and my disposition to help others".*

Equally another **iCRiE** mentioned referring to international collaboration that probably the reason behind choosing him as a collaborator (something that happened since he was in Cuba as **iCRiC**) could be his dedication and commitment to finish the work:

*"I guess that one of the reasons why I succeed in many collaborations is because the contribution I offer ends in publications, mainly because I do most of the work and I think, similarly, this might happen to many Cubans who collaborate with international researchers/ institutions: simply they are interested in what you can offer".*

Probably this sense of working harder when competing among other possible collaborators is not unique to Cuban researchers, and it happen to many other scientists from the South working or aspiring to work in the North (Corley and Sabharwal, 2007). This could be seen in other high-skilled migrants as well.

All interviewed Cuban researchers valued highly the scientific collaboration as part of the process of advancing science and they both conferred paramount importance on international collaboration in their specific field of research.

In general CRiE are searching for excellence wherever they can afford to reach it, while CRiC are deeply involved in the social meaning of their dedication to science and the commitment to the social project of the revolution of which they feel part of (as discussed in chapter 5, section 5.3). The CRiE might feel they have inherited the scientific structure and culture, which is now limiting their individual potential. This is not a unique observation for Cuban scientists as very similar accounts are found in some countries in Latin America associated with the internationalization of the scientific careers (Gaillard et al., 2013, 164) in which both attitudes are also present: the individual search for progressing their careers and the sense of improving science for the benefit of their nations. The challenge remains in bringing back the sense of belonging to the young CRiE, creating opportunities for their interaction and ensuring efficient participation in different sectors of society in particular higher education.

## 7.4 COLLABORATION WITHIN CUBAN RESEARCHERS IN EUROPE: EVIDENCE AND VIEWS

The second part of the interviews with **iCRiE** aimed to explore if any distinctive relation within the group exists and how it might or not be helping their sense as a community of Cuban scientists.

The questions asked to **iCRiE** regarding this topic were:

1. To what extent is your collaboration/ cooperation with Cuban scientists in Europe, both established researchers and PhD students?
2. Are you aware of any academic/scientific organization of Cuban scientists
3. Do you know any other networks of scientists from other nationalities?
4. What is your opinion about the contribution or opportunities these sorts of organizations/ networks can generate for their own community and for the country of origin?
5. Will you be able to contribute or work for the creation/ support of this professional network of Cuban scientists in Europe?

Contrasting with the entire previous general questions the majority of the interviewees gave short-answers with little more to explore their views.

### *7.4.1 Co-operation/collaboration within Cuban Researchers (Answers to Q.1)*

The answers fall regarding collaboration within Cuban researchers indicate:

- Collaboration started in Cuba and continues in Europe: 2/11
- Collaboration started and continues in Europe because they work in the field, not because they are Cubans: 1/11
- Collaboration started in Europe and continues when moving as CRiUS (Cuban researchers in United States): 1/11
- Collaboration started as CRiC in her/his institution in Europe who did not return but moved to the U.S. (CRiUS): 1/11

- Very little contact/ sporadic professional exchanges but not co-authored publications (collaboration): 1/11
- Knowing other CRiE, but not working in the same field of research, therefore no chance of collaboration: 2/11
- Collaboration with CRiLA (Cuban researchers in Latin America) not with CRiE because of the field of research: 1/11
- No contact with CRiE at all: 1/11
- Collaboration with other CRiE is not the essential: 1/11

*7.4.2 Scientific Diaspora or transnational knowledge network (TKN) organization (Q.2 and Q.3)*

Ten out of eleven did not know about any organization of Cuban researchers in Europe or anywhere else. Nine out of eleven did not know about any organization of researchers of other nationalities in Europe.

One **iCRiE** explained about a Cuban association of scientists referring as well, to other transnational scientific networks:

> *"Three years ago a group of Cuban scientists have funded a small association called "Academy of Cuban Biologists" or ABC from the name in Spanish, but it also includes few Europeans who are willing to support the group. The mission is to support our scientific work carry out in our European institutions offering a bank of information to share, a collection of our publications and a platform for discussion and exchanges of ideas while the work is in progress. Members are acknowledging the work of ABC in their publications as a way of increasing the visibility of the association."*
>
> *"There are few scientific networks of other nationalities. Spanish researchers, for instance are very well organized in different countries in Europe known as "Asociaciones de Científicos Españoles (ACEs). They were created six years ago during the economic crisis suffered in the West in which Spaniards had to leave their country to continue their scientific*

*career, mainly because the Spanish government significantly reduced their budget for research and development. Besides the effort of their members, ACEs received support from their Spanish Embassies and from the Institute Cervantes, especially with the celebration of their Annual scientific meeting. I have been invited to participate in some activities and I was able to witness their success"*

Another **iCRiE** has references about how other communities of scientists are beginning to work although not necessarily through an organization:

*"I know Chilean scientists meet monthly in the premises of the Chilean Embassy to talk about their results in research"*

*7.4.3 Relevance of TKN for their own community and for the country of origin (Q.4 and Q.5)*

Two **iCRiE** expressed the lack of relevance of those organizations based on nationality rather than in the field of research, or simply not knowing what could be their role for their own communities or the country of origin. These two **iCRiE** sent their answers by email due to their limited time for the interview and therefore the interviewer did not have the opportunity of mentioning the work of many scientific diaspora operating around the world, including those of Portugal, China, Italy and Spain among others.

Another six **iCRiE** not having previous knowledge of TKNs expressed their interest in such associations with different degrees of vision of the mission or willingness to be a member of one of such association. Equally, the other two **iCRiE** had some information about TKNs before the interviews. Some of their opinions were:

*"If Cuban researchers were organized in such association they can help each other, especially when they arrive for the first time having to face by themselves enormous cultural and social barriers; it might help as well establishing collaboration with Cuban scientists and their institutions".*

*"I will be willing to be part of an organization with the ability to network with Cuban scientists. Actually I have the experience of networking in science to improve the outcome of a particular country. I work for the Nordic Chemical Biology Consortium[47] representing Finland in the network of four Nordic countries"*

*"I will be willing to cooperate if some sort of network operates efficiently".*

*"It will be a pleasure to help"*

*"In practical terms this sort of organization will only work if it is a clear definition of why and what the organization want to achieve. I will be willing to participate depending on the clarity of the purpose, scope and aims"*

*"This sort of organization could be useful if they are well managed and I will be happy to help".*

Those **iCRiE** with more information about TKN and therefore knowing the link between these associations and the country of origin expressed:

*"The impact of this sort of organization of Cuban scientists might generate opportunities for themselves as it happens with the professionals of art and culture living outside Cuba. They know each other and facilitate contacts and contracts among other communities as well. It could provide a framework through which researchers in Cuba could identify and contact researchers abroad (if the researcher in Cuba receives the information of the network)"*

*"Those organizations create opportunities for collaboration and for sharing and exchanging knowledge among the members and to follow closely the work of other colleagues operating as a feedback mechanism of learning.*

[47] Nordic Chemical Biology Consortium: regional organization integrating the Chemical Biology Societies of Sweden, Norway, Finland and Denmark helps coordinates, and makes available, a powerful academic framework of infrastructures for the discovery, development and utilization of small-molecules and molecular probes for life-science application

*These organizations are vital for the country of origin; through them collaborating projects between those working in the country of origin and those abroad can take place. They can also play a key role in society, sometimes we forget how important it is to communicate our findings to the rest of our society …they are platforms for education in science in the broader society then when there is a need for support in some field such as ecology, you will have a great support and collaboration from the population at a ground level".*

*"I think I can contribute to this type of organization and in fact, this is what I have been doing in the last three years by helping to establish the "Academia de Biólogos Cubanos", created and maintained only by our own resources. During the conformation of this association, we debated about the name, the purposes of making something more than a mere network for getting together, but a platform to exchange and create knowledge among biologists (Biochemists, microbiologists, biologist, pharmacists, biomedical and bioinformatics researchers, etc.), with a pragmatic approach in helping the process of funding application for big grants, for fellowship, etc. The name of Academia was chosen for the purpose of establishing our identity as Cuban scientists, since we were excluded from the possibility of being a member of the Cuban Academy of Science".*

Some **iCRiE** clearly manifest their willingness to do something for Cuba but they have not found how or where to start. Another two CRiE not included in this specific sample for interviews, but equally in the larger group of CRiE, are not sure if the conditions are favourable in Cuba for them to return or work for a year in Cuba as part of the options included in their contracts or fellowship in Europe.

## 7.5 COLLABORATION WITHIN THE CUBAN SCIENTFIC COMMUNITY: EVIDENCE AND VIEWS

In aggregate the group of **iCRiE** have generated 664 scientific articles in the period of study (1995-2014) of which 12% (80 papers) were published before working in European universities. International collaboration represents 60% of their scientific publications of which 10% (36 papers) are with co-authors using Cuban affiliations. The main contribution in this 10% came from one **iCRiE** who although having a research position in a European university has always published using as a second address one Cuban affiliation. Five have never published in collaboration with any Cuban institution, of which one has at least two collaborative articles in progress with CRiC and two are willing to cooperate in their field of expertise if it is of interest to the Cuban researchers; and or to cooperate in higher education if it is needed. Nine **iCRiE** would like to do more for the country they praise for the quality of education and formation they received.

The **iCRiC** similarly to **iCRiE** have produced 566 scientific articles of which 68% were with international collaboration (NI+NNI). It was not possible to fully account how many of those publications include the participation of CRiE, or any other Cuban researchers abroad, but at least eight of the **iCRiC** included in the sample for interviews have published once with Cuban researchers abroad. The **iCRiC** were not asked to name or show the origin of their collaborators, but the information in the database allowed to follow in time the affiliation of some Cuban authors working abroad within CRiC publications. Interestingly through the search, Cuban collaborators were found working in Latin America (CRiLA) and in Asia (CRiA) but probably other Cubans might be collaborating from other regions as well.

The questions being asked to Cuban researchers were in Part II and III of the questionnaires as:

Part II (Questions to **iCRiC**) Collaboration/ cooperation between Cuban researchers in Cuba and Cuban researchers abroad

1. In your field of research how much do you know about the contribution made by Cuban researchers working in Europe?
2. How do you see the future of collaboration/ networking with Cuban scientists working abroad? Open question to explore ideas, limitations, roles, etc.

Part III Scientific collaboration with Cuban scientists working in Cuba (Questionnaire to **iCRiE**)

1. How much do you know about Cuban contribution to science in your field of research?
2. Some Cuban researchers in Europe have published with collaborators in Cuba. If this is your case, Can you comment on this particular collaboration about the benefits/ interferences, etc. including the process of publication?

3. Are you in contact with other Cuban scientists who are not directly related to your research?

4. Has your institution in Europe signed any international collaboration with Cuban institutions? Have Cuban scientists visited your institution? If this is the case do you have any participation in this institutional collaboration?

5. How do you see the future of collaboration between Cubans abroad with the ones working in Cuban institutions?

6. Do you think there is a future for Cubans working in European institutions to participate more actively in Cuban science/ education/ industry?

The views of Cuban researchers come from their personal experiences reflecting diverse situations in time and locations. Sometimes the interviewees give more details and others, a short not always productive answer; nevertheless they were taken as personal accounts. Productive here means any explanation regardless its character as positive or negative experiences.

7.5.1 *How **iCRiE** see science in Cuba?*

The question was made addressing their field of research, but often **iCRiE** extended their views to science in general.

Two **iCRiE** knew little about the most recent scientific development of Cuba in their fields of research although having a general knowledge from the days they used to work in Cuba, one of them said: *"I don't know if the field has progressed while I have* *been here”* and the other said simply: *”No”* when asking her knowledge of Cuban contribution in her field of research. Another **iCRiE** simply said *“I know the contribution of Cuban scientists in my field”* with no more comments.

Being more articulate another **iCRiE** expressed:

> *“The contribution of Cuban science to Biotechnology is recognised worldwide, but perhaps less known are the contributions that Cuban scientists have done in my field of theoretical chemistry”* referring to both those working in Cuba and abroad.

In this case the **iCRiE** explained the significant contribution of another two CRiE in the field[48] who are internationally well recognised and they both earned their prestige as researchers in Europe where more possibilities are available to fully develop your career. He continued:

> *“One is Chair of the in Complexity Sciences in the department of Mathematics, University of Strathclyde, in United Kingdom and the other is one of the editors of Current Topics in Medicinal Chemistry, a leader journal in the our field.”*

Another **iCRiE** in theoretical chemistry has a different perception as his knowledge about contribution of Cuban scientists to his field is linked to the scientific collaboration between University College London and University of Havana:

> *“Some sort of communication has always been in place and visiting researchers (from Cuba) have presented their results in theoretical chemistry”*

The **iCRiE** who never worked in Cuba said:

> *“I know the Cuban contribution to science in my field of neuroscience, although I don’t follow it in detail”.*

[48] These two scientists were in the group of highly productive CRiE, one reply regretting not having the time to participate, the other did not reply to the invitation.

Following the advances of the research in Cuba (as a matter of fact any other country) from a distance is not a particular task in the daily work-related activities of a scientist unless there is a clear scientific link to the project in which the researcher is involved. Scientists are constantly seeking new knowledge through literature, seeking connection with their ideas, reviewing methodologies, following those ahead in their field and therefore the type of information they follow depends on the visibility and excellence of the publication and not the nationality involved. Showing knowledge about science in Cuba is either a consequence of the excellence achieved by Cuban researchers in a particular field or the natural attraction for following the progress of the institutions in which they received their degrees and where they started as researchers. For some **iCRiE** their knowledge from science in Cuba is in the context of interaction with previous collaborators:

> *"I know well the work of Cuba researchers in my field. I am in contact with Cuban colleagues and I even managed to invite one of them to work with me for a few months, as a result we will have at least two articles in collaboration".*

### 7.5.2 *Collaborating with the motherland: the individual and the institution*

Migrants with strong roots in their culture appreciate the opportunities offered in the destination country leading to support for their families and friends back in the country of origin (Klugman et al., 2009, 71). Scientists as a sector of the population also follow similar patterns of solidarity with the homeland. Moreover the sense of sharing to achieve a better outcome is part of scientist ethos, as one **iCRiE** working in King's College London, United Kingdom expressed:

> *"We (referring to other CRiE) make an effort to keep the collaboration with Cuban partners because we know we can help in terms of resources and we know the need in Cuba. Scientists are in general collaborative, sharing ideas and resources to take further their aims of completing the research for publication. It is not a particular feature of Cubans, but among scientists".*

Generational ties created as students at university might also play a part in explaining the collaboration with Cuban partners at home, as another **iCRiE** in Karolinska Institute, Sweden reflected on how the collaboration with a Cuba researcher started:

> *"He was a very talented classmate at University of Havana who went through so many difficulties in his life that he deserved support. We shared government residency for rural students and while I enjoyed the support of my family he only received social help from the government because his parents were dead. Family is always essential but now he is close to defend his Doctoral thesis and we have published three papers".*

In this case the **iCRiE** can help him with more publications because both work in similar field of research and have a common background, generational understanding and good communication.

For young scientists their memories of those years at university are still fresh. Almost all interviewed **iCRiE** and others in the bigger sample talk with pride about the quality of education they received and some of them are looking at how to give back something for future generations:

> *"I have always been in close contact with my professors from the School of Biochemistry in the University of Havana because of the affinity and the admiration I have for them. I am looking for possibilities of collaboration among colleagues I know through my network in Finland and researchers in the School of Biochemistry, even when it is not my field of research. On another occasion I received a Cuban PhD student to work in my team and she decided to migrate to the United States affecting the relationship with my Cuban counterpart. This is regrettable but at the same time a real situation that both parties should be prepared to face".*

The last remark brings another subject, which is probably behind the institutional inertia or reluctance to promote exchanges between CRiE and CRiC. Taking the case of two **iCRiEs** wanting to do more things for their '*Alma Mater*' showed opposite outcomes: one succeeded in her attempt giving seminars about her research and the openness encourage her to do more; the other **iCRiE**, exactly in the same School had opposite reaction:

> *" I don't think there is space for us in Cuban science. I have personally approached my ex-Faculty to offer training, classes in methodology of science, in biophysics, neurobiology, things of which I am well prepared and the reception to that was silence, which says it all. I admit not writing a proposal to the Dean of the Faculty, but the lack of reception indicated to me that there was no interest in receiving our contribution. I also know I am not the only one having this experience…if it is happening with the higher education it is impossible to imagine that any collaboration could succeed with the Cuban industry…I believe the apathy is institutional and Cuban scientists fear of not doing the "right thing".*

It was not possible to be precise about the difference in time of these two opposite situations. The welcome cooperation given to two **iCRiEs** including the participation in international meetings organized in Cuba was in 2014, while the "apathy" to an **iCRiE** willing to cooperate seems to be much earlier.

The accounts giving by the **iCRiC** were in favour of strengthening the collaboration between CRiC and CRiE and those who had collaborated with Cuban researchers abroad valued their experiences. Interestingly they seem to frame the event in the context of global changes:

Two **iCRiC** that had not collaborated yet with any Cuban researcher abroad said:

> *"In principle it makes sense to collaborate with them but it depends on their disposition and their capacity to help. Different people might have different possibilities to offer and at the end the country should benefit from that. Perhaps is something to work on in the future".*

> *" I don't know any Cuban researcher abroad working in this specific field related to tropical diseases, but scientists can contribute to science and*

*development regardless where they are… they should be members of our scientific societies in different fields of sciences".*

Examples of other views from **iCRiC** who had collaborated with Cubans abroad are:

*" In a changing world, exchanges between both groups (researchers in Cuba and abroad) are vital for the development of Cuban science, but must be in both directions and bi-equivalent".*

*"The exchanges of work and ideas between both groups should be natural and must contribute to the development of Cuban science".*

There was no explicit reference to policies promoting their views about the vital role of working together to benefit Cuban science, neither a criticism for the lack of it. In the interviews they were not asked those specific questions either, their general knowledge in science policy was not tested, neither **iCRiE** were asked about European policies to support foreign-born scientists helping science in their home country.

The historical context in which the interaction between CRiE and CRiC has had to navigate went through a turbulent climate of national and international events in the period of this study. The post -cold war era emphasised the isolation of a small country (referred to by Cubans as '*Blockaded*') under the American Embargo followed by the Common Position of the European Union. Tourism, service (medical personal working abroad) and science (biotechnology) were the pillars in the strategy of the Cuban government for survival finding new sources to boost the economy. Scientists and workers in science and technology were called to play their roles working long hours ('*consagración'*) to accelerate the scientific results for the benefit of society. The integration of key institutions (including universities) to projects of the Scientific Park of the West of Havana also facilitated the cohesion between researchers, workers and the leadership of the country during the most difficult days of the Cuban revolution. The period of working harder than ever and under extreme scarcity of everything experienced by Cuban researchers (CRiC) might underline their lack of reception to Cuban researchers abroad in those extreme points in time, who they might feel have abandoned the country when they were more needed. More about the theory of evolution of cooperation will be discussed in the next chapter.

## 7.6 LIMITATIONS

The research involved in this chapter can only be considered as exploratory identifying problems in the fieldwork design to be taken into account in further studies. The major limitations were the size of the samples and the heterogeneity of the interviewed researchers in terms of the disciplines, fields of the research (Laudel, 2003) and the institutions where they work. The latter affected more the **iCRiC** control sample, as resources in Cuba were not equally available for all institutions.

The researchers' answers during the interviews were not recorded for the purpose of building trust with Cuban researchers at home and abroad. Then, transcription into English of the notes taken by the interviewer, although approved by the interviewees, was not considered suitable for content analysis often used in qualitative research. Nevertheless the results providing transcriptions of the researchers' own views will be a valuable source creating the data required in content analysis for the case of Cuban researchers.

## 7.7 SUMMARY

The semi-structured interviews allowed for the first time a free flow of ideas of the Cuban researchers about scientific collaboration in general and within the larger community including those Cuban researchers abroad. The ideas linked to the main questions were preserved using their own words as they explained, rather than fragmenting the content for analysis.

Apparently the anecdotal account of these researchers (**iCRiE**) working away from their home country tells the complexity of the individual lives dealing with the challenge of becoming scientists and how motivation, expectation and reality are all involved in their decisions to place themselves in any particular location. Moreover the stories of the **iCRiC** reflected equally their motivation for scientific research and for collaboration, but a different attitude when facing the difficulties confronted during the long period of economic restrictions experience by Cubans. This observation was not followed as a source of derived line of enquires with additional questions since it might divert the main subject of this research.

Some **iCRiE** perceive the reticence of their Cuban counterparts for their choice of pursuing a scientific career abroad, however it is sometimes complex because they see the problem in the institution rather than in the researcher. In those cases when cooperation takes place it is based on personal affinities or long-lasting friendship without involving institutional (official) policies. Some **iCRiE** referred to the resistance in Cuba to receive any sort of support from them trying to help in education *("simply our help is not welcomed")*, especially at university where resources are scarce. This situation is translated by some as a problem in the system and not necessary in the Cuban scientists and vice versa. Those who think that some individuals might be limiting such natural exchanges, also assume that they are not scientists. There are also individual examples of good cooperation and collaboration between CRiE and CRiC in which both sides actively work on improving their actions for the benefit of the home country and their careers.

Through the research enquires it was found that there is no evidence of any Cuban scientific organization of CRiE aiming to work for the benefit of the country (called scientific diaspora or transnational knowledge networks). Some Cuban researchers are members of the organization of Cuban Residents in Europe[49], which carries out an annual conference in defence of the Cuban revolution but do not cover science. Some **iCRiE** are also members of the different Cuban societies of sciences (Cuban Society of Chemistry and Cuban Society of Pharmacology) and others are members of a recent organization of Cuban biologists[50] created to strengthen the academic performance of Cubans working mainly in Europe, however it seems that working for science in Cuba is not yet in their scope.

[49] This organization has the support of the Cuban Ministry of Foreign Affairs (MINREX) through the Cuban Consulates. Associations in each European country have their presence in the world wide web showing their purpose and activities.

[50] Académicos Biólogos Cubanos (ABC) recently created is not yet present in the world wide web showing their mission, scope and activities.

This study was about exploring the potential of the Cuban scientific community beyond frontiers, searching for new modes of collaboration to leverage science in the home country that might provide better global outcomes if properly fostered (Seguin et al, 2006; Palacios-Callender and Roberts, 2015).

Global problems threatening life on the planet are all interconnected and require the international partnership in research and development. Poverty in the South is a source of instability in the North and overproduction-overconsumption of the North is not sustainable and has not been beneficial for the South and neither for the planet. The climate change, in particular the greenhouse effect has been linked to the atmospheric increase of carbon dioxide due to excessive used of fossil oil by humans, which is consumed essentially in the North.

The international collaboration is also shaping the global scientific community, which in their capacity to work together in a common problem when aiming to find the best solution in a short period of time might provide the future mode of organization of sustainable and efficient science for the benefit of all in its capacity of public good.

# CHAPTER 8: DISCUSSION OF FINDINGS

## 8.1 INTRODUCTION

Developing countries have been in constant challenge adapting their resources to improve their capacities to compete on the world stage for the benefit of their societies. With the advent of the knowledge society, the economic growth and social welfare of a country will depend more on the degree of development of its science, technology and innovation system.

Although harnessing science and technology resources in developing countries depends on several factors, scientific collaboration, both national and international, plays a role strengthen their national scientific capacities.

## 8.2 DEVELOPING SCIENTIFIC CAPACITY THROUGH NATIONAL AND INTERNATIONAL COLLABORATION

### 8.2.1 *Evolution under pressure: optimizing collaboration*

Through the analysis of the national and international collaboration of Cuban institutions the results in chapter five show two characteristics of Cuban science: first, conducting their research through cooperation among institutions with different resources and expertise and second, concentrating their effort on those topics affecting the Cuban population helping not only to strengthen the collaboration among top Cuban institutions, but to take science to a broader set of institutions not necessarily involved in S&T.

Jorge Núñez-Jover and López-Cerezo (2008) explained the Code on Professional Ethics of Cuban Scientists adopted by Cuban scientists, who were educated in the socialist system,

> *'While scientists are required to seek the truth and carry out honest and disinterested work to contribute to the advance of science, the main*

*contribution expected from this work is social welfare, to which individual and corporate interests must be subordinated'*

The statement in the code of professional ethics of Cuban scientists is more than a combination of ethics and political will with ideological essence, but practically the only way to survive isolation under economic, financial and commercial siege.

Under those adverse circumstances the nation and particularly its scientists standing by the will of defending the socialist system appeared to have turned the inefficiency of earlier years in which scientific results did not necessarily translate to innovation, into a *network of institutions*, strategies and policy aiming to maintain the health of the population and the creation of new sources of export, based on knowledge and innovation. Evidence of the outstanding transformation in response to health problems in the population was the effort and resources dedicated to fight the epidemic of dengue with the creation of the *Biological Front* in 1981, the embryo of what is now the biotechnology industry in Cuba.

The network of institutions operated through the Scientific Park of the East of Havana in which top research groups of the higher education, academy of science, pharmaceutical industry and other organizations were optimizing their capacities by coordination, cooperation and collaboration. The core institutions were also working fourteen hours a day, six days of the week in what was called *consagración*.

8.2.2 *Strategies overcoming economic restrictions: lessons to be learned*

Choosing *PubMed* as a source database allowed the evaluation of those publications related to biomedical and life sciences reflecting the best Cuban scientific publications. Cuban institutions might selectively publish in international journals those articles strengthened by collaboration, both national and international. Although the evidence from previous years (1989 to 1994) indicated that Cuban scientists increased their publications in international journals by 211% due to the lack of resources in the Cuban publishing sector (Araujo Ruiz et al., 2005), this decreased by 60% the amount of publications in Cuban journals in that period.

Results showed that 30% of net publications involved more than one Cuban institution, which is similar to that found for the multi-university collaboration among U.S. schools in Science and Engineering (Jones et al., 2008) with 32.8% in 2005. The similarity in terms of percentage might indicate that Cuban institutions follow the international trend rather than a particular pattern to overcome the economic restrictions after 1990. In another study using co-authorship bibliometric analysis to evaluate collaboration in countries of Latin American and the Caribbean (period 1995-2002), the authors found that the overall collaborative publications represented 65% of the total (Sancho et al., 2006). Moreover, the authors found that national and international collaboration in the region represented 26.4% and 35.5% respectively, with a very limited regional collaboration (2.7%) with the exception of Cuba with 26%. In this study the authors used the *Science Citation Index* database and recognized that the representation of Latin American journals was very low with only 0.6% of the total.

The results in chapter five also showed that 40% of net publications of Cuban institutions were with international partners equally following the global trend (The Royal Society, 2011, p 4), as it was pointed out in this report*, 'scientists seek for excellence in their work by sharing tasks, costs and experience',* and in the case of Cuba, under the circumstances of this period, it might also have a component of outsourcing to ensure access to otherwise limited materials, modern equipment and better infrastructures. This also suggests that in addition to the government support for areas of applied research related to population needs, the Cuban researchers actively seek collaboration to advance science in subjects of local interest.

Gálvez and collaborators (2000) found that paradoxically developed nations, which accrued more than 85% of world publications, are less inclined to collaborate internationally and at the same time had more transnational publications. International collaboration was 20%, 24%, and 39% for North America, Asia and Western Europe respectively, while for Latin America and the Caribbean, Southern Africa, Northern Africa and Eastern Europe was 62%, 59%, 58% and 52% respectively. The reason, they argue, seems to be that developing nations were becoming more dependent on developed nations, not only economically, but also scientifically. At the same time nations with strong economies naturally tend to develop strong scientific communities (Gálvez et al., 2000) among themselves. Although their results seems to support their views, this conclusion came from analysing a relatively short period between 1991 -1998, and using *Science Citation Index*, which did not evenly cover all regions. While the current study was carried out Zacca González and colleagues (2014) showed that collaboration was a key factor behind the development of scientific activities in Latin America in this century. The areas covered in this article were public health and environmental and occupational health and the database used was *SCImago Journal and Country Rank*. Interestingly they found that Cuba, Colombia and Brazil had the greatest strengths measured by thematic specialization among the countries with most scientific output (Brazil, Mexico, Cuba, Colombia and Argentina).

The pattern of Cuban collaboration was represented through the institutional publications and not through the net publications to give equal representation to all participating national institutions co-authoring the articles. This approach revealed that the Central group is leading the cooperation with almost equal proportion of participation among the three groups. Seventy per cent of Central institutions have articles with institutions in the Distal group. The Institute of Tropical Medicine Pedro Kourí (IPK) showed the highest cooperation with the Distal group with a wider number of institutions often in the same article. Two other institutions by virtue of their policies showed strong collaboration within the Central group and the Distal group: these are University of Havana (UH) (Pérez Ones and Nuñez Jover, 2009) and Centre of Genetic Engineering and Biotechnology (CIGB) (López Mola et al., 2006).

This interaction between the Central group and the rest of the institutions seemed to be different to the study of Jones and collaborators, in which they found that the multi-university collaboration is more stratified by in-group university ranking. However it should be pointed out again the small size of the sample of study, in contrast to 4.2 million articles analysed for a period of three decades (Jones et al., 2008). The approach of the current research focused on the relationship between the most scientifically productive institutions with a wide range of institutions distributed along the country. By taking this approach the attention was centred in the role of leading scientific institutions sharing their resources and experience with less scientifically productive institutions but directly connected either to services or production.

Another approach was used describing the production of knowledge and the role of collaboration between different sectors in Cuba by assessing the model of Triple Helix (Arencibia Jorge et al., 2013), which might fit better for more developed nations or to bigger samples. Similarly, when combining bibliometric, socio-economic and health indicators in the analysis of Latin American output in public health (Chinchilla Rodríguez et al., 2015a), the authors could not find that the tangible achievement in health attained by Chile and Cuba were the result of their publishing pattern in the area of public health.

More research should be carried out characterising the Cuban scientific performance and its social implications in the science, technology and innovation system of the country and more importantly that quantitative methodologies should have also the support of qualitative approaches, as one the pioneers in bibliometric research pointed out: '*Quantity is only one of the qualities'* (Beaver, 2012). It might be plausible in the future to focus on the rise and evolution of scientific parks and in the role-played by older universities fostering scientific research in newly created universities and campuses. Scientific parks embody the essence of the Mode 2 of production of knowledge, described as socially distributed, application orientated, trans-disciplinary and subjected to multiple accountability (Gibbons, 1999; Nowotny et al., 2003).

In the case of Cuba there are other stakeholders within the public sector supporting the process of knowledge production and innovation, such as Youth Technology Brigade (BTJ), with more than 200,000 members and the National Association of Innovators (ANIR) with 100,000 members (Nuñez Jover and López Cerezo, 2008). This expression of mass participation in the process of knowledge creation can also be explained as a result of the struggle and effort to overcome economic restrictions through participation in innovation at every level.

Probably extending the search to other fields such as social sciences will allow the study of more features of Cuban collaboration as it could be foreseen from the model of Yaguajay (Lage Dávila, 2004). However, as it is shown later, collaboration might reach new partners.

8.2.3 *Facing problems of communication in Cuban science*

An unexpected result was the lack of international collaborative articles with Africa as a region, especially with the long lasting policy of international cooperation between Cuba and more than 38 countries of the region (Marimón Torres and Martínez Cruz, 2010) in the area of public health. This finding might reflect the difficulties that still prevail in publishing scientific results in some areas of the health sector in which medical doctors might concentrate more in delivering and reporting the services rather than publishing in scientific journals. The lack of the systematic habit of publishing is also affecting the international visibility of Cuban science (Arencibia Jorge and Moya Anegón, 2010).

It would be interesting to explore why this long-term cooperation with countries in Africa does not correspond to more international scientific publications. In general there is poor tradition in writing in English, which is the main language in scientific communication and maybe priority is given to treat patients rather than publishing the outcome. This explanation was tested by choosing the outbreak of Ebola in Africa in 2014 knowing that the Cuban doctors were among the first medical teams on the ground. A search in *Scopus* using in the field *"title"* the word *<Ebola>* retrieved 2,607 articles, of which 15 had Cuba in any part of the documents and only 4 documents when using <Cuba> in country affiliation, of which only two were by Cuban doctors publishing in national journals, in Spanish. Among those article published in high impact factor journals the non-Cuban authors appraised the Cuban efficiency (Gulland, 2014) and the transferability of the Cuban model of training in Africa (Ebrahim et al., 2011). In the latter, one of the authors was the representative of the Pan American Health Organization in Cuba who in an interview by the medical journal *MEDICC*, pointed out that one of the main problems in the country is that Cubans do not publish enough (Reed, 2012).

The exercise discussed above illustrates that publishing receives less attention than improving public health in Africa and probably the same applies to the research carried out in Cuba. High quality publishing, especially in English language is an area deserving more attention.

Publishing should be promoted and compelled as the duty of the researchers to complete the process of creating knowledge by submitting the finding to peer-reviewers ensuring the quality and the dissemination of science to wider audiences. One can speculate that Cuban researchers have less pressure to publish in international journals in order to progress in their careers, or to compete for job positions, as it is in the case of researchers in developed parts of the globalized world. The reality might need a deeper look, as equally it could be speculated that not all the research effort ended in enough quality for publication. It seems that the pressure of '*publish or perish*' is less evident in the Cuban praxis, although this trend is exposing detrimental effects and it has been recently criticised because it is affecting the accountability and the quality of science (Roland, 2007; Horton, 2015). Then Cuban researchers need to publish more in order to strengthen Cuban science, but quantity should not jeopardise the quality.

The citation analysis of Cuban scientific publications was not part of the scope included in the current research although the raw data for further studies is included in the databases created for the present study. The analysis of citations is mainly used measuring visibility of the scientific production and its value is included in another two important descriptors evaluating quality of scientific production: the excellence and leadership of research groups and institutions.

In a study evaluating Cuban scientific output the authors found that Cuba is among the top seven most productive countries in Latin America, but the worst of the sixteen most productive in the region when evaluating the number of citations by articles an indication of the low international visibility of Cuban science (Arencibia Jorge and Moya Anegón, 2010).

Probably one of the most comprehensive studies and reviews of the situation of Cuban scientific communication and patterns of collaboration in the last decade is the work of Zaida Chinchilla Rodríguez and collaborators (2015b). This article published in *Scientometrics* in March 2015 coincidentally has the same classification of Cuban documents by the type of collaboration as N, NN, NI and NNI, facilitating the comparison of finding with the study presented in this thesis, chapter five. The authors pointed out serious problems in Cuban patterns of communication affecting the visibility of the Cuban scientific contribution. They processed all documents by

Cuban authors between the years 2003 and 2011 accounting for 15,053 documents of which 56% were published in English and 43.4% in Spanish, suggesting that the large number of publications in Spanish might be reducing the reading audience and therefore researchers citing the papers less, due to the large community of English speaking scientists in the world. More importantly, Chinchilla and collaborators argued that it is low international collaboration that is limiting the visibility of Cuban science. Their conclusion arose from the fact that the groups of articles with international collaboration, NI and NNI had citations above the world mean by 10-20%, while those with national collaboration were up to 60% below the world mean citation per document. The most striking finding was that a big volume of Cuban research, almost 50% by 2011 is published without collaboration with the lowest citation up to 80% below the world citation mean. Nevertheless, they also identified a favourable fact that more Cuban journals are indexed in *Scopus*, one of the larger bibliographic databases, from 8 journals in 2003 to 22 in 2011 something that might improve the visibility of Cuban science. Those Cuban journals represent 2.7% of the total source journals used by Cuban researchers, accruing up to 40% of Cuban publications in 2011.

The contribution of Chinchilla Rodríguez and collaborators might seem a discrepancy with the results discussed in chapter five, however their finding helps to understand better the situation in Cuba in terms of the evolution of her scientific capacity.

#### 8.2.4 *Areas for improvements in Cuban scientific capacity: challenges ahead*

The results in chapter five came from a subset of documents published in *PubMed* chosen specifically to study the pattern of scientific collaboration in biomedical research in an area in which scientific capacity was expected to be in progress. This database only includes one Cuban peer-reviewed journal in the field of tropical diseases, an area of research in which Cuba is among the leading countries in the world. The field of author affiliation in *PubMed* was limited to the institution signing the article at the time of the data collection. Therefore the data analysed in chapter five corresponded to a subset of probably the best Cuban contributions to science in the field of biomedical research. Although the study did not include citation analysis because *PubMed* does not provide that information, and therefore visibility was not assessed, it pointed out strength in scientific collaboration led by the most advanced institutions in the country as a key factor in building Cuban scientific capacity.

However the investigation by Chinchilla Rodríguez and collaborators revealed that the above conclusion is probably only true for the case of biotechnology, a field of biomedical sciences over represented in the sample using *PubMed*.

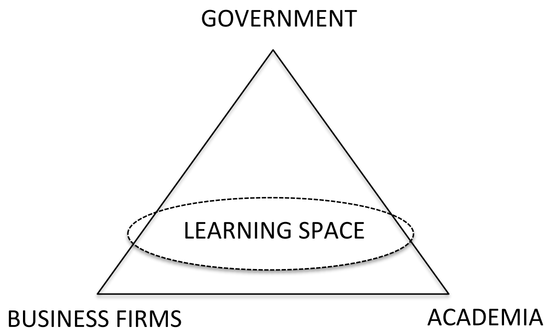
The success of Cuban biotechnology encompasses the new contract of science with society (Gibbons, 1999; Nuñez Jover and López Cerezo, 2008), which takes the form of the Mode-2 previously discussed. Strong interlinks among practitioners of *'biotechnological projects'* progress ensuring the reliability and robustness of the knowledge/innovation created under the "learning space", rather than the old linear model of science-technology-development-production. The success of the model as described earlier in chapter two, sections 2.5.6 and 2.5.7, rested on the premises of developing an innovation system for the social needs called Pharma.3.

Those practitioners are members of diverse institutions from academia, government and industry and the output of the network behind those interlinks working in a learning space do not generate only scientific publications. Andres Cárdenas O'Farrill (2014) showed the interlinks of the network operating in the Cuban biopharmaceutical enterprise including research (academia and industry), technology (academia and industry), quality control (academia, government and industry), regulation and legislation (government and industry), production (academia and industry). Those network connections give strength and cohesion to the innovation system in this particular example. This environment of "learning space" provided by such interlinks creates a culture of '*solving problems'* along different stages of the innovation process which is at the centre of the success.

There is no evidence of any other successful example of innovative industry in Cuba and the case of biotechnology rests on the government as a source of investment and in the human capital accrued in sectors that also had years of well-established tradition: the higher education and the public health system. The latter also includes the Cuban pharmaceutical industry, IMEFA with more than 30 years supplying the national demand of generics.

This brings into account the point made by Rodrigo Arocena and Judith Sultz (2006) in relation to the problems of the developing countries of the South, still stagnating in the pervasive lineal model of innovation rather than as an interconnected system and how those weak structures might promote migration of scientists. They referred to the

Figure 8.1. Sábato triangle (taken from Arocena and Sutz, 2006)




Sábato triangle (Figure 8.1) proposed by the Argentinian Jorge Sábato in 1968 explaining that for development to progress, the edges of the triangle need to be stronger than the vertexes, but on the other hand, if the links between nodes were weak, the strong vertexes will tend to establish links with external partners and the triangle then will get weaker by further brain drain.

The risk of brain drain in the case of Cuba, for other areas of sciences that might not directly tribute to biotechnology is the contradiction of having a large well-educated population (technicians, scientists and engineers) and a relatively low GDP. In an analysis of the Cuban emigration after 1990, Edel Fresneda (2014) validates the Cuban economic migration as a consequence of the structural distortions present in the socialist productive heterogeneity of the country, in which there are limitations of consumption in a relative welfare society (good education and health) and how unequal exchanges affect the process. On the other hands Consuleo Martín Fernández and collaborators (2007) identified that the universal characteristics among professionals of establishing strong links with colleagues in other countries might subjectively induce a sort of de-territorialization in the professional. The authors also pointed to those borderless professional and social networks as factors increasing expectative for a life project abroad.

Other events were also happening simultaneously and Cuba was not exempt from being affected: on the contrary, the intensified migration to the North of young future professionals is happening. In 1990 the U.S. passed the Immigration Act followed by other legislation facilitating the college-educated individuals to move to the United States by creating temporary visa programmes for highly skills workers and attracting international students of science and technology to higher education institutions. Between 1990 and 2000 the college-educated population increased by 89% with 2.8 million new college-educated arriving to the U.S and another 4.6 million between 2000 and 2014 (Zong and Batalova, 2016). Between 1990 and 2000 the number of tertiary educated immigrants in the OECD contries grew from 12.5 million to 20.4 million, representing an increase of 64%, but the proportion representing Latin Amerian and Caribbean region increased by 97% (Docquier et al, 2007).

8.2.5 *Losing human capital or collaborating with Cuban researchers working abroad?*

Thus migration of educated and highly skilled citizens from developing countries towards the developed world was intensified during the last decades (Docquier and Rapoport, 2012), however for the first time developing countries started adopting new strategies looking for policies to harness the potential lost through the brain drain (Le Bail and Shen, 2008). Mobility of scientists also was showing evidence of increasing scientific collaboration between destination and origin countries (Franzoni et al., 2012). Moreover, contributions from the outcome of transnational knowledge flows through diaspora networks have been documented (Mahroum et al., 2006).

Human capital is the vital asset of Cuban science: highly skilled and trained to perform not always under optimal conditions, they embodied creativity, resilience and perseverance, all essential in a scientist (Stone, 2015a and 2015b). But at the same time the human capital is mobile and can often divert their resourcefulness elsewhere in any moment if not bound by ties or contracts. By the same token a risk of migration might be a threat to the effort of building scientific capacity.

Although the exact number of Cubans graduated from science and engineering who went abroad in the last economic migration is not known precisely, the majority of Cuban emigrants do not break away from friends and family ties, indicating a high probability of future either return or contributing to the country development. The decree law 302 in 2012 mentioned earlier might facilitate this process.

The creativity in overcoming difficult times seems to be part of the idiosyncrasy of Cuban socialism and there are many instances in which cooperation works as leverage to create knowledge and innovation (Núñez Jover, 2010, 135; Lage Dávila, 2013, 145 ). However appropriate policies of engagement with the Cubans improving their skills and careers abroad might need a closer look in order to harness the potential further developed in their careers.

## 8.3 CUBAN SCIENTISTS IN EUROPE:

### 8.3.1 *Increasing social capital by training students abroad in centres of knowledge: the old, the revolutionary and the challenges ahead*

The movement of students from the periphery to centres of knowledge in Europe had been taking place since the IXX century when wealthy families could afford to send their teenagers to study in European Universities. In the case of Cuba two well-known academics Paul Lafargue (1842-1911) and Fernando Tarrida del Mármol (1865-1915) both from Santiago de Cuba studied medicine and engineering in Paris and Barcelona but none of the two returned back to Cuba. However the best known in Cuba is Dr Carlos J. Finlay (1833-1915) from Camagüey, who was sent to France and England and studied medicine in the Jefferson Medical College, Philadelphia in the United States returning to Cuba where he devoted his life to the diseases affecting the tropical country. Carlos J. Finlay was a physician and a researcher who found that the mosquito was the agent of the transmission of the yellow fever from an infected to a healthy human (López Sánchez, 1987,165).

The trend of sending young Cubans abroad for completing their higher education continued in the XX century but then the youngsters of wealthy families were going to the United States of America. Some of them became the torchbearers of Cuban revolution as was the case of Vilma Lucila Espin Guillois (1930-2007) graduated in chemical engineering at Massachusetts Institute of Technology, although in this case for Cubans, she was the symbol of a leader working for the women rights for education and equal participation in all areas of society.

From the pattern of a few wealthy students going abroad to complete their higher education, the Cuban revolutionary government sent thousands of students to socialist countries to complete their higher education during the 1960s up to the early 1980s with almost hundred per cent returning home, even when the capacity of completing their higher education in the country did already exist.

The formation of those students abroad contributed to further professional exchanges, scientific collaboration and even building cultural ties with the country where they studied. Interestingly in the study of Lancaster and collaborators (1986) of the link through citations between international collaboration with Eastern Europe and USSR was not discussed as a consequence of previous exchanges through mobility of researchers in those countries, neither the co-authorship with the socialist bloc. The evidence analysing retrospectively indicates that Cubans were building their "invisible college" through the scientific environment they were in contact with.

There are graduates from universities of the socialist bloc in almost all research and academic institutions in Cuba and mobility for training professionals abroad including Western countries has been systematically operating and not only for research institutions, but for areas of production and service.

The way the Cuban socialist system operated in terms of preserving the constant investment in the formation of the human capital was through the government control of the mobility of professionals along the administrative structures. The process of professional training abroad not only was coordinated, but also authorized and controlled by the administrations and political bodies of the institutions sending their professionals[51]. Training abroad was part of the educational program supporting priority areas for developing the scientific and technological capacity of the country in all sectors: education, health and industry.

[51] In every working unit the "Consejo de Dirección (C.D.)" have monthly meetings for following and planning the main activities (research, production, or service). Active members of the C.D. are the administration, the communist party, the youth communist union and the working union.

Then the mobility of professionals proved to be working for accelerating and improving the human capacity of the country by ensuring the coordination with national programmes of development and mechanisms for implementing the transfer of knowledge in their working places once returning home from the training abroad. Those who received the training knew they were needed and highly appreciated back home.

Towards the end of the XX century three fundamental facts were unfolding: the end of the Cold War, the rise of the European Union and the awareness of the emergence of the knowledge society linking the economic growth with knowledge creation. For Cuba, as Jorge Domínguez, professor of International Affairs at Harvard University, remarked, the US-Cuban relationship turned into the *'Colder War'* (1997).

With the rise of the European Union and the implementation of the Bologna Process towards the integration of higher education, the movement of international students within the region was also significantly increased. Further actions also extended the benefit of being educated outside the country of origin by implementing the Lisbon Recognition Convention in 1997 emphasizing the student's right to receive fair recognition of his or her educational qualification within the European region (Altbach et.al., 2009). All of these new features in the global market of professionals facilitate researcher mobility including the Cubans receiving their post-graduate education in Europe.

Institutions of higher education are increasingly viewed as the major engine of economic development in those countries with strong knowledge-based economies. Universities are adopting new features with more interactions between industry and government in what has been called the triple helix. It would be expected that students from the developing world furthering their education in top universities in the North could be trained in those environments of knowledge creation to contribute later to their countries of origin. However opportunities of acquiring additional organizational skills in the creation of knowledge and innovation and establishing networks for further opportunities in their home country comes with the risk of losing them as key members of the society of developing economies.

There is therefore a big adverse effect coming from the massive movement of international students particularly through the South-North flows. From what would be a universal way of acquiring knowledge and culture away from home has turned into a migration of talents affecting the country of origin as it was discussed by Philip Altbach and collaborators in the report for the World Conference of Higher Education in 2009 (Altbach et al, 2009, 94):

> *'These diaspora can play a significant role by keeping in contact with the academic communities in their home countries and sharing research and experience. The fact remains that the global flow of academic talent works to the disadvantage of the developing world'.*

The two main factors involved in this failure have been pointed out: the high demand for highly skilled workers in which the economic growth depended on creating knowledge and innovation and second the lack of opportunities in the country of origin (pull and push theory) and lower wages. The whole process of globalization has created the *new divide* with pockets of wealth demanding more highly skill workers *versus* extended areas struggling to cope with the economic growth which depend more and more on the advances in science and technology and the scientific capacity of the country. The differential in this divide is promoting the one-way movement of international students (Arocena and Sutz, 2006).

The international mobility of students has grown in the last decade from an estimate of 1.8 million internationally mobile students in 2000 to 2.7 million in 2007. The presence of students from developing countries in academic institutions in Europe and North America is also a consequence of the global growth (26% in 2007) of the gross-enrolment ratio in tertiary education in which developing countries have had a dramatic growth (Altbach et al., 2009, 98). By 2013 the number of Latin American international students was 166,352 of which 79% were studying in North America and Europe and the rest in other countries of the region. Interestingly Cuba was the main destination country with 17,000 Latin American students (Lemarchand, 2015).

Increasing numbers of graduate students in higher education might create an overflow of qualified workers in areas where the full capacity to allocate them is not yet ready or the options might not correspond with the expectations for those educated abroad.

According to the data available from the Cuban Office of Statistics (ONE, 2015a), the number of higher education graduates increased from 44,755 to 89,558 (100.3%) and in branches of sciences and engineering increased by 68.7% between 2007 and 2012. However in the same period, the number of university graduates working in institutions of Science and Technology only increased by 51% with a reduction in number of researchers by 11% (ONE, 2015b). Regardless of other areas of employment in which graduates in science and engineering can also work, the general economic situation of the country might prompt them for considering a work project abroad.

Cuban sociologists have offered some views about migration in general that might also be applied to those graduates searching to further their education abroad having in mind the uncertain future the country might offer them. Edel Fresneda (2013) argues that the contradiction between the heterogeneity of the socialist production (sub-developed) in Cuba, affected by unequal global exchanges and the high human social development (health and education) is at the root of the last two decades of Cuban economic migration. Angela Casaña (2007) on the other hand addressed the migration of highly-skilled Cuban migrants analysing the general characteristics of the professional work force, identifying two main factors: the attraction to poles of high development and the individual need for advancing their careers. Moreover, she explained, the internationalization of the scientific world and the high exchanges facilitated by ICT has also created in young Cuban professionals an expectation of future outcomes in the developed world, where they can improve their careers and unleash their potential while enjoying salaries up to 30 times higher.

But additional considerations are important as well in the case of those with the intention of continuing or following a career in science. Scientists are driven by a passion for puzzle solving and the joy of discovering and communicating the findings to colleagues and are less interested in the monetary remuneration of their work

(Stephan, 2012,16) but they also have a need for social recognition (Casaña, 2007). Recognition and reputation in science is built by being the first to communicate a finding, as Merton described as a race for priority (Merton, 1969), but also with the professionalization of science prestige and reputation are indispensable to guarantee the funding as Paula Stephan (2012, 19) describes in her book "How economics shapes science":

> *'Recognition is key in science, not only as an end in itself but also as a means for acquiring the resources to continue to engage in puzzle-solving activities'.*

Then, the process of puzzle solving and ensuring the priority of discoveries obviously linked the places where science takes place with the funding to compete worldwide.

The first generation Cuban scientists of the early days of the revolution were additionally committed to develop science in Cuba (Baracca et al., 2006). The puzzle solving had then an additional meaning and challenges to overcome difficulties from the restrictions imposed by the northern neighbour of the Unites States. The new revolutionary government and in particular the leader Fidel Castro gave the maximum support and recognition to the effort of this generation of scientists. As Angelo Baracca accounted in his book *The history of physics in Cuba*: *'The whole country was swept by the wind of change and enthusiasm'* (2014, 34) and Richard Stone from *Science* magazine reported '*Cuba is a place of outsized ambitions'* when describing recently what Cuban scientists have achieved under extremely economic restrictions imposed by the U. S. for more than 60 years (Stone, 2015). That generation stood against the odds because the protagonist role they were called to play: they were part of the whole process of building scientific capacity in the country, understanding every single personal sacrifice with a sense of collective purpose and convictions.

Sixty years later a new generation, who was born after the revolution might approach the new reality differently, perhaps they were passive players or not players at all in the worst economic period of the revolution after the collapse of the socialism in Europe. During the 1990s emigration of young professionals towards advanced countries increased worldwide and in Cuba the steady mobility of professionals in the earlier years started weakening. The economic crisis of the country showed the *abandonment of the mission* and *decision to stay abroad* (Martín Fernández et al., 2007) most likely in the younger professionals. The latter implied migration because there was by law a restriction to return to the country if the professional decided to extend unauthorized the time of staying abroad for more than 12 months. This situation changed in 2012 by the new Decree Law 302 in 2012 eliminating the restrictions of citizens to travel and return to the country.

Although Angela Casaña (2007) argued that Cuban professionals are not an essential part of the Cuban emigration, representing only between 10 to 13% of total migration, the data from the OECD showed that tertiary-educated Cuban migrants represented 17% in 1990 and 32% in 2000 (Docquier et al., 2009). The discrepancy might be due to the definition of the type of migrant: Casaña identifies professionals as graduates of higher education, while for OECD classification as tertiary educated migrant included graduates of colleges and technological institutes. On the other hand, it might also indicate the contradiction of inclusion/exclusion migration policies of the developed world, accepting migrants with high qualification while excluding those without tertiary education (Castles, 1998) and therefore foreign-born professionals in OECD are over represented compared to their distribution in the rest of the world.

This study has been about identifying the Cuban scientists and engineers working in European institutions of science and technology aiming to explore the human capital further developed abroad and the possibilities it might represent to Cuba if new policies were in place to help turning the loss in some gain for the country within the adversity of the current brain drain.

There is no available information of the number of Cuban scientists and engineers who have migrated to Europe or North America after 1990. Even the data of the National Science Foundation (Kannankutty and Burrelli, 2007) referring to 64,000 Cuban professionals of science and engineering in the U.S., did not exclude the Cuban Americans who received their higher education in the U.S. The work of Menja Holtz (2014) about Cuban academic migration in East Germany is limited to Cuban academics in social sciences, and furthermore the investigation of the transnational knowledge of those involved was subjected to the political changes after 1989 at home and abroad.

This study is a first attempt to identify and characterise a successful group of young Cuban scientists (and in less extent engineers) working in European institutions of science and technology, representing a new source of human capital with the potential to be transnational agents of knowledge for the future of the Cuban science, technology and education systems.

With the migration reform in 2013 Cuba has taken steps with the potential of reverting the brain drain by allowing citizens to spend two years overseas without losing residency rights at home. The global work market for scientific research depends on short-term contracts or temporary positions associated with grant applications; long-term positions are not often available and are extremely competitive. What might be attractive for a while at the beginning of the scientific career could turn into too demanding in the later life and the project of coming back home after earning enough prestige and international contacts might be a desirable decision. This scenario was explained by one of the interviewees in section 7.3.2.1, a Spanish post-doc at University of Pennsylvania returning home after successful years in her scientific career, she changed her priority to become a mother, explaining that in Spain the academic work will not affect her family and vice versa.

Globalization and the advances in Information and Communication Technology have made the world more interconnected both for people and sectors of the economy and society beyond geographic borders. Changes in one section of the interrelated system might have a big or small impact depending on local factors and the capacity to compensate for the external forces. The new approach of developing countries finding their own ways of harnessing their human capital further developed abroad might need a closer analysis by Cuban policymakers. The dynamic conflict of interests between North and South in the twenty-first century requires constant monitoring and evaluation to identify risks, challenge and opportunities and place policies accordingly (Khadria, 2009).

8.3.2 *Cuban researchers in Europe (CRiE) are part of the international web of scientific collaboration.*

*Data source used for processing scientific publications and mobility of CRiE*

Previous analysis showed that *Scopus* is the most suitable bibliographic database for the study of Cuban scientists in Europe considering that the cohort group of Cuban scientists in Cuba is also included in this study (chapters four and five).

Assessing the scientific potential of Cuban researchers in Europe faced some challenges essentially as a consequence of the small sample. The methodological references discussed in chapter three of A. Plume (2012a and 2012b) and M. Moed and collaborators (2013) evaluating seniority, productivity, mobility and migration of scientists using *Scopus* was the suitable database for their studies because their samples were more than two orders of magnitude bigger than in this study. They used the researcher unique identification number (UIN) of *Scopus* a technical feature of this bibliographic database to follow the researchers along their scientific careers, allowing a neglected source of error for the given size of their sample. In the starting sample of 135 Cuban researchers there were 31 cases of splitting names with more than one UIN representing an error of 23% and one case of ambiguity that was excluded.

Addresses in the author affiliation field were in different languages, interfering with the automatic identification of the places through a computer program, besides the presence of word symbols. Errors in the country affiliation were also found but to a lesser extent, i.e. three out of 1,727 entries of affiliations representing 0.02% (Neuromuscular Diseases Unit, Kantonspital St Gallen, St Gallen, <u>Swaziland</u> instead of Switzerland; Department of Neurology, University Hospital Basel, Basel, <u>Swaziland</u>, instead of Switzerland and Institut fur Chemie, Universiteit Rostock, Rostock, <u>Netherlands,</u> instead of Germany).

Therefore the data collection and processing in this study was time consuming, as it required an extensive handling to minimize those error-prone spellings.

*Prospects of CRiEs in research: joining the global knowledge nomads while networking with researchers at home*

In addition to the bibliometric source, the information about age, gender and the academic institution awarding their degrees was completed by searching public information in professional networks and curriculum vitae published by their institutions in Europe.

The results indicate that 77% of CRiE were younger than 40 years old and predominantly males (66%). The main destination country is Spain (34%) at least for entry to Europe and the mobility of this group seems to follow the Spanish scientific diaspora working later in United Kingdom and other destinations in Europe. The economic crisis of 2008 prompted the brain drain in Spain as the austerity measures limited substantially new positions at universities (Buck, 2014), besides the reduction in GERD and a shrink in the headcount of researchers of more than 8% each (UNESCO, 2015, 769; Pujol Gebelli, 2015). It is estimated that more than 12,000 Spanish researchers are currently working abroad and by 2011 the Spanish scientific diaspora around the world were emerging as organized networks supporting their researchers abroad, helping new arrivals to settle in the destination countries, promoting science in both sending and destination societies and building bridges of international scientific collaboration (Melchor, 2014; Oliver, 2016).

The economic crisis post-2008 experienced by Spanish researchers also affected Cuban researchers, who were at the time furthering their careers in sciences and those who arrived later. However Cuban researchers did not return home: instead they move to other countries in Europe or North America as the knowledge nomads keep circulating wherever they find the right environment for research (Day and Stilgoe, 2009). Regardless the differences between the Cuban and the Spanish economic crisis there are common points deserving discussion.

Cuba concentrated resources in developing the biotechnology industry and managed to succeed in a high-tech sector contributing to the economy of the country through the strength of its applied research in the field of medical sciences. Cuba increased by 25.5% the number of patents, trademarks and industrial designs (aggregate values) between 2006 and 2014 (WIPO, 2015) in which pharmaceuticals and biotechnology share 43.6% and 27.8% respectively of the total contribution to intellectual property. Regardless of the scientific collaboration supporting this effort previously discussed, science in other sectors demanded more resources. Between 2000 and 2008 Cuba increased the GERD by 35% from 0.45 to 0.6% of the GDP (UNESCO, 2010), however in the period between 2009 and 2013 the GERD decreased by 32% from 0.6 to 0.41% of the GDP and the number of researcher headcounts was reduced by 8.1% (UNESCO, 2015).

In addition to the determinants previously mentioned (Martín Fernández et al., 2007; Fresneda, 2014) the mobility/migration of young Cuban scientists to Europe in the last decade seems to be also a consequence of the steady increase of graduates in sciences and engineering with an annual average of 11.4% between 2006 and 2012 (Table 4.2, page 161) and fewer opportunities to progress their careers in areas different than biotechnology.

Young researchers going abroad should be seen as the pioneers participating in the international network of creating knowledge and innovation, which can create great opportunities if those networks can be routed back home either by collaboration or by returning home eventually. In one of the contributions to the *Atlas of Ideas* the authors revealed how the foreign-born scientists coming from emerging economies *'are usually keen to maintain scientific and informal links with their home countries'* (Day and Stilgoe, 2009, 79). Working on the line of '*the new invisible college'* Day and Stilgoe found that the scientists at Imperial College collaborate because they seek complementary knowledge, skills and insights wherever those collaborators are, lifting the network to a global level where juniors and seniors interact with little regards to hierarchy. They argued that the research environment created through those networks is shaping the way in which good science is progressing through the global experience of those involved.

On the other hand, recent evidence from high-emigration countries indicate that expatriate researchers are more productive than returnees or those who never migrate, but returnee researchers contribute to knowledge transfer from international experience to local setting (Gibson and McKenzie, 2014). The empirical study by

Patrick Gaule (2011) produced a different outcome, not in the higher output of the foreign-born researchers but in the very low return rate (5.1%): essentially the return mainly takes place to those home countries with high GDP. The current economic scenario in Cuba suggests that Cuban researchers in Europe might not be attracted to return but will be willing to interact and collaborate with researchers at home, making them part of their networks while progressing in their scientific career abroad. Moreover on behalf of this cooperation, researchers abroad can identify funding and opportunities in the destination country benefiting home. Indeed this form of transnational cooperation has been pointed to the UK government in different reports to the Department for Innovation, Universities and Skills (Day and Stilgoe, 2007, 80). To maximise the benefit coming from the growing trend of expatriate scientists co-authoring publications with scientists back home will require the implementation of policies and agreements between sending and destination countries

*Scientific performance of Cuban researchers in Europe: what can we see through this window?*

The sample of CRiE was not obtained randomly and therefore results discussed here are not totally representative of the whole population of Cuban researchers in Europe. Instead the hard-to-reach method helped to initiate the search for potential Cuban researchers in Europe that were further refined by their pattern of publication as active researchers. The process generates a set of researchers that are successfully working in institutions of science and technology in Europe.

Some key points deserve mention regarding the empirical evidence generated in this study. No survey was carried out in this study to assess the mobility of the cohort group of CRiC but it is likely to assume that those top Cuban researchers are mobile through regular exchanges abroad and returnee scientists with doctorates attained abroad sustain mobility via networks (Alonso Becerra and Rodríguez, 2014).

The CRiE group on the other hand, are assumed to be research migrants because of the home country migration policy of retaining their human capital until the decree law 302 of Cuban government in 2013 allowing citizens to return home after two year abroad. In addition, more than 50% of CRiE are young researchers who started publishing in the last ten years therefore, the direct comparison inferring if migration has or not improved the performance of scientists does not proceed. Instead this study aimed to investigate the potential of CRiE evaluating how they stand in relation to the best performers in the home country. The reason behind this empirical design aimed to evaluate indirectly the human capital at home.

The dynamic of CRiE acquiring knowledge, experience and expanding their networks through their circulation in European institutions is remarkable. One hundred and six CRiE have been in more than one hundred and ten institutions in Europe. Sixty-four CRiE have worked in sixty universities of the 500 top World University Ranking *(ARWU*) in more than 130 positions spanning from PhD students up to Principal Investigators of research groups. CRiE have been working in top research institutes of international reputation as well, such as Max-Planck institutes in Germany and the Consejo Superior de Investigaciones Científicas, CSIC, Spain (table 6.5) among others. Eighty per cent of the European institutions (95) where CRiE have been working have the critical mass, the infrastructure and resources to support their researchers generating four times more publications per researcher than the institutions of the Cuban cohort (figure 6.4). However Cuban researchers in Cuba (CRiC), selected as the top performers in their institutions are more senior and published relatively more than CRiE, most of them are principal investigators (*investigador titular*) accruing the scientific contribution of the team.

The fact that those top CRiCs from thirty-one different institutions have 24.8 ± 7.3 years publishing is an indication of the country's progress of building scientific capacity, and the young CRiE can be seen as the potential further developed abroad because of the long period of economic restrictions. However, the latter was not promoted or mediated by government or institutions as it was in the cases of China (Jonkers, 2010, 10) and Germany (Jöns, 2009), but by personal decision of the researchers to move abroad. Therefore this potential remains disconnected to the national STI of the country, assumed as such in this study because of the predominant view in Cuba of those departures as defection, mainly those associated to the abandonment of the contract while working abroad (Martín Fernández et al, 2007).

All the interviewed CRiC understand the need of collaborating and strengthening the links with those Cuban scientists abroad, and some of them have even published together but there was not reference to any top-bottom indication of this behaviour rather than the personal interest in doing so. Responses of the interviewed CRiE were mixed, as highly collaborative researchers they recognised the importance of the network collaboration for the development of science but some of them feel the lack of interest in Cuban institutions to support such links. However, that did not stop those with this view to have co-authored articles on a personal basis. However others had a wider interaction with a collective of multi-institutional CRiC or members of a department, not only co-authoring publications, but organizing international meetings or helping establishing contact with relevant international researchers of their network. The perception gathered from interviewing CRiE suggests that different and sometimes opposite attitudes towards collaboration between them is related to the circumstances around their departure and their decision to remain abroad.

The window opened through this study showed that the decision of young researchers of continuing the careers abroad and improving their basic needs did not sever the ties with the Cuban scientific community. Every other CRiE has published with Cuban institutions (57 out of 106) at least once, and eight of them have been publishing with CRiC even when moving from different institutions in Europe generating 248 institutional publications with 37 Cuban institutions. The numbers pointed to strong ties between CRiE and CRiC with preferential collaboration within Latin American countries and a robust network of European collaborators promoting the flow of knowledge and information within the network. In the process of co-authoring international publications with researchers working in European institutions, Cuba not only gets the credit for the quality of the work carried out there, but also increases the probability of profiting from the flows of knowledge and information within the CRiE network. Moreover the proportion of CRiE in top ranking European institutions can be seen in this study as the successful public education and research training of the higher education system of socialist Cuba (Hernández Pérez, 2005), and as one of the interviewed **iCRiE** reflected, it shows the *formal education* as well.

The contribution of migrant researchers to their country of origin in the developing world is still under debate and more evidence-based studies are looking at the returnees and how the flow of knowledge of those remaining in the destination countries might work for sending countries. Returnee researchers can bring home funding from agencies in the destination country and the loss in their research output when returning home (Gibson and McKenzie, 2014) might improve if the institutions in the origin country become part of the integration process. Stefano Baruffaldi and Paolo Landoni (2012) focussed on the typology of those links between the research migrants and their home countries and the effect on the scientific productivity while been abroad by surveying 238 and 259 migrant researchers from four world source regions working in researcher institutions in Portugal and Italy respectively. Although they concluded *'that the presence of home linkages directly benefits both countries in addition to the indirect benefit of expanding the scientific network'*, one of the limitations of this study recognized by the authors was the lack of bibliometric evaluation of the scientific production in their probabilistic models because, as they argued the surveys were anonymous and therefore there was no way of searching databases with their names for researchers output.

Another pitfall in this study was considering the *'intention to return*' as a possible returnee, rather than evaluating real returnees back at home, although they accounted in the prediction for different return-related factors through the questionnaire. However those econometric models did not take into account the current mode of scientific knowledge production called *'the new invisible college'* and its implication in the leverage of science for development (Wagner, 2001 and 2008), in which the networks of scientific diasporas could be a measurable component linked to the S&T system in the home country paving the road for future returns physically and knowledge/information related (Gaillard and Gaillard, 1998; Meyer, 1997).

However in the case of Cuba the same two-way road seems to be paving the brain drain in younger generations. Although knowing that the sizes of interviewed samples were very small, five out of twelve CRiC (42%) have a doctorate degree attained in European institutions mainly in years before the economic restrictions (table 7.3), while eight out of eleven interviewed CRiE (73%) were PhD graduated in Europe, of which three had their PhD degree recognized in Cuba and in the partner institution abroad through bilateral agreements (table 7.4). The situation also applies to the region because '*in an environment of increasing internationalization of research and education, talented young researchers from Latin America often go abroad to make a better life for themselves and to progress in their fields*' (Holm Nielsen et al., 2005, 42).

Mobility, migration, networking and return of researchers have been as instruments mediating the insertion to the home system in the international network of science (Jonkers and Tijssen, 2008). Investigations carried out looking more at the contribution of foreign work experience of returnee researchers to the home country through bibliometric evaluation of their patterns of international collaboration found that the returnees collaborate to a higher degree with their former institutions abroad (Jonkers and Cruz Castro, 2013) in addition to publishing in higher impact factor journals and a significant share without international collaboration, which might indicate that the returnees are having an impact in the excellence and leadership of the home country scientific production.

8.3.3 *The global science, the transnational knowledge of expatriates and the returnees: maximizing possibilities through the networks of scientific collaboration.*

Science in the XXI century has become a global enterprise through the borderless extension of international collaboration among scientists (The Royal Society, 2011). The history of scientists searching for exchanges of knowledge among elites of advanced countries, who had the means for travelling and setting collaboration, has expanded since the XVI century to a wider population of professionals of sciences around the world. Researchers in quantitative sociology of science (Price, 1961; 1963; and 1979; Beaver and Rosen, 1972) paved the way in the field of scientific collaboration for the researchers in science policy to reveal how international scientific collaboration was seen as a good per se and becoming a political objective (Luukkonen et al., 1992). International scientific collaboration was seen as a network-system of self-organized researchers carrying the potential of social and economic development around the world (Wagner, et al., 2001; Wagner and Leydesdorff, 2005b) demanding new governance of science and views in foreign policies (Wagner, 2002). Similarly economists have taken from the quantitative sociology of science and from the labour economics and organizational science to advance the understanding and the implications of academic mobility (Stephan, 2011; Geuna, 2015). For nations to join fairly in this mode of knowledge-related economic growth will require new policies and agreement among nations as more breakthroughs in science might be coming from international research teams.

Although the network-systems give opportunities for developing countries to participate and leverage their resources while building scientific capacity, it also carries the risk of losing their human capital migrating to centres of knowledge while participating in those networks. Researchers in science and development revealed another web of connections between expatriate researchers and their home country emerging as another expression of leveraging resources (Meyer, 1997; Gaillard and Gaillard, 1998,) prompting the shifting of the brain drain paradigm into brain gain. The transformation of foreign-born scientists in agents for development working as transnational knowledge networks operating in host and sending countries requires additional mechanisms. Béatrice Séguin and collaborators (2006) found that the success of any transnational knowledge networks in having an impact in the development of their home countries needs policies and implementations of options from the governments of their home countries, but that was not going to be enough if the destination countries did not engage in the process, suggesting *'that developed countries traditionally benefited from brain drain have the responsibility to foster internationally partnership between developing countries and their skilled diasporas and that developed countries should make the diaspora option an integral part of their international development policy'.*

The research carried out here on mobility, migration and networking of Cubans working in European institutions of S&T represents an empirical evidence of the potential value rather than a loss of Cuban researchers for the home country. The study started exploring scientific collaboration in Cuban institutions as part of the national system strengthening the scientific capacity of the country with the purpose of establishing the country's ability to incorporate additional contributions of human capital. Although the study provided evidence of a successful effort in biotechnology, the current economic situation of the country is still under severe economic, commercial and financial embargo and is impairing further advances, and might stagnate the progress in science.

The Cuban researchers of this study arrived in Europe during the economic crisis and were not politically motivated: educated and trained in Cuban institutions they also carried the social and moral values acquired in the socialist system and all together allowed them to succeed and excel in their performance as researchers in top universities in Europe. Besides the lack of any policy to promote their collaboration with the home country, Cuban researchers in Europe and in Cuba have co-authored sufficient publications to show their self-preference for collaboration. The network of CRiE situates two Cuban academic institutions: University of Havana and University “Marta Abreu”of Las Villas (in Spanish Universidad Central de Las Villas) in the core of the network together with another fifteen academic institutions (four in the top 50 *ARWU* ranking and the rest in the top 500 of the ranking), and nine research institutions.

The data building the network reflects institutional collaboration and not individual co-authorship, then other forms of cooperation might exist and were not included; also some institutions represented by their authors might not necessary be in close collaboration. However those institutions represented in the core of the network have strongest links and therefore more probability of having an impact in the CRiE network. Because there was no differentiation of fields of research, the aggregate values of all collaboration should be assessed in the future to precise the best possibilities for having an impact in Cuba science and education. The CRiE network of scientific collaboration should be interpreted as the aggregate of nodes and links of the researchers involved in their particular epistemic communities.

The flows of information and knowledge between those interconnected nodes of research institutions conform the web of knowledge of CRiE contributing to the ‘*new invisible college’* but it does not mean that CRiE were aware of each other’s contribution. During the interviews of CRiE the lack of contact within CRiE was evident and it only exists if researchers are part of the same scientific community. The acknowledgment of each other’s contributions within CRiE will only emerge if the numbers of CRiE were higher or concentrated in a specific favourable location to promote their identity as Cuban researchers abroad.

Cubans abroad are in general well integrated into the European society sharing their cultural and educational values without concentrating themselves in any area of the communities where they live. This pattern might promote better integration and adaptation to their new lives away from home but does not contribute or facilitate activities among themselves, especially in science, in which the strongest links are at work place and within their research communities worldwide. Therefore it is likely that the scientific communities from home and abroad might facilitate the awareness and cohesion within CRiE.

It can be said that both the Cuban researchers abroad and at home have the essential scientific capability to progress in a successful transnational knowledge network for the development of the home country but this possibility can only be achieved if the necessary nexus exists within and at both ends of CRiE network in the sending and destination countries.

### 8.4 The necessary NEXUS harnessing the blooming of global science

This section aims to discuss theoretically key elements of the evolutionary process of the concept of diaspora for development in the context of the results of this study characterising the Cuban researchers in Europe, but the views should be considered preliminary, as further investigation will be required. First there was not enough fieldwork to provide the necessary elements for discussing the appropriate nexus between Cuba and her scientific diaspora. Second the best approach carrying this type research ensuring practical results should be through Action Research involving all stakeholders at home and abroad.

However the views discussed here might provide insights for the next necessary project of making the potential of CRiE a reality for Cuban scientific capacity. The main concept of discussion is about the convergence of two emergent structures of our modern society: “the new invisible college” of the network of international collaboration and the transnational knowledge networks or scientific diaspora both with the potential to contribute to the process of improving scientific capacity in the developing world. The concept was previously explored by Koen Jonkers (2009) investigating the rapid growth of Chinese scientific publications and the role of co-authorship of Chinese working abroad and their partners in the Mainland China.

Placed in key academic and research institutions in Europe, CRiE are actors of the European contribution to the global science, acquiring skills to compete and collaborate in their respective fields of research, increasing their probability of learning organizational management in conducting scientific research efficiently and interacting with other sectors of the innovative industry enabling them to transfer knowledge between the core of Europe to the peripheral Cuba. However weak connections of the researchers abroad and their institutions in the home country may dissipate the potential impact. On the other hand, if the spontaneous collaboration shown in this study can get stronger and the ties are efficiently used through a home-destination nexus the probability of turning the loss of talents into brain networking, brain circulation and useful return might be achieved but is a fragile entity as yet.

As this study confirms Cuban researchers in Europe are not yet fully organized themselves in any sort of association to either look at their own needs, or to establish projects for development in Cuba. One small embryonic association of *'Académicos Biólogos Cubanos (ABC)'* was found through this research aiming to increase the scientific capacity of their members through discussion of research theories and methodologies, writing grant applications, co-authoring international scientific articles and sharing ideas encouraging creativity, bridging themselves as ABC-members with the global cognitive communities '*(new invisible college')* where they belong. Interestingly their members have created an innovative mechanism for giving visibility to the association using the "acknowledgement" in their scientific publications.

The concept of diaspora for development evolved from the original paradigm of brain drain within the theories of World System, the Human Capital and Actor Network Theory. Different countries in the North have experienced the drain of their scientists in different periods (Balmer et al., 2009; Gaillard and Gaillard, 1998) but the inflow of foreign-born scientists attracted by much better conditions than in their home countries, has compensated for the loss in the form of brain circulation (Plume, 2012a and 2012b) preserving their centrality as hubs of knowledge in the global network of scientific collaboration (Wagner and Leydesdorff, 2005a) and innovation (Griffith et al., 2006).

Other countries of emerging economies have the advantage of the size of their population enabling them to work with a *critical mass* of their overseas scientists through policies and programmes aiming to benefit the home countries from their large communities of researchers abroad. Big countries can allocate a fraction of their GDPs to achieve a sizable result implementing their strategies. By the early years of the twenty-first century China and India were running such strategies of scientific diasporas for development with some success (Jonkers, 2010, 85; Khadria, 2003).

As a result of this home-destination Nexus, Chinese science was increasingly embedded in the global science system of the self-organized networks, growing in visibility and in the share of the international scientific publications (Bornmann et al., 2015).

Smaller countries went through similar experiences but with different outcomes. With increasing numbers of migrants around the world the "Cambrian" explosion of organized diaspora of immigrant communities were constantly evolving under different socio-economic environments influenced by both the sending and destination countries and therefore different endogenous dynamics. The globalization, the impact of communication technologies and cheaper air travelling contributed to preserve the expatriate nexus with the home country fostering transnational practices.

The role of the states of the sending countries also started to play a central part aiming to use the human capital abroad as instruments for development either as virtual networks of scientists (Ciumazu, 2010) or catalysing their return in some countries of Latin America (Caplan, 2015) and Eastern Europe (Chirita, 2013, 18). In the particular case of scientific diasporas, the policies and their implementations were taken mainly by the Ministry of Science and Technology; the Ministry of (Higher) Education, but also by the Ministry of Foreign Affairs through their consulates. However this effort in the sending countries needs the backing of the country's capacity to transform the potential of the diaspora into tangible projects or transactions (Kuznetzov, 2005). The reality sadly remains of not been able to use the brain loss abroad for the majority of developing countries, but it does not imply that it is unachievable.

There are lessons to be learned from the way in which China succeeded transforming the brain drain into leverage for the development of science and technology through policies of engagement with the Chinese scientific diaspora and strategies of building capacity at home. In other words, for the successful undertaking of any the transnational knowledge network essential prerequisites should be satisfactorily in place:

- *The brain drain of previous years generated a successful crop of scientists: The Chinese scientific diaspora*. In the case of China, about one million Chinese students studied abroad between 1980 and 2006 (Jonkers, 2010, 80). Because of the return rate of graduates was low, the debate questioned if it was a *brain drain* or *brain overflow* due to the limited capacity of the country in research organization and innovation, which lead to the next point. More importantly, this also shows the China's commitment to invest in the formation of their human capital (Li, 2004) since 1978.
- *The scientific capacity of sending countries, organizational and financial:* The radical transformation of the Chinese research system in science including the gradual re-establishment of research at universities, strengthening the linkage between S&T and innovation by converting the state-owned research institutes into state-owned research enterprises and the consistent increase of GERD from 0.9% in 2000 to 2.8% of the GDP in 2013 (UNESCO Science Report 2010, 461; 2015, 621).
- *The state involvement was ensuring the link between their scientists abroad and the national science system and education*: The Chinese government and intermediary agencies established policies and programmes to engage the Chinese scientific diaspora into the national system of science, technology and innovation. The first of those programs continued by others was the *Special Fund for Chinese Scholars Abroad Returning for Short Period of Work*, or Lecture in China launched by National Natural Science Foundation of China (NSFC), by which the Chinese researchers spent one month a year in China

for a period of three years (Jonkers, 2010, 85). Other programmes were tailored to young scholars funding seventy projects annually by NSFC but others agencies as well, the Ministry of Science and Technology and the Ministry of Education (Li, 2004).

- *The role of destination institutions and governments*: Placed in the developed world (OECD) scientific institutions and agencies in the destination countries might find the Official Development Assistance (ODA)[52] the instrument to allocate funds aiming to contribute to sustainable development in developing countries in projects of S&T[53]. Research institutions and agencies of sending countries when supporting research projects should consider the needs and priorities defined by the sending countries, and the latter should be open to accept the expatriate scientists as research co-operators representing the sending country on the bases of excellence and respect. In the case of Cuba maybe the misuse of ODA by some countries[54] has prompted the hesitation of the country for receiving help of expatriate citizen.

The last remark regarding the nexus of sending-destination countries demonstrates the need of international policies and regulation through good practices to which partner countries must conform and comply. In 2007, International organizations (UNESCO and International Labour Organization) in collaboration with academia (Ecole Polytechnique Federale de Lausanne, EPFL) supported the project of the Swiss Network of Scientific Diasporas to enforce the role of highly skilled migrants as partners in development. The project generated a Tool Kit to assess Good Practices of skilled migrants and scientific diaspora through the empirical evaluation of the performances of three scientific diaspora of Colombia, South Africa and India with EPFL (Tejada et al., 2010).

[52] ODA. (Official Development Assistance): According to section 1 of the International Development Act 2002

[53] In the case of UK the Department of Business, Innovation and Skills the funds are allocated through the Global Challenges Research Fund and Newton Fund https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/505308/bis-16-160-allocation-science-research-funding-2016-17-2019-20.pdf (Accessed 25 March 2016)

[54] In the present study, the researcher, searching databases of OECD of world distribution of donors and receiving countries found that the bigger donor country to Cuba was United States with USD 13 million in 2014 for Social Infrastructure (representing 83% of US ODA to Cuba), given to NGOs for Human Rights not necessarily for the benefit of the country development. Interestingly Newton Fund invested £20 million in projects with China (28%) in 2014 but Cuba is not included in the program. http://www.compareyourcountry.org/aid-statistics?cr=302&cr1=oecd&lg=en&page=1 Accessed 25/03/2016

In terms of increasing the participation of developing countries in the global organization of science, this study intends to provide preliminary evidence that expatriate scientists through transnational knowledge collaboration with researchers in home institutions might increase the home country possibility for recognition and exchange in the network of international communication. The international scientific collaboration is a self-organized network driven by the mechanism of preferential attachment (Barabási et al., 2002; Wagner and Leydesdorff, 2005b) of researchers, characterised by Caroline Wagner and Loet Leydesdorff (2005) as:

> *‘ Highly dynamic, quickly changing and very influential…and it feeds back into the national, regional and local levels influencing the organization of science’.*

Interestingly, the authors (Bornmann et al., 2015) recently found that China showed an exceptional increase in the number of most frequently cited scientific papers among the BRICS countries while Russia fell below expectations with the lowest increase. Coincidentally one of the differences between both countries lies in opposite views regarding the engagement with their scientific diaspora, while the relationship of China can be used as a model of good practice, Russia is among few countries without policy or strategy regarding the Russian scientists living abroad.

Further studies increasing the sample of Cuban researchers abroad might show regional differences and will allow confirming the preferential attachment of expatriate researchers for colleges at home.

Finally, policies addressing the balance between investment and exploitation of the knowledge grid generated through the network of international collaboration in science might arise from areas of good practices of diaspora knowledge network.

# CHAPTER 9: CONCLUSIONS

## 9.1 INTRODUCTION

The investigation undertaken in this study addressed questions of interest in the field of how developing countries can turn the brain drain into brain gain and brain circulation applied to the case study of Cuban researchers in Europe with the potential to be a Transnational Knowledge Network (TKN).

The approach starts by analysing how science has been increasingly expanding from centres of knowledge towards new emerging participating countries through the link between mobility of scientists and international collaboration (Wagner, 2001; Jonkers, 2009; Bornmann et al., 2015). Participating countries in this global network of international collaboration will benefit only if their national scientific capacities are strong enough to ensure the diffusion of knowledge from the centres and across their nodes of innovation and production or services. Through this vision scientists and engineers abroad are actors of the global production of knowledge with the potential for sharing the output between sending and destination countries. Actors embedded in academic institutions enjoy the freedom and flow of knowledge as a public good beyond borders within the internationalization of higher education and might be the critical players for developing countries.

This mechanism of international collaboration has been functioning within developed countries of different sizes (Luukkonen et al., 1993) and has been at the core of brain circulation of European countries in which academic and research institutions are active participants.

Developing countries with expatriate researchers working in top academic institutions in the North have the potential to increase their presence in the global network of international collaboration and with an adequate mechanism of TKN they might ensure the circulation of knowledge between North and South. However, in order for the diaspora to fully contribute to national development, for example by exploiting the process of TKN, the home country requires an appropriate scientific capacity to allow diffusion of knowledge within the national grid of science. These transmission points need policies and good practices in place between sending and destination countries (EPFL, 2007) working with their TKNs.

The dynamic of the globalization is currently reinforcing the knowledge divide, information divide and learning divide, and therefore is at the root of the mass migration from the South towards the North looking for better life and opportunities. The situation might get worse unless destination countries understand that more effective collaboration with the South improving their capacity for development is the only way for the world to progress.

## 9.2 CONTRIBUTION TO THE MAIN RESEARCH QUESTIONS

### 9.2.1 Cuban scientific capacity and scope for improvement

The main Cuban asset is the education of the population. The Cuban socialist government built the backbone of the Cuban society with the literacy campaign in 1961 and the university reform in 1962. Both events transformed the high illiteracy country into a population with growing motivation for learning.

The education of the masses allowed the “diffusion of knowledge” through the networks of organizations and places reaching all sectors of the population. This foundation prepares the country for the second most important achievement benefiting the society: the Cuban Public Health.

Science and technology were considered essential for the country’s development and the needs of the Cuban population were the focus of research programmes and explicit in the ethos of Cuban scientists. Institutes and centres for scientific research were created in all ministries with strong holds in higher education and public health.

The success of transforming scientific research into a high-tech biotechnology industry rested in the three pillars strengthened in earlier years: the higher education, the public health and the Cuban pharmaceutical industry of generics.

The socialist model of the innovative biotechnology industry ensures maximal diffusion of knowledge across the national grid creating learning spaces and through the interaction with academia and government.

The capacity of higher education has been consistently growing across the country and with it the opportunities emerging from the internationalization of universities. However, decades of economic restrictions have seriously affected the living standard of the population reducing the possibilities of the country for growth from the investment in education. The situation has prompted the economic migration of young educated citizens towards the developed world, some of them through the channels of the internationalization of higher education aiming to further their education and improving their lives. There is no policy addressing the integration or interaction with those young researchers living abroad with the country's grid of knowledge. Therefore their assets as members of the global network of international collaboration have not been used by academia or other sectors of the economy.

The effort of the country in developing scientific capacity does not correlate with the country's number of international publications and their citations affecting the visibility of Cuban science.

The country lacks other innovative industries or start-up small enterprises from academia in other fields of science and technology, with the capacity to translate knowledge or processes into economic contributions to society through the standard of novelty achieved in the “experimental milieu” of the embryonic biotechnology industry.

### 9.2.2 *Cuban scientists in Europe as valuable actors for development*

The age composition of the sample of this study indicates that the sector of the Cuban scientific emigration was essentially young and obviously linked to the period of Cuba engaging in the internationalization of higher education when the country was suffering severe economic restrictions.

The high ranking of the European institutions where the sample of CRiE are conducting successfully their research and building strong international collaboration offers opportunities to boost the home academic performance through different modalities of cooperation and agreements. Additionally the progress seen in the CRiE individual achievements credited the quality of the Cuban higher education and Cuban education in general. However, this positioning of CRiE in high-ranking universities has not been identified and therefore has not been exploited.

By ignoring this reality the home country behaves as a facilitator of the brain drain, rather than using the opportunities to strengthen the national capacity by making expatriates and their new institutions aware of the sending countries realities and possibilities for collaboration. The institutions of the destination countries will not take the initiative of promoting those connections with the home countries of their researchers unless it comes from and with the support of the home institutions. Then, institutions of higher education in the North cannot be blamed totally for profiting from the South. Interestingly the effort to preserve ethnic and cultural diversity in the European institutions of higher education is an achievement that has not been fully used and praised by countries in the South. Institutions in the sending and destination countries should provide a platform for bottom-up projects benefiting both ends.

Moreover, connectivity with the home country at different levels, from families and friends to colleagues, alma mater's and specific projects, will definitely increase the likelihood for return at different stages of the researchers' careers, or increase their partial mobility towards home institutions, from sabbatical exchanges, summer courses, temporal contracts, and permanent return.

### 9.2.3 *The nexus as an environment for improving TKN platforms*

The first step in any attempt implementing the possibilities of the TKN is recognizing the intrinsic value they carry for development.

This vision might be used to discuss with the potential expatriate PhD students and post docs before departing to top or designated universities either in the South or the North. The possibility of accepting them as collaborators from a distance might imprint 0n them the sense of a mission for the development of the home country opposed to severing the ties with their academic roots.

Expatriate researchers should be offered the opportunity to continue and even to promote the collaboration between home institutions and those in the adopted destination country.

Policies and platforms supporting the emerging TKN as structure for development should be a concern of all stakeholders and therefore elaborated with the agreement of all parts.

## 9.3 OVERALL RESEARCH CONTRIBUTION

Science policies in developing countries should take into account these naturally occurring networks within global epistemic communities, which are also linked to the innovation systems of destination countries. Researchers of a given developing nation belonging to the web of the invisible college might be working in the country of origin or in top institutions in the developed world.

This study shows that the self-organized collaboration between Cuban researchers in Europe with the scientists in Cuba has not been recognized, neither fully exploited. The potential and willingness of these expatriate researchers should be valued for the knowledge as a public good that they can bring to the country especially to universities. Additionally these expatriates are members of other networks of related activities such as scientific publishing and professional associations for which they could be ideal ambassadors.

The integration of Cuban scientists working abroad and in Cuba through transnational networks of knowledge might increase the probability of routing the global network of knowledge to the output of the home country by adding more players to profit from the full potential of the intrinsic scientific capacity building, which the “new invisible college” carries.

The findings in this present research need further studies to corroborate that the geopolitical pressure through the U.S embargo and the EU common position after the collapse of the socialism in Europe interfered in the country's process of building her scientific capacity, particularly in terms of human capital of young scientists being drained away. Some interviewed (CRiC more than CRiE) referred to the hardship of domestic life even when the topic was not included in any question.

The creativity, dedication and communality of scientists conducting international collaboration should be nurtured and supported by both sending and destination countries as part of the commitment signed in the '*Declaration of Budapest on Science and the use of scientific knowledge*' in the XXI century (ICSU-UNESCO, 1999). Countries in the developed North have been implementing policies addressing this issue, but the role of scientific expatriates has not been included as a valuable working force by both sending and destination countries.

The developing countries in the South should make use of the potential of their expatriates as collaborators in the North-South programmes for development and in the South-South strengthening programmes. Lessons must be learned from the way China worked with their expatriates helping the process of embedding the Chinese research in the global enterprise of science. Conducting research investigations aiming to find transferable experiences and identifying particularities of countries and regions might accelerate the development of the South towards the sustainable progress.

The race for the best and brightest to ensure competitive economic growth without caring for the consequences in the country of origin of those recruited talents is not a responsible business and can not be sustained in the long run. Science policies and foreign affairs cannot afford to be elusive any more in the global and universal contexts. New governance of science in countries of the North will also require the understanding and management of this risk as a threat to the world social stability and peace due to extreme economic differences between advanced countries and the rest of the world.

The responsibility is not only for the countries in the North, as emerging economies in the South are creating opportunities and mechanisms for those who further their education abroad, either by returning home or by contributing to the country's knowledge growth through transnational knowledge networks. Crucially destination countries should coordinate the assistance and support to TKN according and under the requirements established by the sending country observing the respect to the country's sovereignty.

A research investigating the evolution of Cuban scientists in Latin America and the Caribbean should be carried out on a similar methodological basis to expose the potential generated through these *new invisible colleges* in the knowledge-based economic integration of the region.

This study has also pointed towards the next applied research in science policy involving the institutions of both sending and destination countries in an Action Research investigation offering to researchers and practitioners of science the opportunity to improve new working structures facilitating the work of potential TKN activity in Cuba.

## 9.4 FURTHER DEVELOPMENT AND RESEARCH OPPORTUNITIES

The work presented in this thesis opens a new area of research about the Cuban human capital abroad and its potential for strengthening the processes of internationalization of higher education and the science, technology and innovation system in Cuba.

Similar studies can be carried out for Cuban academics living in Latin America and the Caribbean, who also contribute to the region's integration and economic development.

Research in diaspora for development has been of interest to different international organizations and agencies. The methodological aspects of this thesis make a contribution for further research in this field.

## REFERENCES:

NOTE ON CONVENTION USED FOR SPANISH / HISPANIC NAMES:

In this reference listing author names in Spanish have been standardized to a form compatible with the *Harvard Style Guide*, the University of Cambridge *Copyediting guide* and the *Style manual* of the University of Chicago Press. The two or more surname elements found in Hispanic names are not hyphen (-) separated e.g. *Mesa Lago, C*. Some original documents consulted follow local style rules where the hyphen is used e.g. *Mesa-Lago, C.* The non-hyphenated form is used to ensure a consistent appearance to the reference list. In the case of a surname with a Hispanic and a British element a hyphen can be used e.g. *Palacios - Callender*.

Afgan, N.H. and Carvalho, M.G. (2010) Knowledge society and sustainable development. *Cadmus*, 1 (1), pp. 28-41.

Agunias, D.R. and Newland, K. (2012) Engaging the Asian diaspora. *Issue in Brief,* (7), pp.1-11, November 2012. https://publications.iom.int/books/iom-mpi-issue-brief-no-7-engaging-asian-diaspora [Accessed: 12/07/2015]

Aikins, K. and White, N. (2011) *Global diaspora strategies toolkit*. Dublin: Ireland Funds.

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

Alonso Becerra, E. and Rodríguez, L.A. (2014) The mobility of Cuban scientists and the growth of knowledge networks. Paper presented to *Conference on global science and transnational knowledge networks.* London: University of West London, March 24th 2014.

Altbach, P.G., Reisberg, L. and Rumbley, L.E. (2009) *Trends in global higher education: tracking an academic revolution. Report prepared for UNESCO 2009 on Higher Education.* Paris: United Nations Educational, Scientific and Cultural Organization.

Aragón, de U., Domínguez, J., Duany, J., Mesa Lago, C. Márquez, O. and Blanco, J.A. (2011) *Cuban Diaspora in the 21st century: report of the research committee working at the Cuban Research Institute*, Miami: Florida International University (FIU).

Araujo Ruíz, J. A., Arencibia Jorge, R. and Gutiérrez Calzado, C. ( 2002) Ensayos clínicos cubanos publicados en revistas de impacto international: estudio bibliométrico del período 1991-2001. *Revista Española de Documentación Científica*, 25, pp. 254-266.

Araujo Ruíz, J. A.,Van Hooydonk,G.,Torricella Morales, R.G. and Arencibia Jorge, R. (2005) Cuban scientific articles in ISI Citation Indexes and CubaCiencias databases (1988-2003). *Scientometrics*, 65 (2), pp.161–171.

Arencibia Jorge, R., Corera Alvarez, C.E., Chinchilla Rodríguez, Z. and Moya Anegón, F. (2013) Intersectoral relationships, scientific output and national policies for research development: a case study on Cuba 2003-2007. *ACIMED. Revista Cubana de Información en Ciencias de la Salud*, 24(3), pp. 243–254.

Arencibia Jorge, R. and Moya Anegón, F. (2010) Challenges in the study of Cuban scientific output. *Scientometrics*, 83 (3), pp. 723–737.

Arocena, R. and Sutz, J. (2006) Brain drain and innovation systems in the South. *International Journal of Multicultural Societies*, 8 (1), pp. 43-60.

Arrow, K. (1987) Reflections on the essay. In Feiwel, G.R. ed. *Arrow and the ascent of modern economic theory.* New York: New York University Press. pp.685-687.

Auriol, L. (2007) *Labour market characteristics and international mobility of doctorate holders in seven countries. Statistical analysis of science, technology and industry*. DSTI/DOC (2007) 2 p. 36.

Balmer,B., Godwin, M. and Gregory, J. (2009) ‘Brain drain’: natural scientists meet social science. *Notes and Records of The Royal Society*, 63, pp. 335-343.

Barabási, A.L., Jeong, H., Néda, Z., Ravasz, E., Schubert, A. and Vicseck, E. (2002) Evolution of the social network of scientific collaborations. *Physica A*, 311, pp. 590-614.

Baracca, A., Fajer, V. and Rodríguez, C. (2006) A look at physics in Cuba. *Physics Today*, 59 (2), pp. 42-48.

Baracca, A. (2014) The history of physics in Cuba. In Baracca, A., Renn, J. and Wendt, H. eds. *Boston Studies in Philosophy and History of Science*. Vol. 304. Berlin: Springer.

Barjak, F. (2006) Research productivity in the internet era. *Scientometrics,* 68 (3), pp. 343-360.

Barre, B., Hernández, V., Meyer, J.B. and Vinck, D. (2003) *Diasporas scientifiques: Comment les pays en développement peuvent-ils tirer part deleurs chercheurs et de leurs ingénierus expatries? [Scientific diasporas: How can developing countries benefit from their expatriate scientists and engineers?]* Paris: IRD Éditions.

Baruffaldi, S.H. and Landoni, P. (2012) Return mobility and scientific productivity of researchers working abroad: the role of home country linkages. *Research Policy*, 41 (9), pp. 1655-1665.

Bassarsky, L. (2007) Enfoque de redes sociales en las migraciones de América Latina hacia Francia. *Anuario de Estudios Americanos*, 64, pp.141–172.

Beaver, D. dB. and Rosen, R (1978) Studies in scientific collaboration: part 1: the professional origins of scientific co-authorship. *Scientometrics*, 1 (1), pp. 65-84.

Beaver, D. dB. and Rosen, R. (1979) Studies in scientific collaboration: part 3: professionalization and the natural history of modern scientific co-authorship. *Scientometrics*, 1 (3), pp. 231-245.

Beaver, D. dB. (2001) Reflections on scientific collaboration: past, present and future. *Scientometrics*, 52 (3), pp. 365-377.

Beaver, D. dB. (2012) Quantity is only one of the qualities. *Scientometrics*, 93, pp. 33- 39.

Bejarano, M. (2015) La Inmigracion cubana y la politica migratoria de los EE. UU. (1902-1933). *Estudios interdisciplinarios de America Latina y el Caribe,* 4 (2). <http://eial.tau.ac.il/index.php/eial/article/view/1242/1270.> [ Accessed: 10/11/2015]

Beldarraín Chaple, E. (2005) Cambio y revolución: el surgimiento del Sistema Nacional de Salud en Cuba, 1959-1970. *DYNAMIC. Acta Hisp. Med. Sci. Hist. Illus*. 25, pp. 257-278.

Berg, M.L. (2015) 'La Lenin is my passport': schooling, mobility and belongings in socialist Cuba and its diaspora. *Identities: Global Studies in Culture and Power*, 22 (3), pp. 303-317.

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

Bhandari, R and Blumenthal, P. (2011) Global student mobility and the twenty-first centrury silk road: national trends and new directions. In Bhandari, R. and Blumenthal, P. eds. *International students and global mobility in higher* *education: national trends and new directions*. New York: Palgrave, Macmillan. Chapter 1. pp. 1-24.

BIS (Great Britain: Department of Business Innovation and Skills) (2011) *International comparative performance of UK research base: a report prepared for the Department of Business Innovation and Skills*. London: Department of Business Innovation and Skills. < www.nationalarchives.gov.uk/doc/open-government-licence > [Accessed: 26/03/2016]

Blanco Gil, J.A. (2013) *Remesas de conocimiento: del brain drain al brain gain.* Miami: Eriginal Books.

Borgatti, S.P., Everrett, M.G. and Johnson, J.C. (2013) *Analysing social networks.* London: SAGE Publications, p.296.

Bormann, L., Wagner, C. and Leydesdorff, L. (2015) BRICs countries and scientific excellence: a bibliometric analysis of most frequently cited papers. *Journal of the Association for Information Science and Technology*, 66 (7), pp. 1507-1513.

Brown, M. (2002) Intellectual diasporas network: their viability as a response to highly skilled emigrations. *Diasporas développements et mondialisations*, 2 (22), pp.167-178.

Brücker H., Capuano, S. and Marfouk, A. (2013) *Education, gender and international migration: insights from a panel-dataset 1980-2010.* Mimeo. <http://www.iab.de/en/daten/iab-brain-drain-data.aspx#Sources> [Accessed: 19/04/2014]

Boyle, M. and Kitchin, R. (2011) Towards a new generation of diaspora centred development: current practices 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. School of Interdisciplinary and Trans-disciplinary Studies, Indira Gandhi National Open University, New Delhi.

Boyle, M. and Kitchin, R. (2014) Diaspora centred development: current practice, critical commentaries, and research priorities. In Sahoo, S. and Pattanaik, B.K. eds *Global diasporas and development: socioeconomic, cultural and policies perspectives*, New Delhi: Springer. Chapter 2.

Buck, T. (2014) Migration: the drain from Spain. *Financial Times. UK edition on-line* < https://next.ft.com/content/f7bdd5ce-995e-11e3-91cd-00144feab7de> [Accessed: 16/03/2016]

Caplan, C. (2015) Redes y asociaciones de diasporas. In Meyer, J.B. ed. *Diaspora, hacia una nueva frontera*. Montpellier: Institut de Reserche pour le Developpement. Chapter 3, pp. 95-112.

Cárdenas O'Farrill, A. (2009) The Cuban biotechnology industry: innovation and universal health care. Bremen: Institute for Institutional and Innovations Economics, University of Bremen. pp. 1-37. <http://www.theairnet.org/files/research/cardenas/andres-> [Accessed: 27/09/2014]

Cárdenas O'Farrill, A. (2014) State and innovationeEnterprises: the case of the Cuban biopharmaceutical industry. *Business and Economic History,* 22, pp.1-76. <http://www.thebeh.org/publications/BEHonline/2014/ofarrill.pdf>[Accessed: 21/07/2015]

Casanova Codina, J. (1995) Movimiento obrero y lucha anti-colonialista en Cuba despues de la abolicion de la esclavitud. *Boletin Americanista*, 45 pp.23-41.

Casaña, A. (2007) La emigracion de profesionales desde el pais que la emite: el caso cubano. *Aldea Mundo*, 11 (22), pp.33-42.

Castells, M. (1996) *The Information age: economy, society and culture, the rise of the network society*. Malden (Mass): Blackwell.

Castles, S. (1998) Globalization and migration: some pressing contradictions. *International Social Science Journal*, (156). pp. 179-186.

Castro Ruz, F. (1960) Remarks by the Primer Minister of Cuba Fidel Castro Ruz in the speech at the Cuban Speleology Society, Academy of Sciences, January 15th Havana: National Agrarian Reform Institute (INRA).

Castro Ruz, R. (2009). Remarks by Army General Raul Castro Ruz, President of the Republic of Cuba, at the 15th NAM Summit, Sharm el Sheikh, Egypt, July 15, 2009. *Cuba MINREX Official website of the Ministry of Foreign Affairs of Cuba* <http://www.cubaminrex.cu/en/remarks-army-general-raul-castro-ruz-president-republic-cuba-15th-nam-summit-sharm-el-sheikh-egypt>. [Accessed: 29/10/2015]

Chaparro, F., Jaramillo, H. and Quintero, V. (2004) Aprovechamiento de la Diaspora e Insercion en las Redes Globales de Conocimiento: el caso de la Red Caldas. *Informe presentado al Instituto del Banco Mundial (Knowledge for Development Program)*. Bogota, April 2004. <http://siteresources.worldbank.org/EDUCATION/Resources/278200-1126210664195/1636971-1126210694253/Colombia_Diasporas.pdf> [Accessed: 26/02/2013]

Chinchilla Rodríguez, Z., Zacca González, G., Vargas Quesada, B. and Moya Anegón, F. (2015a ) Latin American scientific output in public health: combined analysis using bibliometrics, sociometrics and health indicators. *Scientometrics.* 102, pp.609-629.

Chinchilla Rodríguez, Z., Arencibia Jorge, R., Moya Anegón, F. and Corera Alvarez, E. (2015b) Some patterns of Cuban scientific publications in *Scopus*: the current situation and challenges. *Scientometrics*. 103, pp.779-794.

Chirita, O. (2013) EU policies and initiatives on migration and development towards Eastern partnership countries: the implications for skilled mobility from Armenia, Georgia and Moldova. In *Skill migration and Development Practices: Republic of Moldova and the countries of South East Europe.* Vazari, V., Tejada, G., Porcescu, S and Bolay , J.C. eds. Lausanne: Impressum S.R.L. pp. 18 -34.

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

Clark Arxer, I. (2011) Cuba. In *UNESCO Science Report 2010:the current status of science around the world,* Paris: UNESCO. pp. 123-132.

Clark Arxer, I. (2015) El capital humano: un recurso invaluable. *Revista Anales de la Academia de Ciencias de Cuba*, 5 (1), pp.1-4.

Commission of European Communities (2001) A mobility strategy for the European research area. *COM (2001)331 final*, 20.06.2001. Brussels: CEC. pp.1-14

Corlan, D. (2012), *Medline spatial trends for dengue 2008-2012.* <http://dan.corlan.net/medline_spatial_trend/e6kbELom/JCSindex.html> [Accessed: 13/07/2015]

Corley, E.A. and Sabharwal, M. (2007) The foreign-born academic scientists and engineers: producing more and getting less than their U.S.-born peers. *Research in Higher Education,* 48 (8), pp. 909-940.

Crane, D. (1972) *Invisible colleges: diffusion of knowledge in scientific communities.* Chicago: The University of Chicago Press.

DAAD (Deutscher Akademischer Austausch Dienst) (2014) *Wissenschafl weltoffen Kompak. Facts and figures on the international nature of studies and research in Germany.* Bielefeld, Bertelsmann Verlag for DAAD. <http://www.wissenschaftweltoffen.de/kompakt/wwo2014_kompakt_en.pdf> [Accessed: 07/10/20 13]

Daar, A.S., Thorsteinsdottir, H., Martin, D.K., Smith, A.C., Nast, S. and Singer, P. (2002) Top ten biotechnologies for improving health in developing countries. *Nature Genetics*, 32, pp. 229–232.

Daar, A.S., Berndtson, K., Persad, D.L. and Singer, P.A. (2007) How can developing countries harness biotechnology to improve health? *BMC Public Health,* 7, pp 346-354.

David, P. and Foray, D. (2002) An introduction to the economy of the knowledge society. *International Social Science Journal*, 54 (171), pp. 9-23.

Day, N. and Stilgoe, J. (2009) *Knowledge nomads: why science needs migration.* London: Demos.

De Los Ríos, J. and Rueda, C. (2005) Fuga de cerebros en Perú: sacando a flote el capital hundido. *Economía y Sociedad,* 58, pp. 111- 132.

De Vos, P., García Fariñas, A., Alvarez Pérez, A., Rodríguez Salva, A., Bonet Gorbea, M. and Van de Stuyft, P. (2012) Public health services: an essential determinant of health during crisis. Lessons from Cuba, 1989-2000,. *Tropical Medicine & International Health,* 17, pp. 469-479.

Delgado Vázquez, D. (2012) Theoretical conceptions in the studies of international migrations: a look from the Cuban sociology. *Anfora*, 10 (32), pp.159-191.

Delgado Vázquez, D. (2014) Emigración cubana: tendencias y dinámica actuales. *Cuba contemporánea online*. <http://www.cubacontemporanea.com/noticias/emigracion-cubana-tendencias-y-dinamicas-actuales> [Accessed: 14/04/2014]

Didou Aupetit, S. (2008) Movilidades académicas y profesionales en América Latina: entre la ignorancia y la polémica. *Revista de la Educación Superior*, 27 (148), pp. 71-85,

Didou Aupetit, S. (2009) Pérdida de cerebros y ganancia de saberes? La movilidad internacional de recursos altamente calificados en America Latina y el Caribe. In Didou Aupetit, S. and Gerard, E. eds. *Fuga de cerebros, movilidad académica y redes científicas.* Mexico, D.F: Centro de Investigación y Estudios Avanzados de México (CINVESTAV) IESALC. pp. 20 - 62.

Didou Aupetit, S. and Jaramillo de Escobar, V. (2014) *Internationalization of higher education and science: state of the art*. Mendoza: UNESCO, IESALC

(International Institute for Higher Education in Latin America and the Caribbean, Universidad Nacional de Cuyo), p.215.

Docquier, F. and Marfouk, A. (2006) International migration by educational attainment (1990-2000) - Release 1.1. In Ozden, C. and Schiff, M. eds. *International migration, remittances and development*. New York: Palgrave Macmillan.

Docquier, F, Lohest, O. and Marfouk, A. (2007) Brain drain in developing countries. *World Bank Economic Review*, 21 (2), pp. 193-218.

Docquier, F, Lowell, B.L. and Marfouk, A. (2009) A gender assessment of highly skilled emigrants. *Population and Development Review,* 35 (2), pp.297-321.

Docquier, F. and Rapoport, H. (2012) Globalization, brain drain, and development. *Journal of Economic Literature*, 50 (3), pp.681–730.

Domínguez, J.I. (1997) The U.S.-Cuban relations: from Cold War to the Colder War. *Journal of Interamerican Studies and World Affairs*, 39 (3), pp.49-75.

Dorta Contreras, J.A., Arencibia Jorge, R. Martí Lahera, Y. and Araujo Ruiz, J.A. (2008) Productividad y visibilidad de los neurocientíficos cubanos: estudio bibliometrico del periodo 2001-2005. *Revista de Neurologia*, 47, pp.355-360.

Drucker, P.F. (1994) The age of social transformation. The *Atlantic Monthly*, Digital edition. (November), pp 1-30.
< http://www.theatlantic.com/politics/ecbig/soctrans.htm (2 of 30) [4/10/2001 10:32:55>
<http://www.adishakti.org/pdf_files/age_of_social_transformation_%28theatlantic.com%29.pdf> [Accessed: 22/10/2015]

Duque, R.B., Ynalvez, M., Sooryamoorthy, R, Mbatia, P., Dan-Bright Dzorgbo, S. and Shrum, W. (2005) Collaboration paradox: scientific productivity, the internet, and problems of research in developing areas. *Social Studies in Science*, 35 (5), pp. 755-785.

Ebrahim, S., Squires, N., Bauza Diaz, M., Di Fabio, J.L., Reed, G., Bourne, P.G., Keck, W. and Chalkidou, K. (2016) Ebola control: the Cuban approach. *The Lancet*, 384, (9959), p.2022.

Eckstein, S. (2004) The clash between the Cuban immigrant cohort. In Mauricio A. Font, M.A. ed. *Cuba today, continuity and change since the Periodo Expecial.* New York: City University of New York, Bildner Centre for Western Hemisphere, The Graduat Center. Chapter 10, pp.129-146.

EHEA (European Higher Education Area) (2012) *Mobility strategy 2010 for European Higher Education Area (EHEA)*. Bucharest. pp.1-5. <http://www.ehea.info/Uploads/%281%29/2012%20EHEA%20Mobility%20Strategy.pdf> [Accessed: 26/06/2015]

Empirica (2005) *NetReAct* (The role of networking in research activities) survey. Post-docs in life sciences. *Report. Deliverable D 3.2. Institute for Prospectives Studies , Commission of European Communities*, Pages 16, 31 and 46 . <http://www.netreacteu.org/documents/NetreactDeliverable3.2.pdf > [Accessed: 20/09/2014]

EPFL (Ecole Polytechnique Federale de Lausanne) (2007) *An action orientated tool kit to assess good practices of skilled migrants and scientific diasporas. A Swiss network of scientific diasporas to enforce the role of skilled migrants as partners in development. Document of the workshop hosted by International Migration Programme at the International Labour Organization on October 26th 2007.*[Geneva] : ILO.

Etzkowitz, H. and Leydesdorff, L. (2000) The dynamics of innovation: from national systems and mode 2 to a triple helix of university - industry - government relations. *Research Policy*, 29 (2), pp 109-123.

Escobar Rodríguez, A.M. (2005) Sistemas de innovacion de redes de aprendizaje en Cuba. *Argumentos de Razón Técnica*, 8, pp. 84-124.

Escobar-Rodríguez, A.M. (2007) Es posible otro Sur? La política cubana en Ciencia y Tecnología. *Tesis Doctoral.* San Sebastian, Universidad del Pais Vasco.

Fisher, D. (1978) Rockefeller philanthropy and the British Empire: the creation of the London School of Hygiene and Tropical Medicine. *History of Education*, 7, pp.129-143.

Forattini, O.P. (1997) The international language of science. *Revista de Saúde Pública*, 31 (1), pp.3 - 8.

Franzoni, C., Scellato, G. and Stephan, P. (2012) Foreign-born scientists: mobility patterns for 16 countries. *Nature Biotechnology*, 30 (12), pp.1250-1253.

Freeman, R.B. (2006) Does globalization of the scientific/engineering workforce threaten US economic leadership? *Innovation Policy and the Economy,* 6 (6), pp.123–157.

Freeman, R.B. (2010) Globalization of scientific and engineering talent: international mobility of students, workers, and ideas and the world economy. *Economics of Innovation and New Technology*, 19, pp.393–406.

Fresneda, E.J. (2014) Migrantes en el socialismo: el desarrollo cubano a debate. *Revista Problemas del Desarrollo*, 176 (45), pp.107-132.

Gailland, J. (1992) Use of publication lists to study scientific production and strategies of scientists in developing countries. *Scientometrics*, 23 (1), pp.57-73.

Gaillard, J. and Gaillard A.M. (1998) The international circulation of scientists and technologist: a win lose or a win-win situation? *Science Communication*, 20(1), pp.106-115.

Gaillard, J. (2000) Monitoring and evaluation system for impact assessment (MESIA). Conceptual framework and guidelines. Report 1, April, pp.1-38. *MESIA Impact Studies*. Stokholm: International Foundation of Science,

Gaillard, J. and Arvanitis, R. (2013) Science and technology collaboration between Europe and Latin America: towards a more equal partnership?. In Gaillard, J. and Arvanitis,R. eds. *Research collaboration between Europe and Latin America: mapping and understanding partnership*. Paris: Éditions des archives contemporaines.

Gaillard, A.M., Gaillard, J.,Russel, J.M., Galina, C.S., Canesse, A.A., Pellegrini, P., Ugartemendia, V. and Cardenas, P. (2013) Drivers and outcomes of S&T international collaboration activities: a case study of biologists from Argentina, Chile, Costa Rica, Mexico and Uruguay. In Gaillard, J. and Arvanitis,R. eds. *Research collaboration between Europe and Latin America: mapping and understanding partnership*. Paris: Éditions des archives contemporaines.

Gaillard, J., Gaillard, A.M. and Krishna, V.V. (2015) Return from migration and circulation of highly educated people: the never-ending brain drain. *Science Technology and Society,* 20 (3), pp.169-168.

Gálvez, A., Maqueda, M., MartÍnez Bueno, M. and Valdivia E. (2000) Scientific publication trends and the developing world: what can the volume and authorship of scientific articles tells us about scientific progress in various regions?, *American Scientist*, 88, pp. 526-533.

Gasperini, L. (2000) *The Cuban education system: lessons and dilemmas*. Washington: The World Bank, Latin American and the Caribbean Regional Office. Human Development Department. LCSHD Series, No.48.

García Capote, E. (2012) Ciencia y técnica en la Revolución Cubana: repaso a la etapa de promocion dirigida 1960-1975. *Revista Anales de la Academia de Ciencias de Cuba*, 2 (1), pp. 1-41.

García Capote, E. (2015) La idea de un sistema de ciencia, tecnología e innovación en Cuba: orígenes, vicisitudes, futuros. *Revista Anales de la Academia de Ciencias de Cuba*, 5 (1), pp.92-129.

Garfield, E. (1979) Is citation analysis a legitimate evaluating tool? *Scientometrics,* 8, pp. 359-375.

Gaulé, P. (2011) Return migration: evidence from academic scientists. Cambridge (Mass): Massachussetts Institute of Technology. Mimeo.

Geuna, A. (2015) Global mobility of research scientists: the economics of who goes where and why. London: Elsevier.

Gibbons, M., Limonges, C., Nowotny, H., Schwartzman, S., Scott, P. and Trow, M. (1994) *The new production of knowledge: the dynamics of science and research in contemporary societies.* London: Sage Publications Ltd.

Gibbons, M. (1999) Science's new social contract with society. *Nature*, 402 (Supplement, 2 December). C-81-C84.

Gibson,J. and McKenzie, D. (2014) Scientific mobility and knowledge networks in high emigration countries: evidence from the Pacific. *Research Policy,* 43 (9), pp.1486-1495.

Glänzel, W. (2004) Towards a model for diachronous and synchronous citation analysis. *Scientometrics*, 60 (3), pp.511-522.

GCIM (Global Commission on International Migration) (2005) Migration in an interconnected world: new directions for action. Geneve: SRO-Kundig.

GCIM (Global Commission on International Migration) (2012) Developing a road map for engaging diaspora in development: a handbook for policymakers and practitioners in home and host countries.Geneva: International Organization of Migration.

Godin, B. (2006) On the origin of bibliometrics. *Scientometrics*. 68 (1), pp.109-133.

González, E. and Ronfeldt, D. (1992) *Cuba adrift in a post-communist world.* Santa Monica: RAND. (RAND study, R-4231 USDP).

González, E. and Ronfeldt, D. (1994) *Storm warning for Cuba*. Santa Monica: National Defense Research Institute, RAND. (RAND study, MR-452-OSD).

González, E. and Ronfeldt, D. (1996) Clearing Perilous Waters. Santa Monica : RAND. MR-673-OSD.

Griffith, R, Huerga, E., Mairesse, J. and Peters, B. (2006) Innovation and productivity across four European countries. *Oxford Review of Economic Policy*, 22 (4), pp.483-498.

Guerrero Bote, V.P., Olmeda Gómez, C. and Moya Anegón, F. (2013) Quantifying the benefits of international scientific collaboration. *Journal of the American Society for Information Science and Technology*, 64, pp.392–404.

Gulland, A. (2014) Cuba pledge 165 health workers to treat Ebola patients in Sierra Leone. *The BMJ*, 349, g5647.

Gusmão, R. (2001) Research networks as a means of European integration. *Technology and Society*, 23, pp. 383-303.

Guzmán Sánchez, M.V., Sanz Casado, E. and Sotolongo-Aguiar, G. (1998) Bibliometric study on vaccine (1990- 1995) part I: scientific production in Iberian-American countries. *Scientometrics*, 43, pp. 189-205.

Haseltine, B., 2012. *The Cuban biotechnology industry*. Washington DC: Brookings Institution. <http://www.brookings.edu/~/media/newsletters/pres_letter/052012/cuba_biotech_report > [Accessed: 28/09/2014]

Heckathorn, D.D. (2011) Snowball versus respondent-driven sampling. *Sociological Methodology*, 41 (1), pp. 355-366.

Henry, L., Mohan, G. and Yanacopolus, H. (2004) Networks as transnational agents of development. *Third World Quarterly*, 25 (5), pp. 839-855.

Hernández Pérez, R. (2005) Internationalization of higher education in Cuba. In De Wit, H., Jaramillo, I.C., Gacel Avila, J. and Knight, J. *Higher education in Latin America: the international dimension.* Washington DC. International Bank for Reconstruction and Development. Chapter 7, p 211-238

Hernández Elías, R. and Márquez, M. (1976) Docencia médica media en Cuba. *Educación Médica y Salud*, 10 (1), pp. 1-41.

Hernández, R., (2012) Carta a un joven que se va. *La Joven Cuba*. Junio 13, 2012. <https://jovencuba.com/2012/06/13/carta-a-un-joven-que-se-va/> [Accessed: 30/10/2015]

Hoekman, J., Frenken, K. and Tijssen, R.J.W. (2010) Research collaboration at a distance: changing spatial patterns of scientific collaboration in Europe. *Research Policy*, 37(5), pp. 662-673.

.

Hollanders, H. and Soete, L. (2010) The global role of knowledge in the global economy. In: *UNESCO Science Report 2010*. Paris: UNESCO Publishing. pp.1-27.

Holm-Nielsen, L.B., Thorn, K., Brunner, J.J. and Balán, J. (2005) Regional and international challenges to higher education in Latin America. In De Wit, H., Jaramillo, I.C., Gacel Avila, J. and Knight, J. *Higher education in Latin America: the international dimension.* Washington DC: International Bank for Reconstruction and Development. Chapter 2. pp. 37-70.

Holtz, M. (2014) The Cuban Experience in East Germany: migration 1960-2000. *Bulletin of Latin American Studies*, 23 (4), pp.468-483.

Horton, R. (2015) Offline: what is medicine's 5 sigma? *The Lancet,* 385, p.1380.

Huggett, S. (2012) The rise of Latin American science. *Research Trends*, 31, (November) pp.15 -18. <http://www.researchtrends.com/issue-31-november-2012/the-rise-of-latin-american-science/> [Accessed: 2/10/2015]

Hunter, R.S., Oswald, A.J. and Charlton, B.G. (2009) The elite brain drain. *The Economic Journal* , 117 (June) F231 - F251.

ICGC (International Cancer Genomic Consortium) (2010) International network of cancer genome projects. *Nature Genetics*, 464, pp.993- 998.

Inter-American Development Bank (2010) *Science, technology and innovation in Latin America and the Caribbean: a statistical compendium of indicators*. Washington DC: Science and Technology Division. Inter-American Development Bank.

International Council for Science (ISCU) and UNESCO (1999) Declaration on science and the use of scientific knowledge. *World Conference: Science for the Twenty-first century, $26^{th}$ June-$1^{st}$ July,* Budapest, Hungary.

Izsak, K., Markianidou, P., Lukach, R. and Wastyn, A. (2013) *The impact of the crisis on research and innovation policies. Study for the European Commision DG Research.* Technopolis group, Belgium and IDEA consult, Spain. <https://ec.europa.eu/research/innovation-union/pdf/expert-groups/ERIAB_pb-Impact_of_financial_crisis.pdf > [Accessed: 21/09/2015]

Jiménez, J., Escalante, J.C., Rodriguez, C. Ramírez, J.M. and Morales Arroyo, M.A. (2010) Mobility or brain drain? The case of Mexican scientists. *Sociology of Science and Technology*,1, pp 90-108. <http://cyberleninka.ru/article/n/mobility-or-brain-drain-the-case-of-mexican-scientists> [Accessed: 23/11/2015]

Joint Science Conference (2013) *Strategy of the Federal and Länder Ministers of Science for the Internationalisation of the Higher Education. Resolution of the 18th Meeting of the Joint Science Conference, Berlin, 12 April, 2013* . <http://www.bmbf.de/pubRD/Internationalisierungsstrategie_engl.Fassung.pdf> [Accessed: 12/07/2015]

Jones, B.F., Wuchty, S. and Uzzi, B. (2008) Multi-university research teams: shifting impact, geography, and stratification in science. *Science*, 322, pp.1259–1262.

Jöns, H. (2008) Academic travel from Cambridge University and the formation of centres of knowledge, 1885-1954. *Journal of Historical Geography*,34, pp.338–362.

Jöns, H. (2009) Brain Circulation and transnational knowledge networks: studying long-term effect of academic mobility to Germany, 1954 -2009. *Global Network*, 9 (3), pp. 315 -338.

Jonkers, K. and Tijssen, R. (2008) Chinese researchers returning home: impacts of international mobility on research collaboration and scientific productivity. *Scientometrics*. 70 (2), pp. 309-333.

Jonkers, K. (2009) Emerging ties: factors underlying China's co-publication patterns with Western European and North American research systems in three molecular life science sub-fields. *Scientometrics.* 80 (3), pp.775-795.

Jonkers, K. (2010) *Migration, mobility and the Chinese scientific research system.* London: Routledge. (Routledge Contemporary China Series).

Jonkers, K. and Cruz Castro, L. (2013) Research upon return: the effect of international mobility on scientific ties, production and impact. *Research Policy*, 42, pp. 1366-1377.

Kapcia, A. (2005) Educational revolution and revolutionary morality in Cuba: the "New Man" youth and the "New Battle of Ideas". *Journal of Moral Education*, 34 (4), pp. 399-412.

Kapcia, A. and Newson, L.A. (2014) *Report on the state of UK-based research on Latin America and the Caribbean.* London: University of London Institute of Latin American Studies.

Kannankutty, N. and Burrelli, J. (2007) Why did they come to the United States? A profile of immigrant scientists and engineers. Arlington (VA): National Science Foundation. pp.1-8. (Science Resources Statistics. NSF 07-324).

Keck, C.W. and Reed, G.A. (2012) The curious case of Cuba. *American Journal of Public Health*, 102 (8), pp.e13-e22.

Kelly, U., McNicoll, I. and White, J. (2014) The impact of universities in UK economy. Universities UK. London: UniversitiesUK. (Report for *UniversitiesUK.* Produced by Viewforth Consulting Ltd).

Khadria, B. (2003) *Case study of Indian diaspora.* Montpellier: Institut de Researche pour le Developpement. pp.1-16. (Scientific Diaspora/ Diasporas Scientifiques).

Klapan, W. and Laing, R. (2005) *Local production of pharmaceuticals: industrial policy and access to medicines: health, nutrition and population (HNP) of the World Bank's Human Development Networks*. Washington, DC: The International Bank for Reconstruction and Development.

Klugman,J., Rodriguez, F.R., Azcona, G., Cummins, M., Fuentes Nieva, R., Gebretsadik,M., Ha, W., Kleemans, M., Letouz, E., Menon, R., Ortega, D., Medalho Pereira, I., Purser, M., Ugaz, C., Kennedy, A, Carvajal, L., Gaye, A., Jha, S., Seck, P., Thornton, A., Jespersen, E., Mwangi, M.A., Pagliani,P., Scott, T., Sanjines, M., Boelt, W., Hamel, J.I, Hernández, M., Moreno, P.M., Polo, Y., Aiello, C., Mend, S., Juarez Shanaham, F. and Bernal, O. (2009) *Human Development Report 2009. Overcoming barriers: human mobility and development*. New York: United Nations Development Programme (UNDP).

Knight, F.W. (2008) *The Historical Society's 2008 Conference on migration, diaspora, ethnicity and nationalism in history, June 5th-9th, 2008*. Baltimore (Md): The John Hopkins University.

Kozak, M., Bormann, L. and Leydesdorff, L. (2015) How have the Eastern Europe countries of the former Warsaw Pact developed since 1990? A bibliometric study. *Scientometrics*.102, pp.1101-1117.

Kuhn, T.S. (1962) *The structure of scientific revolutions.* Chicago: The University of Chicago Press.

Kuznetsov, Y. ed. (2005) *Leveraging diaspora of talent: towards new policy agenda. In diaspora networks and international migration of skills. How countries can draw on their talents abroad.* Washington DC: The World Bank.

Lage Dávila, A. (2004) La economía del conocimiento y el socialismo (II): reflexiones a partir del proyecto de desarrollo territorial en Yaguajay. *Revista Cuba Socialista*, 33, pp.3–23.

Lage, A. (2008) Connecting immunology research to public health: Cuban biotechnology. *Nature Immunology*. 9 (2). pp. 109-112.

Lage Davila, A. (2013) *La economía del conocimiento y el socialismo.* Havana: Editorial Academia. p.303.

Lancaster, F.W., Porta, M.A., Plagenz, K., Szymborski, K. and Krebs, M. (1986) Factors influencing sources cited by scientists: a case study for Cuba. *Scientometrics*, 10, pp.243-257.

Latour, B. (1987) *Science in action: how to follow scientists and engineers through society.* Milton Keynes: Open University Press.

Laudel, G. (2003) Studying the brain drain: can bibliometric methods help? *Scientometrics*, 57(2), pp.215-237.

Le Bail, H. and Shen, W. (2008) The return of the "brains" to China: what are the social, economic and political impact? *Asie: Vision,* 11 (November). (Institut Francais des Relations Internationales)

Lemarchand, G.A. (2010) Sistemas nacionales de ciencia, tecnologia e innovacion en Latinoamerica y el Caribe. Estudios y documentos de politica cientifica en LAC. Volume 1. Montevideo: UNESCO, Oficina Regional, MERCOSUR.

Lemarchand, G.A. (2015) Latin America. In *Towards 2030*. Paris: UNESCO. pp. 171-209. (*UNESCO science report).*

Levin, S.G and Stephan, P.E. (1999) Are the foreign-born a source of strength for U.S. science? *Science,* 285, pp.1213-1214.

Levitt, P. and Glick Schiller, N. (2004) Conceptualizing simultaneity: A transnational Social Field perspective on Society. *International Migration Review*, 38 93), pp. 1002-1039.

Leydesdorff, L. (1990) Prediction of science indicators using information theory. *Scientometrics,* 19 (3-4), pp. 297-324.

Leydesdorff, L. and Etzkowitz, H. (1998) The triple helix as a model for innovation studies. *Science and Public Policy*, 25 (3), pp. 195-203.

Li, C. (2004) Bringing Chinese best and brightest back home: regional disparities and political tensions. *China Leadership Monitor*, 11, pp. 1-19 <http://media.hoover.org/sites/default/files/documents/clm11_lc.pdf> [Accessed: 25/03/2015]

Lotka, A.J. (1926) The frequency distribution of scientific productivity. *Journal of the Washington Academy of Sciences*, 16, pp 317-323.

López Mola, E., Silva, R., Acevedo, B., Buxado, J.A., Aguilera, A. and Herrera L. (2006) Biotechnology in Cuba: 20 years of scientific, social and economic progress, *Journal of Commercial Biotechnology*, 13, pp. 1–11.

López Sánchez, J. (1987) *Finlay: El hombre y la verdad científica.* La Habana: Editorial Científico Técnica, Instituto Cubano del Libro.

Luukkonen, T., Persson, O. and Silvertsen, G. (1992) Understanding patterns of international scientific collaboration. *Science, Technology & Human Values, 17 (1)*, pp.101-126.

Luukkonen, T, Tijssen, R.J.W., Persson, O. and Silvertsen, G. (1993) The measurement of international collaboration. *Scientometrics*, 28 (1), pp.15-36.

Macías Chapula, C.A. (2001) Papel de la infometría y de la cienciometría y su perspectiva nacional e internacional. *ACIMED*, 9 (1), pp. 35-41.

Mahroum, S, Elddrige, C and Daar, A. (2006) Transnational diaspora options: how developing countries could benefit from their emigrant population. *International Journal of Multicultural Societies*, 18 (1), pp. 25-42.

Marimón Torres, N. and Martínez Cruz, E. (2010) Evolution of the Cuban medical co-operation during one hundred years of the ministry of public health (In Spanish). *Revista Cubana de Salud Pública*, 36 (3), pp. 254-262.

Martín Fernández, C., Aja Díaz, A., Casaña Mata, A. and Martín Quijano, M. (2007) La emigracion de Cuba desde finales del XX y principios del XXI: lecturas y reflexiones mirando a la Ciudad de la Habana. *CEMI-UH, Proyecto CITMA.*

*Ciencias Sociales,* pp.137-179. <http://www.uh.cu/centros/cemi/resultados-investigadores/2/> [Accessed: 15/11/2015].

McLeod, R. (1993) Passages in imperial science: from empire to commonwealth. *Journal of World History*, 4, pp. 117-150.

Melchor, L. (2014) Científicos españoles en el Reino Unido. Interview by Marina Fernández Cano for *La Carta de España, Abril, 703*. <http://www.cartadeespaña.es/index.php?seccion=0&reportaje=537 > [Accessed: 13/05/2014]

Melon, C.C., Ray, M., Chakkalackar, S., Li, M., Cooper, J.E., Chadder, J., Ke, W., Li, L., Madkour, M.A., Aly, S., Aldy, N., Chafurvedi, S., Konde, V., Daar, A.S., Singer, P.A. and Thorsteinsdottir, H. (2009) A survey of South-North health biotech collaboration. *Nature Biotechnology*, 27 (3), pp. 229-232.

Merton, R.K. (1957) Priorities in scietific discovery: a chapter in sociology of science. *American Sociological Reviews*, 22(6), pp. 635-659.

Merton, R.K. (1969) Behaviour patterns of scientists. *The American Scientist*, 57 (1), pp. 1-23.

Meyer, J.B., Charum, J., Bernal, D., Gaillard, J., Granés, J., Leon, J., Montenegro, A., Murcia, C., Narvaez-Berthelemot, N., Parrado, L.S. and Schlemmer, B. (1997) Turning brain drain into brain gain: the Colombian experience of the diaspora option. S*cience Technology and Society*, 2 (2), pp. 285-315.

Meyer, J.B. and Brown, M. (1999) Scientific diaspora: a new approach to brain drain. In *World Conference on Science, UNESCO, 26th June to 1st July, Budapest, Hungary.* (Management of social transformation. Discussion paper 41). <http://www.unesco.org/most/meyer.htm> [Accessed: 12/11/ 2014].

Meyer, J.B. and Wattiaux, J.P. (2006) Diaspora knowledge networks: vanishing doubts and increasing evidence. *International Journal of Multicultural Societies,* 8 (1), pp.4-24.

Meyer, J.B. (2007) *Building sustainability: new frontiers of diaspora knowledge network.* Montpellier and Buenos Aires**:** Centre on Migration, Citizenship and Development (COMCAD). *Working Paper Series,* No. 35, pp 1- 27.

Meyer, J.B. ed. (2015) *Diaspora hacia la nueva frontera*. Marseille and Montevideo: Institut de Recherche pour le dèveloppement, Marseille and Universidad de la Republica de Uruguay. <http://www.observatoriodiasporas.org/#!libro/cgkd> [Accessed: 24/03/2016]

Mezke, W. and Fernández de Aliza, M.C. (1990) Structure and development of the scientific and technological potential in the Republic of Cuba. *Scientometrics*. 18 (1-2), pp. 137-155.

Miguel, S. (2011) Revistas y producción científica de América Latina y el Caribe: su visibilidad en SciELO, RedALyC y SCOPUS. *Revista Interamericana de Bibliotecología*, 34, pp. 187–199.

Mills, E.J., Kanters, S., Hagopian, A., Bansback, N., Nachega, J., Alberton, M., Au-Yeung, C.G., Mtambo, A., Bourgeault, I.L., Luboga, S., Hoggs, R.S. and Ford, N. (2011) The financial cost of doctors emigrating from Sub-Sahara Africa: human capital analysis. *British Medical Journal*, 343, pp.1-13.

Moed, H.F., Aisati, M. and Plume, A. (2013) Studying scientific migration in Scopus. *Scientometrics*, 64 (3), pp. 929-942.

Montero Cabrera, L.A. (2012) Visión de la ciencia y la tecnología: problemas actuales. *Temas*, 69 (enero-marzo), pp. 4-11.

Moral, L.P. (1989) Elements for a diagnosis of applied research and development in Cuba using patent information: 1968 - 1983. *Scientometrics*, 17, pp. 83-96.

Moreno Ginarte, M.R. (2008) Un acercamiento a la introduccion y desarrollo de las tecnologias de la informacion y comunicaciones en Cuba en el periodo 1983-1999. *Ciencias de la Información*, 39 (1), pp. 3-18.

Nikolic, S., Mraovic, B. and Cosic, E. (2010) *The scientific diaspora as a brain option: exploring the case of Bosnia and Herzegovina.* Sarajevo: Alumni Association of the Centre for Interdisciplinary Post-graduate studies (ACIPS).

Nowak, M.A. (2006) Five rules for the evolution of cooperation. *Science*, 314, pp. 1560-1563.

Nowak, M.A. (2012) Evolving cooperation. *Journal of Theoretical Biology*, 299, pp.1-8.

Nowotny, H., Scott, P. and Gibbons, M. (2003) Mode 2 revisited: The new production of knowledge, *Minerva,* 1 (3), pp.179-194.

NSF (National Science Foundation) (2000) *Science and engineering indicators 2000. Patterns of International co-authorship in S&E*. Arlington (VA): National Science Foundation. Appendix table 6-61, p.141. <www.nsf.gov/statistics/seind00.pdf/c6/co6.pdf > [Accessed: 20/07/2014]

NSF (National Science Foundation) (2014) *Science and engineering indicators 2014. International co-authored S&E articles by selected regions/countries/economies, 1997- 2012.* Arlington (VA): National Science Foundation. Appendix table 5-56. <www.nsf.gov/ststistics/seind14/index.cfm/appendix > [Accessed: 20/07/2014]

Núñez Jover, J. and Castro Sánchez, F. (2005) Universidad, innovación y sociedad: experiencia de la Univerisidad de la Habana. *Revista de Ciencias da Administracao,* 13 (1), pp. 1-21.

Nuñez Jover, J. and López Cerezo, J.A. (2008) Technological innovation as social innovation: science, technology and the rise of STS in Cuba. *Science, Technology & Human Values,* 33 (6), pp.707-729.

Núñez Jover, J. (2010) *Conocimiento académico y sociedad: ensayos sobre política universitaria de investigación y post-grado*. Habana: Editorial UH.

OECD (Organization for Economic Co-operation and Development) (2014) Net disbursments of ODA in 2014. Interactive webpage within oecd.org <http://www.compareyourcountry.org/aidstatistics?cr=625&cr1=oecd&lg=en&page=0> [Accessed: 11/02/2016]

Oliver, E. (2016) A corazón abierto: diaspora científica, redes de talento para colaborar. *Gaceta médica.com.* <http://www.gacetamedica.com/noticias-medicina/2016-02-26/editorial-opinion/a-corazon-abierto-diaspora-cientifica-redes-de-talento-para-colaborar/pagina-opinion.aspx?idart=968321> [Accessed: 15/03/2016]

ONE (Oficina Nacional de Estadística) (2010) *Anuario estadístico de Cuba 2010. Edición 2011.* <http://www.one.cu/aec2010/esp/20080618_tabla_cuadro.htm http://www.one.cu/aec2011/esp/16_tabla_cuadro.htm> [Accessed: 10/05/2014]

ONE (Oficina Nacional de Estadística) (2015a) *Data: Higher education graduates in every branch of science (2007-2012). Excel table18.1* <http://www.one.cu/aec2010/esp/20080618_tabla_cuadro.htm> [Accessed:10/11/2015]

ONE (Oficina Nacional de Estadística) (2015b) *Data: Science and technology working staff according to their educational level. Excel table 16.1* <http://www.one.cu/aec2010/esp/20080618_tabla_cuadro.htm> [Accessed: 13/12/2015]

Palacios-Callender, M. and Roberts, S.A. (2015) Help academic diasporas seed international collaboration. *Research Fortnight*. 14th October, View 21.

Palacios-Callender, M., Roberts, S.A. and Roth-Berghofer, T. (2016) Evaluating patterns of national and international collaboration in Cuban Science using bibliometric tools. *Journal of Documentation*, 72 (2), pp.362-390.

Parmar, I. (2002) American foundations and the development of international knowledge network. *Global Networks*, 2, pp. 13-30.

Pascual, M.A., Jiménez, G., Torres, A., Fors, M.M. and Lopez, I. (2011) Cuba's National Clinical Trials Coordinating Centre: emergence, evolution and main results. *MEDICC Review*, 13 (1), pp.46-51.

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

Pérez Ones, I. and Nuñez Jover, J. (2009) Higher Education and socio-economic development in Cuba: high rewards of a risky high tech strategy. *Science and Public Policy*, 36, 97-101.

Plume, A. (2012a) Behind the data. The evolution of brain drain and its measurement: Part I. *Research Trends*, (26, January 2012), pp. 3-4.

Plume, A. (2012b) Behind the data. The evolution of brain drain and its measurement: Part II. *Research Trends*, ( 27, March 2012), pp. 4-5.

Portes, A. (1996) Globalization from below: the rise of transnational communities. In Smith, W.P. and Korczenwicz, R.P. eds. *Latin America and world economy*. Westport: Greenwood Press. pp. 151-168.

Portes, A., Guarnizo, L.E. and Landolt, P. (1997) The study of transnationalism: pitfalls and promise of an emergent research field. *Ethnic and Racial Studies*, 22 (2), pp. 217-37.

Press, L. (1996) *Cuban telecommunications, computer networking, and the U.S. policy implications.* Santa Monica: RAND. (Report DRU-1330-OSD prepared for the Office of the Secretary of Defense).

Press, L. (2001) The past, present and future of the Internet in Cuba. Cuba in transition. *ASCE (Association for the Study of the Cuban Economy)*, 21, pp.186-193.

Price, D.J. de Solla (1961) *Science since Babylon*. New Haven and London: Yale University Press. p.136.

Price, D.J. de Solla (1963) *Little Science, big Science*. New York and London: Columbia University Press. p.115.

Price, D.J. de Solla and Beaver, D.dB. (1966) Collaboration in an invisible college. *The American Psycologist*, 21 (11), pp1011-1018.

Price, D.J. de Solla (1976) A general theory of bibliometric and other cumulative advantage processes. *Journal of the American Society for Information Science,* 27 (5-6), pp. 292-306.

Price, D.J. de Solla (1980) The citation cycle. In Griffith, B.C. ed. *Key papers in Information Science.* White Plains (NY): Knowledge Industry Publications. pp. 195 - 210.

Pruna Goodgall, P.M., Alvarez Sadoval, O., Valero González, M., BeldarraÍn Chaple, E., Ramos Guadalupe, L.E., GarcÍa Blanco, R., Duarte Hurtado, M., González López, R.M., DÍaz MatÍn, R. (2014) *Historia de la Ciencia y la Tecnología en Cuba*, La Habana: Editorial CientÍfico-Técnica.

Pujol Gebelli, X. (2015) Política científica: diáspora científica? *Revista de la Sociedad Española de Bioquímicos y Biológos Moleculares*, 185 (Septiembre), pp. 1-4.

Quang, Z. (2003) Internationalization of higher education: towards a conceptual framework. *Policy Futures in Education*, 1 (2), pp. 248-270.

Ramkissoon, H. and Kahwa, I.A. (2011). The CARICOM countries. In *UNESCO Science Report 2010.* The Current Status of Science around the World, Paris: UNESCO Publishing, pp. 123-132.

Reed, G. (2012) PAHO's presence in Cuban Health: Jose Luis Di Fabio, PhD, PAHP/WHO representative in Cuba. *MEDICC Review*, 14 (4), pp.10-13. ( Interview published in *MEDICC Review* ).

RICYT (Red de Indicadores de Ciencia y Tecnología) (2011) *El Estado de la ciencia. indicadores de la movilidad de los recursos humanos*. Buenos Aires: Edición de Artes Gráficas Integradas. pp. 409-460.

Reid-Henry, S.M. (2008) Scientific innovation and non-Western regional economies: Cuba Biotechnology's 'experimental milieu'. *Environment and Planning*, 40, pp. 1966-1986.

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

Robson, C. (1993) Real world research: a resource for social scientists and practitioners-researchers. Oxford: Blackwell. p.501.

Rogaeva, E. et al. (2007) The neuronal sortilin-related receptor SORL1 is genetically associated with Alzheimer disease. *Nature Genetics*, 39, pp.168–177.

Roland, M.C. (2007) Publish and perish: hedging and fraud in scientific discourse. *Journal of Molecular Biology Organization*, 8 (5), pp.424-228.

Rosenblum, M.R. and Hipsman, F. (2015) Normalization of relations with Cuba may portend changes to U.S. migration policy. *Migration Information Source*, January 14th, 2015.
< http://www.migrationpolicy.org/article/normalization-relations-cuba-may-portend-changes-us-immigration-policy> [Accessed:16/03/2015]

Sáenz, T.W. and García Capote,E. (1993) El desarrollo de la ciencia y la tecnología en Cuba: algunas cuestiones actuales. *Interciencias,* 18 (6) pp. 289-294. <http://www.interciencia.org/v18_06/art01/ > [Accessed:10/08/2015]

Sáenz, T.W. (2005) Biotechnology for Medical Applications: The Cuban experience. *Science Technology Society*, 10 (225), pp. 226-248.

Sáenz, T.W., Thorsteinsdóttir, H. and de Souza, M.C. (2010) Cuba and Brazil: an important example of South-South collaboration in health biotechnology. *MEDICC Review*, 12, pp.32–35.

Sancho, R. (1992) Misjudgments and shortcomings in the measurement of scientific activities in less developed countries. *Scientometrics*, 23 (1), pp.221–233.

Scopus. <http://www.info.sciverse.com/scopus/scopus-in-detail/tools/authorprofile>.

Séguin, B., State, L., Singer, P.A. and Daar, A. (2006) Scientific diasporas as an option for brain drain: re-circulating knowledge for development. *International Journal of Biotechnology,* 8 (1/2), pp.78-90.

Sen, B.K. (2010) Lotka's Law: a view point. *Annals of Library and Information Studies*, 57, June 2010, pp.166- 167.

Singer, P.A. and Daar, A.S. (2001) Harnessing genomics and biotechnology to improve global health equity. *Science,* 294, pp 87-89.

Small, H. (2004) On the shoulders of Robert Merton: towards a normative theory of citations. *Scientometrics*, 60 (1), pp. 71-79.

Sorolla Fernández, I. (2012) Estado actual del debate internacional sobre la gestion de los flujos migratorios calificados. *Cuadernos Turquinos*, 1 (1), pp. 97-117.

Sorolla Fernández, I. (2013) Reconfiguración del patrón migratorio externo cubano en el período 2000-2010. *Mundi Migratios*, 1(1), pp.1-40.

Stephan, P.E. and Levin, S.G. (1991) Inequality in science performance: adjustments for attribution and journal impact. *Social Studies of Science*, 21, pp. 351-368.

Stephan, P.E. and Levin, S.G. (2001) Exceptional contribution to US science by the foreign-born and foreign educated. *Population Research and Policy Review*, 20, pp. 59-79.

Stephan, P.E. (2012) *How economics shapes science*. Cambridge, (MA): Harvard University Press.

Stone, D. (2003) Knowledge networks and global policy. Paper presented to the *CEEISA/ISA Conference. Central Europe University of Budapest, Hungary, 28th June, 2003.*

Stone, R  (2015a) From the cold: after keeping science alive during decades of scarcity, Cuba's "guerrilla scientists" are ready to rejoin the world. *Science*, 348 (6236), pp.746-749.

Stone, R. (2015b) Graying Cuba strains socialist safety net. *Science*, 348 (6236) , pp.750-751.

Swinburne, J.K. (1983) The use of English as the international language of science: a study of the publications and views of a group of French scientists. *The Incorporated Linguist*, 22, pp.129–132.

Tejada Guerrero, G. ( 2007) *Diasporas cientificas: una oportunidad para impulsar el desarrollo de Mexico.* Lomas de Santa Fe (Mexico, D.F.): Universidad Iberoamerican, **A.C**., pp. 5-23.

Tejada, G., Dia, I.A. and  Kwankam, F. (2010) Colombian, Indian and South African scientific diasporas: concluding remarks and implications for policy and research. In  Tejada, G. and Bolay, J.C. eds.  *Scientific diasporas as development partners. Skilled migrants from Colombia, India and South Africa in Switzerland: empirical evidences and political responses*. Bern: Peter Lang, pp. 487-513

Tejada, G. (2012) Mobility, knowledge and cooperation: scientific diasporas as agents of development. *Migration and Development,* 10 (18), pp. 59 -92.

Tejada, G., Varsari, V. and Procescu, S. (2013) Scientific diaspora, transnationalism and home country development: evidence from a study of skilled Moldovans abroad. *Southest European and Black Sea Studies*,13 (2), pp.152-173.

The Royal Society (2011) *Knowledge, networks and nations: global scientific collaboration in the 21st century*. London: The Royal Society. (RS Policy Document 03/11. Issue March 2013 DES2096).

Thorsteinsdottir, H. (2004 a) Regional cooperation for ensuring access and capacity building. Paper presented to *2nd Conference on biotechnology for Asia development, 7-8th April, New Delhii, India. Organized by the Research and Information System for the Non-Aligned and Developing countries.* <http://newasiaforum.org/Conference_on_Biotechnology_for_Asia.htm> [Accessed : 7/10/2014].

Thorsteinsdottir, H., Quach, U., Daar, A.S. and Singer, P.A. (2004 b) Conclusion: promoting biotechnology innovation in developing countries. *Nature Biotechnology*. 22 (Supplement), DC 48 -52.

Thorsteinsdottir, H., Melon, C.C., Ray, M., Chakkalacka, S., Li, M., Cooper, J.E., Chadder, J., Sáenz,T.W., de Souza Paula, M.C., Ke, W., Li, L., Madkour, M.A., Adly, S., El-Nikhely, N., Chafurvedi, S. Konde, V., Daar, A.S. and Singer, P.A. (2010) South-South entreprenurial collaboration in health biotech. *Nature Biotechnology*, 28 (5), pp. 407 -416.

Tuiran, R. (2009) Fuga de cerebros: algunos comentarios a partir del caso mexicano. In Didou Aupetit, S. and Gerard, E. eds *Fuga de cerebros, movilidad academica y redes científicas.* Mexico D.F.: Centro de Investigación y Estudios Avanzados de México (CINVESTAV) and IESALC. pp. 11-14. <www.ielsalc.unesco.org.ve/dmdocuments/biblioteca/libros/**fuga**.pdf> [Accessed: 27/11/2015]

Truslow, F.A. (1951) *Report 10764 on Cuba: Findings and recommendations of economic and technical mission organized by the International Bank for Reconstruction and Development in collaboration with the Government of Cuba in 1950.* Washington D.C.: International Bank for Reconstruction and Development. <http://www.wds.worldbank.org/servlet/WDSContentServer/WDSP/IB/2000/01/01/000178830_98101911094155/Rendered/INDEX/multi0page.txt > [Accessed: 03/03/2013]

Turner, W.A. (2005*) Diaspora knowledge network: report for the International Committee for Social Science Information and Documentation.* Paris: Universite de Paris-Sud. <http://portal.unesco.org/shs/en/files/4783/10841746551Diaspora_Knowledge_Network

s_Draft_Proposal.pdf/Diaspora+Knowledge+Networks+Draft+Proposal.pdf >
[Accessed: 27/08/2015]

UNESCO (2005) *Towards knowledge societies*. *UNESCO World Report*. Paris: UNESCO Publishing.

UNESCO (2010*) Science Report 2010: the current status of science around the world.* Paris: UNESCO Publishing.

UNESCO (2012) Skilled migration and brain drain. *Diversities,* 14 (1), pp. 1-116.

UNESCO (2015) *UNESCO science report: towards 2030*. Paris: UNESCO Publishing.

United Nations (1964) *International co-operation in the application of science and technology to economic and social development.1267th plenary meeting 11th December 1963* . UN Document: A/RES/1944(XVIII), A/PV 1276. <http://research.un.org/en/docs/ga/quick/regular/18> [Accessed: 24/07/2014]

Uthoff, A. and Beccaria, L. (2008) *Social panorama of Latin America*. Santiago de Chile: United Nations. Economic Commission for Latin America and the Caribbean (ECLAC).

Valdés, N. and Rivera, M. (1999) The political economy of the Internet in Cuba: Cuba in Transition. *ASCE (Association for the Study of the Cuban Economy),* 9, pp. 141-154.

Van Noorden, R. (2012) Global mobility: science on the move. *Nature*, 490, pp.326 - 329.

Van Noorden, R. (2014) South America by the numbers. *Nature*, 510, pp. 202 - 203.

Vega Almeida, R.L., Arencibia Jorge, R. and Araujo Ruiz, J.A. (2007) Producción científica de los institutos de salud de Cuba en el *Web of Science* en el período 2000-2004. *ACIMED*, 16 (3), pp. 1-17.

Wagner, C.S., Brahmakulam, J, I., Nung, A. and Tatsuro, Y. (2001) Science and technology collaboration: building capacity in developing countries? In *RAND Science and Technology Report for the World Bank*. Santa Monica: RAND. (MR-1357-WB).

Wagner, C.S. (2002) The elusive partnership: science and foreign policy. *Science and Public Policy*, 29 (6), pp.409-417.

Wagner, C.S. (2004) *International collaboration in science: a new dynamic for knowledge creation.* Doctoral Dissertation, Amsterdam School of Communication

Research; Faculty of Social Behavioural Science. Amsterdam: University of Amsterdam. <UvA-DARE, the institutional repository of the University of Amsterdam (UvA) <http://dare.uva.nl/document/74489> [Accessed: 12/02/2015]

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

Wagner, C.S. and Leydesdorff, L. (2005b) Network structure, self-organization, and the growth of international collaboration in science. *Science Policy*, 34 (10), pp.1608- 1618.

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

Wagner, C.S. (2008) *The new invisible knowledge: science for development.* Washington D.C. : The Brookings Institution Press,

Wall, S. (2006) An autoethnography on learning about autoethnography. *International Journal of Qualitative Methods*, 5 (5), pp.1-12.

Walsh, J.P. and Bayma, T. (1996) The virtual college: computer mediated communication and scientific work. *Information Society International Journal,* 12 (4), pp. 343- 363.

Weinar, A. (2009) Instrumentalizing diasporas for development: international and European policy discourses. In Bauböck, R. and Faist, T. eds. *International migration, integration and social cohesion (IMISCOE) research. Diaspora and transnationalism: concepts, theories and methods*. Amsterdam: Amsterdam University Press. Chapter 4.

WIPO (World Intellectual Property Organization) (2015) *Statistical country profile: Cuba*, <http://www.wipo.int/ipstats/en/statistics/country_profile/profile.jsp?code=CU> [Accessed: 17/03/2016]

WHO (World Health Organization) (2008) *Public policies for the public's health. In: Primary health Care: Now more than ever*. Geneva: WHO. (World Health Organization Report 2008, Chapter 4).

WHO (World Health Organization) (2010) *The WHO global code of practice on the international recruitment of health personnel. Sixty-third Health Assembly. Eight* *plenary meeting, 21th May, 2010.* Geneva: World Health Organization. (Committee A, IV Report, WHA63.16).

Woo Park, H., Barnett, G.A. and Joo Chung, C. (2011) Structural changes in the 2003-2009 global hyperlink network. *Global Networks*, 11 (4), pp. 522-542.

Yaffe, H. (2009) *Che Guevara: the economics of revolution*. London: Macmillan / Palgrave. pp. 163-198 [Chapter 7:*Science and technology*].

Zacca González, G., Chinchilla Rodríguez, Z., Vargas Quesada, B. and de Moya Anegón, F. (2014) Bibliometric analysis of regional Latin America's scientific output in public health through *SCImago Journal & Country Rank*. *BMC Public Health*, 14, pp. 632-643.

Zacca González, G., Chinchilla Rodríguez, Z., Vargas Quesada, B. and de Moya Anegón, F. (2015) Patterns of communication and impact of Cuban scientific output in public health. *Revista Cubana de Salud Pública,* 41 (2), pp.200-216.

Zong, J. and Batalova, J. (2016) *College-educated immigrants in the United States.* Migration Information Source, Spotlight, February 3rd. Migration Policy Institute <http://www.migrationpolicy.org/article/college-educated-immigrants-united-states>. [Accessed: 01/03/2016]

# APPENDICES

Appendix 1 Academic Ranking of World Universities (top 20 universities)

ACADEMIC RANKING OF WORLD UNIVERSITIES SINCE 2003

| World Rank | Institution | Country /Region | National Rank |
|---|---|---|---|
| 1 | Harvard University | | 1 |
| 2 | Stanford University | | 2 |
| 3 | Massachusetts Institute of Technology (MIT) | | 3 |
| 4 | University of California, Berkeley | | 4 |
| 5 | University of Cambridge | | 1 |
| 6 | California Institute of Technology | | 5 |
| 7 | Princeton University | | 6 |
| 8 | Columbia University | | 7 |
| 9 | University of Chicago | | 8 |
| 10 | University of Oxford | | 2 |
| 11 | Yale University | | 9 |
| 12 | University of California, Los Angeles | | 10 |
| 13 | Cornell University | | 11 |
| 14 | University of Pennsylvania | | 12 |
| 15 | University of California, San Diego | | 13 |
| 16 | University of Washington | | 14 |
| 17 | University of California, San Francisco | | 15 |
| 18 | The Johns Hopkins University | | 16 |
| 19 | University of Wisconsin - Madison | | 17 |
| 20 | University College London | | 3 |

**University College London**

General Information | Introduction | Students Profile | Program

| | |
|---|---|
| **English Name:** | University College London |
| **Region:** | Northern Europe |
| **Country:** | UK |
| **Found Year:** | 1826 |
| **Address:** | Gower Street |
| **Website:** | http://www.ucl.ac.uk |

## Appendix 2

### Questionnaire towards the geographical distribution of Latin American researchers in Science and Technology through the top European Universities

This data collection questionnaire has been prepared by Dr Miriam Palacios-Callender (a registered higher degree candidate at University of West London) to assist in a study into mobility, migration and networking of Cuban Scientists and Engineers in Europe. Any data provided will be treated confidentially and interpreted only in aggregate form without reference to any individual in any particular institution.
The questionnaire must be completed by the designated specialist from the Human Resources Department of the above Universities.
The information required is the number of researchers per field of Research from the listed countries.

| Institution: | ARWU rank: | Country Rank: | Europe Rank: |
|---|---|---|---|
| University College London | 17 | 3 | 3 |

| Country/Regions | Science | | | | | Engineering | | | | | ICT |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nat. Sci. | Life Sci. | Formal Sci. | Clin. Sci. | Med. | Chem. | Civil | Elect. | Mech. | Inter-discipl. | |
| **All nationalities** (total) | | | | | | | | | | | |
| **Latin America** | | | | | | | | | | | |
| Argentina | | | | | | | | | | | |
| Brazil | | | | | | | | | | | |
| Chile | | | | | | | | | | | |
| Colombia | | | | | | | | | | | |
| Cuba | | | | | | | | | | | |
| Mexico | | | | | | | | | | | |
| Venezuela | | | | | | | | | | | |
| others | | | | | | | | | | | |
| **Caribbean** | | | | | | | | | | | |
| Cuba | | | | | | | | | | | |
| Dominican Republic | | | | | | | | | | | |
| others | | | | | | | | | | | |
| **Europe** | | | | | | | | | | | |
| Spain | | | | | | | | | | | |
| Portugal | | | | | | | | | | | |
| others | | | | | | | | | | | |

Notes:
Sciences:
Natural Science: Physics, Chemistry, Earth Science
Life Sciences: Biology (Cell and Molecular Biology, Biochemistry): Botany, Human Biology and Zoology
Formal Sciences: Decision Theory, Logic, Mathematics, Statistics, Systems Theory and Theoretical Computer Science
Applied Sciences: Clinical Sciences and Medicine
Engineering:
Chemical Engineering: Biomolecular Engineering, Material Engineering, Molecular Bioengineering and Process Engineering,
Civil Engineering: Environmental Engineering, Geotechnical Engineering, Structural Engineering and Transport Engineering
Electrical Engineering: Computer Engineering, Electronic Engineering, Optical Engineering and Power Engineering
Mechanical Engineering: Aerospace Engineering, Acoustic Engineering, Manufacturing Engineering, Thermal Engineering and Vehicle Engineering
Interdisciplinary Engineering: Agricultural Engineering, Applied Engineering, Biological Engineering, Building Service Engineering, Energy Engineering, Industrial Engineering, Mechatronic engineering, Nanoengineering, Nuclear Engineering and Petroleum Engineering
ICT: Researchers in Information and Communication Technology

Appendix 3 Webpage: Transnational Knowledge Network-Bibliometrics <https://bibliometricintkn.wordpress.com/>

TRANSNATIONAL KNOWLEDGE NETWORK-CUBAN SCIENTISTS IN EUROPE

*Bibliometric methods to study scientific publishing patterns*

HOME / INICIO • ABOUT THE RESEARCHER / ACERCA DEL INVESTIGADOR • PUBLICATIONS

# *About this research*

EDIT

Transnational Knowledge Networks in global science and technology is a research theme within the Information Management research group at the University of West London School of Computing and Technology (SOCAT).

The researcher Miriam Palacios-Callender is working on a project within the group titled “Mobility, migration and networking of Cuban scientists and engineers working in Europe”.

In the current phase of the project I need to study the demography and performance of the community of Cuban scientists and engineers in Europe using bibliometric tools. The main source of information for my study is the Scopus database using the name and surname of Cuban researchers. Scopus (www.scopus.com) is the largest abstract and citation database of peer-reviewed literature, provided with smart tools to track, analyze and visualize research.

It is essential for this project to have the correct names of the author to which Scopus associates an identification number of 10 digits. However, more than one identification number might be associated with one author due to the differences in display of the name(s) and surname(s) of the same author. In order to achieve the quality that this project deserve I will need the support of the Cuban colleagues working in Europe providing the essential information for the bibliometric study and having your Scopus author ID will ensure the quality of the data collection. You can find your Scopus author ID before completing the FORMULARIO. The information collected through this questionnaire will only be used for the purposes of the project described in this site. Your personal details will remain confidential and will not be disclosed to any third party (neither personal nor institutional). In any report or publication arising from this work your data will be reported only in aggregated and anonymized form.

Through this website I would like to ask to those members of the community of Cuban scientists and engineers in Europe to complete the fields in the following FORMULARIO.

Cuban scientific community in Europe is small compared to other countries, however it might be useful for this community to know the possibilities coming from other transnational knowledge networks like Spanish Researchers in UK (see http://www.sruk.org.uk) in times in which Science is becoming a global enterprise.

Contributed by Miriam Palacios-Callender and Raul Cristobal Liz, London, June, 2014

# Appendix 4 Questionnaire (Formulario estudio bibliometrico)


* Required

**Nombre(s) ***
como aparecen en las publicaciones cientificas

**Apellidos ***
como aparecen en las publicaciones cientificas

**Otros nombres y apellidos registrados en sus publicaciones ***

**Correo electronico ***
usuario@dominio

**Areas de investigacion**
Marcar todas las areas relacionadas con tus publicaciones

- ☐ Medicina
- ☐ Neurociencia
- ☐ Bioquímica/Biología Celular/Genética/Biología Molecular
- ☐ Inmunología/Microbiología
- ☐ Farmacología/Toxicología/Ciencias Farmacéutica
- ☐ Química
- ☐ Ingeniería Química
- ☐ Ciencias Agrícolas
- ☐ Ciencias Biológicas
- ☐ Ciencias del Medio Ambiente
- ☐ Ciencias de Materiales
- ☐ Ciencias de La Tierra y Astronomía
- ☐ Ciencias Informaticas
- ☐ Other:

**Código SCOPUS**
Identificador de autor de 10 digitos

**Centro de estudios universitarios en Cuba**

Contributed by Miriam Palacios-Callender and Raul Cristobal Liz, June 2014

## Appendix 5 Codification used to identify countries where CRiE work (chapter 4, section 4.5.2,e)

| COUNTRY | CODE |
|---|---|
| Belgium | 201 |
| France | 202 |
| Germany | 203 |
| Finland | 204 |
| Italy | 205 |
| Portugal | 206 |
| Spain | 207 |
| Switzerland | 208 |
| Sweden | 209 |
| United Kingdom | 210 |
| Hungary | 211 |
| Ireland | 212 |
| Netherland | 213 |
| Poland | 214 |
| Romania | 215 |
| Denmark | 216 |
| Austria | 217 |
| Slovenia | 218 |
| Norway | 219 |
| Russia Federation | 220 |
| Czech Republic | 221 |
| Croatia | 222 |
| Turkey | 223 |
| Yugoslavia/ Servia | 224 |
| Greece | 225 |
| Estonia | 226 |
| Serbia | 227 |
| Luxembourg | 228 |
| Cyprus | 229 |

Appendix 6 Code of Cuban institutions in the cohort group of CRiC

| INSTITUTIONS | NAME (SPANISH) | CODE |
|---|---|---|
| ICCC | Instituto de CArdiologia y Cirujia Cardiovascular | 101002 |
| UH | Universidad de la Habana | 101003 |
| CNIC | Centro Nacional de Investigaciones Cientificas | 101004 |
| UCLV | Universidad Central de Villa Clara | 101005 |
| IF | Inst. Finlay de Investigación y Producción de Vacunas y Sueros | 101006 |
| CIM | Centro de Inmunologia Molecular | 101007 |
| InTEC | Instituto Superior de Ciencias y Tecnologías Aplicadas | 101008 |
| IIIA | Instituto de Investigacion de la Industria Alimenticia | 101010 |
| IPK | Instituto de Medicina Tropical Pedro Kouri | 101011 |
| CIGB | Centro de Ingenieria Genetica y Biotecnologia | 101014 |
| CIRAH | Centro de Invest. y Asistencia Médica para Ataxia Cubana | 101015 |
| IPSJAE | Instituto Politecnico Superior Jose Antonio Echevarria | 101017 |
| CNC | Centro de Neurociencias de Cuba | 101025 |
| CEADEN | Centro de Estudios Aplicados al Desarrollo Nuclear | 101028 |
| CIDEM | Centro de Investigacion y Desarrollo de Medicamentos | 101029 |
| UMCC | Universidad de Matanzas Camilo Cienfuegos | 101030 |
| ICIMAF | Instituto de Cibernetica MAtematica y Fisica | 101039 |
| ICA | Instituto de Ciencia Animal | 101042 |
| UCI | Universidad de Ciencias Informaticas | 101044 |
| UO | Universidad de Oriente Patricio Lumumba | 101048 |
| HHA | Hospital Hermanos Amejeiras | 101049 |
| ISCM-H | Instituto Superior de Ciencias Medicas de la Habana | 101050 |
| IHI | Instituto de Hematologia e Inmunologia | 101051 |
| INOR | Instituto Nacional de Oncologia y Radiobiologia | 101052 |
| INHA | Instituto de Nutricion e Higiene de los Alimentos | 101053 |
| INHEM | Instituto Nacional de Higiene y Epidemiologia | 101054 |
| INN | Instituto de Neurologia y Neurocirujia | 101055 |
| CIREN | Centro Internacional de Restauración Neurológico | 101056 |
| INIFAT | Inst. de Investigaciones Fundamentales en Agricultura Tropical | 101057 |
| FCM-ME | Facultad de Ciencias Medicas Miguel Henriquez | 101060 |
| UHo | Universidad de Holguin | 101069 |

## Appendix 7 Consent form of voluntary participation

UNIVERSITY OF WEST LONDON

**Consentimiento de participación**

Título del proyecto: "Desarrollo de redes de investigación en ciencia y tecnología globales: formación de redes en la comunidad científica cubana en Europa".

Usted está invitado a tomar parte en el proyecto de investigación que lleva a cabo Miriam Palacios-Callender, de University of West London. Antes de decidir si desea o no participar en este estudio es importante que usted conozca más información sobre el proyecto y sobre lo que esperamos de su participación. El estudio investiga la demografía, los esquemas de colaboración y el desempeño de los cubanos que trabajan en instituciones europeas de ciencia y tecnología. El estudio también incluye un grupo de control de científicos que trabajan en instituciones de ciencia y tecnología en Cuba.

Usted ha sido seleccionado por ser un investigador activo. Para nuestro estudio, esto se define como aquel científico que haya publicado en la mayoría de los años entre 1995-2014 o que haya publicado anualmente en los últimos cuatro años analizados (1995-2014).

Su participación en esta entrevista, de carácter cualitativo, complementará el análisis cuantitativo ya realizado y en el que se utilizaron instrumentos de análisis bibliométrico y de redes sociales para evaluar la colaboración científica.

**Para aclarar sus dudas sobre este proyecto por favor contacte a:**

- Miriam Palacios-Callender, investigadora asociada

  Correo electrónico: Miriam.Palacios-Callender@uwl.ac.uk

- Prof, Stephen A. Roberts, Profesor Asociado (Gerencia de Información) y tutor

  Correo electrónico: Stephen.Roberts@uwl.ac.uk

Su participación en este proyecto es voluntaria y no remunerada. Usted puede abandonar su participación en el estudio en cualquier momento y sin consecuencias. Igualmente, usted tiene el derecho de no responder preguntas, sin tener que dar razones. Si decide abandonar el estudio toda la información que usted ha ofrecido será destruida. Su participación en el estudio y en cualquier futura publicación es totalmente anónima y confidencial.

Su firma a continuación indicará que usted acepta a participar en este estudio titulado: "Desarrollo de redes de investigación en ciencia y tecnología globales: movilidad, migración y formación de redes en la comunidad científica cubana". (título en inglés: "Developing research networks in global science and technology: networking in the Cuban scientific community in Europe").

Nombre - ____________________________________Firma__________________________________

Fecha ____________________

Muchas gracias por su participación en este estudio.

# Appendix 8 Participant Information Sheet: Cuba 2015 (chapter 4, section 4.5.3,a)

UNIVERSITY OF WEST LONDON

Título original: **Developing research networks in global science and technology: mobility, migration and networking in the Cuban scientific community**

**Guía de entrevistas**
**(Versión en Español)**

**Desarrollo de redes de investigación en ciencia y tecnología globales: movilidad, migración y formación de redes en la comunidad científica cubana**

Investigadora: Miriam Palacios-Callender, estudiante de PhD
Tutor: Prof. Stephen A. Roberts
University of West London

**Visita a Cuba (29 de enero – 13 febrero 2015)**

Durante su visita a Cuba, la investigadora Miriam Palacios-Callender debe conducir una serie de entrevistas con el objetivo de complementar, con datos cualitativos, el estudio bibliométrico sobre un grupo de control de científicos cubanos que laboran en instituciones cubanas de ciencia y tecnología (llamados en este estudio CRiC – Cuban Researchers in Cuba).

Los datos cualitativos se obtendrán a partir de entrevistas semiestructuradas, a un mínimo de 10 científicos provenientes del grupo de control de 100 investigadores destacados por el número de artículos publicados y registrados en la base de datos Scopus. La información generada a partir de estas entrevistas proporcionará material de interés a considerar en las entrevistas al grupo de estudio de científicos cubanos que trabajan en instituciones europeas de ciencia y tecnología (llamados en este estudio CRiE – Cuban Researchers in Europe).

**Esquema de trabajo**

1. Identificar posibles científicos a entrevistar, seleccionados a partir de una lista de 20 CRiC, teniendo en cuenta la disponibilidad de los mismos durante el período de la visita.
2. Documentación: Disponer de una versión impresa de los datos bibliométricos de cada uno de los 20 científicos seleccionados, para conformar las preguntas específicas en



1. las que se refleje la colaboración internacional (especialmente con instituciones europeas), o en las que CRiE sean autores o coautores.
2. Lugar de la entrevista: Las entrevistas se llevarán a efecto en el lugar de preferencia del entrevistado. Alternativamente, las entrevistas pudieran celebrarse en cualquiera de las instituciones que han manifestado interés en el proyecto (instituciones colaboradoras) y que tengan una ubicación favorable en cuanto a transporte (por ejemplo, el Centro de Estudios Demográficos – CEDEM-, Universidad de La Habana).
3. Aspectos éticos: Antes de iniciar la entrevista se le ofrecerá al entrevistado el documento de consentimiento. Este documento describe el objetivo de la entrevista e incluye un resumen del proyecto de investigación. Adicionalmente, se le ofrecerá una versión digital de la publicación VISTAS 2012, que contiene una información ampliada sobre el proyecto.
4. No se ha previsto grabar las entrevistas por motivos prácticos. En su lugar se le ofrecerá a los entrevistados un resumen de sus respuestas a las preguntas formuladas.

De esta forma, el proceso se concluirá al final de la entrevista para evitar la necesidad de volver a reunirse para obtener el consentimiento sobre la información recogida.

**Objetivos específicos**

Obtener información cualitativa en relación con la experiencia personal de los científicos (CRiC) en la colaboración científica internacional y nacional; así como al papel que han desempeñado en el desarrollo de la ciencia, la tecnología y la innovación en Cuba (Parte I). Se incluirá además, un aspecto particular de la colaboración científica internacional relacionado con la comunicación/colaboración con científicos cubanos residentes en Europa (CRiE) (Parte II). La Parte III ofrece al entrevistado la oportunidad de brindar otros criterios sobre el tema.

**Preguntas**

**Parte I**

1. Nombre de la universidad donde obtuvo su grado universitario, título obtenido y nombre de la facultad o escuela. Si estudió en el extranjero, podría describir el proceso antes, durante y después de la obtención de su título universitario? Qué tipo de vínculos ha mantenido o mantiene con dicha institución de educación superior o académica?

En qué institución obtuvo su grado científico y año. Si estudió en el extranjero, podría describir el proceso antes, durante y después de concluir sus estudios? (Pregunta abierta para explorar experiencias durante la estadía en el exterior -aspiraciones, frustraciones, problemas familiares, etc.-). Las relaciones de



1. cooperación continúan, se interrumpieron o cumplieron su objetivo y por tanto la colaboración terminó (carácter temporal)?
2. En su caso particular, cómo evolucionó la colaboración científica internacional desde que usted se inició como investigador? Cómo cree que se conformó dicha colaboración? Fue acorde a tendencias internacionales, a necesidades nacionales, o a ambas?
3. En la escala de 1 a 10 (donde 1=mínimo y 10 =máximo), qué valor atribuye al impacto que la colaboración internacional ha tenido en el desarrollo científico de Cuba? Cómo ha sido su evolución en el tiempo o en determinados períodos? Experiencias personales.
4. En la escala de 1 a 10 (donde 1=mínimo y 10 =máximo), qué valor atribuye a la colaboración internacional y cuál sería su principal objetivo? Cómo ha sido su evolución en el tiempo o en determinados períodos? Experiencias personales.
5. Qué le ha motivado a conducir o a participar en trabajos de colaboración internacional cuyos resultados se han reflejado en sus publicaciones? Por ejemplo, complementar o compartir capacidades en cuanto a conocimiento, acceso a materiales o muestras, apertura a otras disciplinas y/o recursos específicos no disponibles en Cuba.
6. Cómo conoció o se puso en contacto con su contraparte extranjera: en congresos nacionales, internacionales, a partir de publicaciones especializadas, búsqueda en internet, o fue usted contactado por la contraparte extranjera? Qué beneficios han aportado los miembros de la contraparte extranjera? Por qué piensa que lo prefieren a usted?
7. Cómo mantiene la comunicación con su contraparte a lo largo de la duración del proyecto de investigación? En términos de contenido: por ejemplo, intercambio de datos, evaluación de resultados, escritura del borrador del documento. En términos de forma o vías: a través de correos electrónicos, correspondencia convencional, por teléfono o personalmente.
8. En cuanto a la colaboración internacional, pudiera comentar acerca de la relevancia de las instituciones europeas en contraposición a las instituciones latinoamericanas o de Estados Unidos, en su esfera de actividad científica?
9. Cómo ha sido la distribución de los gastos entre las instituciones participantes en el proyecto? Responsabilidades de las partes.
10. Cómo cree que se refleja en sus publicaciones el grado de colaboración nacional e internacional? Comente sus experiencias positivas y/o negativas.
11. A partir de la información sobre sus publicaciones aparecida en la base de datos Scopus, pudiera precisar:
1. Cuántos de sus artículos no aparecen en el listado entregado? Cuántos les han sido atribuidos erróneamente? Comente cualquier otro error que haya detectado.
2. Cuáles de sus artículos considera que constituyen su mayor contribución a la ciencia y a la sociedad hasta el presente?
3. Cree que a estos artículos se les ha dado una cobertura apropiada y que han sido citados adecuadamente en la literatura científica internacional? En caso negativo, qué factores considera que han influido en esto?



**Parte II**

1. Conoce usted la contribución de científicos cubanos radicados en Europa (CRiE) en su especialidad?
2. Qué tipo de colaboración o comunicación mantiene con ellos?
3. Mantiene comunicación o recibe cooperación de otros CRiE no relacionados directamente con su campo de investigación pero que entienden sus necesidades o requerimientos profesionales?
4. Cómo ve el futuro de la colaboración entre los científicos cubanos en el país y los que residen en el exterior? (Pregunta abierta para explorar ideas, limitaciones, riesgos, oportunidades)

**Parte III**

El entrevistado tiene la posibilidad de expresar cualquier idea relevante al tema que considere que no ha sido tratada en el cuestionario.

# Appendix 9 Names of Cuban institutions -1 (chapter 5, section 5.2.1)

Institutions in Central group (in Spanish), abbreviations and categories

1. Universidad de la Habana, UH (HE&R)
2. Instituto de Medicina Tropical Pedro Kourí, IPK (R&S)
3. Centro de Ingeniería Genética y Biotecnología, CIGB (R, D&P)
4. Centro Nacional de Investigaciones Científicas, CNIC (R&D)
5. Universidad Central de Villa Clara, UCLV (HE&R)
6. Centro de Inmunología Molecular, CIM (R, D&P)
7. Centro Internacional de Restauración Neurológico, CIREN (R&S)
8. Instituto de Neurología y Neurocirugía, INN (R&S)
9. Hospital Hermanos Amejeiras, HHA (R&S)
10. Instituto Finlay de Investigación y Producción de Vacunas y Sueros, IF (R, D&P)
11. Centro de Química Farmacéutica, CQF (R&D)
12. Centro de Neurociencias de Cuba, CNC (R, D&P/S)
13. Universidad de Oriente Patricio Lumumba, UO (HE&R)
14. Instituto Superior de Ciencias y Tecnologías Aplicadas, InSTEC (HE&R)
15. Centro Nacional de Sanidad Agropecuaria, CENSA (R, D&P/S)
16. Instituto de Oncología y Radiobiología, INOR (R&S)
17. Instituto Superior de Ciencias Médicas de La Habana, ISCM-H (HE&ResMed)
18. Centro de Inmuno Ensayo, CIE (R, D&P)
19. Instituto de Nefrología Abelardo Buch López, IN-ABL (R&S)
20. Universidad de Matanzas Camilo Cienfuegos, UM-CC (HE&R)

Institutions in Middle group(in Spanish), abbreviations and categories

1. Centro de Investigaciones Biológicas, CIB (R, D&S)
2. Instituto Nacional de Endocrinología y Enfermedades Metabólicas, INEEM (R&SH)
3. Centro Nacional para la Producción de Animales de Laboratorio, CENPALAB (R, D&P)
4. Instituto Superior de Ciencias Básicas y pre-Clínicas V. Girón, ISCMpC (HE&R)
5. Centro Nacional Coordinador de Ensayos Clínicos, CENCEC (R&S)
6. Instituto de Cardiología y Cirugía Cardiovascular,(ICCC) (R&SH)
7. Instituto Nacional de Gastroenterología, ING (R&SH)
8. Instituto Nacional Hematología e Inmunología, INHI (R&SH)
9. Instituto de Cibernética, Matemática y Física, ICIMAF (R&D)
10. Centro Nacional de Genética Médica, CNGM (R&SH)
11. Instituto Cubano de Oftalmología, ICO-RPF (R&SH)
12. Centro de Investigaciones Médico Quirúrgicas, CIMEQ (R&SH)
13. Centro de Investigaciones y Asistencia Médica para Ataxia Cubana, CIRAH (R&SH)
14. Instituto Cubano de Investigaciones de los Derivados de la Caña de Azúcar, ICIDCA (R&D)
15. Instituto de Ecología y Sistemática, IES (R&D)
16. Centro de Bioactivos Marinos, CEBIMAR (R&D)
17. Centro de Estudios Aplicados al Desarrollo Nuclear, CEADEN (R&D)
18. Estación Experimental para Caña de Azúcar, Cienfuegos, EECA-C (R, D&P)
19. Instituto Superior Politécnico José Antonio Echeverría, ISPJAE (HE&R)
20. Instituto de Medicina Militar, IMM-LDS (HE&R)
21. Hospital Universitario -Gustavo Aldereguía, HU-GAL (R&GH)
22. Centro de Protección e Higiene de las Radiaciones, CPHR (R&S)
23. Dirección Nacional del MINSAP, DN-MINSAP (R&S)
24. Centro de Investigación y Desarrollo de Medicamentos, CIDEM (R&D)
25. Centro Nacional de Biopreparados, BIOCEN (R, D&P)

# Appendix 9 Names of Cuban institutions -2 (chapter 5, section 5.2.1)

## Institutions in the Distal group (continuation)

1. Centro de Isótopos, CENTIS (R, D&S)
2. Centro Nacional de Bioinformática, NBioC (S&T)
3. Escuela Latinoamericana de Salud Pública, ELAM (R, D&P)
4. Universidad de Ciego de Avila, UNICA (HE&R)
5. Universidad de Cienfuegos, UCF (HE&R)
6. Universidad de Pinar del Río, UPR (HE&R)
7. Universidad Agraria de la Habana y Colegio de Medicina Veterinaria, UACMV (HE&R)
8. Instituto de Oceanología, IO (S&T)
9. Instituto de Geografía Tropical, IGT (S&T)
10. Centro de Ingeniería Genética y Biotecnología-Camagüey, CIGB-Ca (R,D&P)
11. Centro de Ingeniería Genética y Biotecnología-Sancti Spiritu, CIGB-SS (R,D&P)
12. Centro de Reproducción de la Ictiofauna Indígena, CRII (S&T)
13. Centro de Investigaciones de Ecosistemas Costeros, CIEC (S&T)
14. Centro de Estudios Ambientales de Cienfuegos, CEACi (S&T)
15. Centro de Desarrollo de Equipos e Instrumentos Científicos, CDEIC (R&D)
16. Centro de Investigaciones para la Mejora Animal, CIMA (R&D)
17. Centro de Investigaciones Clínicas, CIC (R&S)
18. Instituto de Angiología y Cirugia Vascular, IACV (R&SH)
19. Instituto Nacional de Higiene, Epidemiología y Microbiología, INHEM (R&S)
20. Centro Nacional de Txicología, CNT (R&SH)
21. Instituto Nacional de Investigación Fundamental en Agricultura Tropical, INIFAT (S&T)
22. Agencia para la Generación de Conocimiento y Tecnología, AGCT (S&T)
23. Museo de Historia Natural Tomás Romay, BIOECO (S&T)
24. Centro de Ingeniería Ambiental-Camagüey, CIA-Ca (S&T)
25. Instituto de Salud Vegetal, ISV (R&D)
26. Instituto de Ciencia Animal, ICA (R&D)
27. Escuela Nacional de Salud Pública, SNSP (HE&R)
28. Instituto Superior de Ciencias Médicas de Villa Clara, ISCM-VC (HE&R)
29. Instituto Superior de Ciencias Médicas de Matanzas, ISCM-Ma (HE&R)
30. Instituto Superior de Ciencias Médicas de Camagüey, ISCM-Ca (HE&R)
31. Instituto Superior de Ciencias Médicas de Santiago de Cuba, ISCM-SC (HE&R)
32. Instituto Superior de Ciencias Médicas de Bayamo, ISCM-Ba (HE&R)
33. Instituto de Nutrición e Higiene de Alimentos, INHA (R&D)
34. Centro Iberoamericano para la Tercera Edad, CITED (R&SH)
35. Instituto de Medicina Legal, IML (R&SH)
36. Instituto de Medicina del Deporte, IMD (R&SH)
37. Centro de Referencia para Investigaciones de Artereosclerosis, CRIA (R&SH)
38. Centro Nacional de Referencia de Anatomía Patológica, CNRAP (R&SH)
39. Laboratorio de Investigaciones sobre SIDA, LISIDA (R&SH)
40. Centro de Genética Médica _Holguín, CGM-Ho (R&SH)
41. Centro de Investigación sobre Enfermedades Infecciosas, CIEI (R&SH)
42. Hosp. Clínico Quirúrgico Doc. M. Asunce Domenech- Camagüey, HCQD-Ca HE&SH)
43. Hospital Universitario Provincial A. Milán Castro-Santa Clara, HUP-VC (HE&SH)
44. Escuela de Medicina de la Habana, Hosp. Julio Trigo, EMJT-H (HE&SH)
45. Hospital General Docente Dr. Ernesto Guevara Serna, Las Tunas, HGD-EGS-H (HE&SH)
46. Hosp. Prov. Doc. Clínico Quirúrgico A. Luaces Iraola, Ciego de Avila, HPDCQ-CiAv (HE&SH)
47. Hospital Universitario "Gral. Calixto García", HU-GCG (HE&SH)
48. Hospital General Docente "Carlos J. Finlay", HGD-CJF (HE&SH)
49. Hospital Universitario "Cmdte. Faustino Pérez", HU-CFP (HE&SH)
50. Hospital General Docente Matanzas"J. R. López Tabranes", HGDMa-JRLT (HE&SH)
51. Hospital General Docente Enrique Cabrera, HGD-EC (HE&S)

# Appendix 9 Names of Cuban institutions -3 (chapter 5, section 5.2.1)

## Institutions in the Distal group (continuation)

52. Hospital Pediátrico Universitario “Pedro Borras”, HPU-PB (HE&SH)
53. Hosp. Pediátrico Universitario-Cienfuegos “P. González Cueto”, HPU-PGC-Ci (HE&SH)
54. Hosp. General Docente-Las Tunas “Guillermo Domínguez”, HGD-GD-LT (HE&S)
55. Facultad de Ciencias Médicas “Dr. Miguel Enríquez”, HGD-DME (HE&S)
56. Hospital Docente Clínico Quirúrgico “10 de Octubre”, HCQD-DO (HE&SH)
57. Hospital Pediátrico Docente-Villa Clara “José Luis Miranda”, HPD-VC (HE&SH)
58. Hospital Clínico Quirúrgico Docente “Dr. Salvador Allende”, HCQD-DSA (HE&SH)
59. Hospital Pediátrico Universitario “Juan Manuel Márquez”, HPU-JMM (HE&SH)
60. Facultad de Medicina Finlay-Albarrán, Marianao, HGD-FAM (HE&SH)
61. Clínica Dental Docente “Raúl González Sanchez”, CDD-RGS (HE&SH)
62. Clínica Dental Docente de Bauta, CDD-B (HE&SH)
63. Hosp. Clínico-Quirúrgico Doc. “Cmdte. Manuel Fajardo”, HCQD-MF (HE&SH)
64. Hosp. Quirúrgico Universitario-Pinar del Río “Abel Santa Maria”, HCQD-PR (HE&SH)
65. Hosp. General Docente-Holguín“Vladimir Ilich Lenin” HGD-Ho (HE&S)
66. Hosp. General Docente- Bayamo “Carlos Manuel de Céspedes”, HGD-Ba (HE&S)
67. Policlínico Docente- Camagüey “José Martí”, PD-Ca (HE&S)
68. Hospital Pediátrico de Camagüey, HP-Ca (S)
69. Cardiocentro-Santa Clara “Ernesto Che Guevara”, CC-VC (SH)
70. Hospital Gineco-Obstétrico “Eusebio Hernández”, HGO-EH (SH)
71. Hospital Materno América Arias, HMAA, (S)
72. Hospital Pediátrico de San Miguel del Padrón, HPSMP (SH)
73. Hospital Pediátrico “William Soler”, HPWS (SH)
74. Hospital Neumológico Nacional Benéfico Jurídico, HNNBJ (SH)
75. Hospital Psiquiátrico “Eduardo Bernabé Ordaz”, HPsEBO (SH)
76. Hospital Psiquiátrico “Gali Garcia”, HPsGG (SH)
77. Hospital Provincial de Ciego de Avila, HP-CiA (S)
78. Clínica Central “Cira García”, CCCG (SH)
79. Hospital Infantil Sur- Santiago de Cuba, HIS-SC (SH)
80. Hospital Gíneco-Obstétrico “América Arias”, HGO-AA (SH)
81. Hospital_Santiago Cuba “Conrado Benítez” HCB-SC (S)
82. Hospital Gíneco-Obstétrico “R. González Coro” HGO-RGC (SH)
83. Hospital Pediátrico “Leonor Pérez”, HP-LP (SH)
84. Hospital “Freire de Andrade”, HFA (S)
85. Hospital de Camagüey “Maria Curie”, HMC-Ca (S)
86. Hospital de Villa Clara “Celestino Hernández Robau”, HCHR-VC (S)
87. Hospital de Camagüey “Amalia Simoni”, HAS-Ca (S)
88. Hospital Rural de Limonar, Matanzas HRL-Ma (S)
89. Hospital de la Isla de la Juventud “Héroes de Baire”, HHB-IJ (S)
90. Policlínico de la Isla de la Juventud “Orestes Falls Oñat”, POFO-IJ (S)
91. Policlínico de la Isla de la Juventud “J. M. Páez Incháustegu”, PJMPI-IJ (S)
92. Policlínico de la Isla de la Juventud “Leonilda Tamayo Matos”, PLTM-IJ (S)
93. Centro de Atención Primaria de Salud “Corynthia”, CAPS (S)
94. Policlínico “26 de Julio”, PVJ (S)
95. Hospital Pediátrico de Centro Habana, HPCH (SH)
96. Clínica Dental de Caimito, CDC (S)
97. Policlínico “19 de Abril”, PDA (S)
98. Hospital Pediátrico de Centro Habana, HPCH (SH)
99. Sociedad Cubana de Esclerosis Múltiple, SCEM (R&SH)
100. Laboratorio Central de Criminalística, LCC (R&SH)
101. Centro de Control Estatal de Equipos Médicos, CCEEM (R&S)
102. Centro Nacional para el Control Estatal de la Calidad de los Medicamentos, CECMED (
103. Centro Nacional de Información de Ciencias Medicas, CNICS (S)
104. Centro de Protección e Higiene del Trabajo, CNPHT (R&SH)
105. Centro Nacional para la Educación y Promoción de Salud, CNPES (S)
106. Centro para el Desarrollo de la Epdemiología, CDE (R&SH)
107. Unidad Nacional de Salud Ambiental MINSAP, UNASA (R&S)
108. Centro Prov. Santiago de Cuba de Salud Pública y Epidemiología, CPE-SC (R&SH)

## Appendix 9 Names of Cuban institutions -4 (chapter 5, section 5.2.1)

## Institutions in the Distal group (continuation)

109. Centro Provincial de Epidemiología y Higiene, Camagüey, CPHE-Ca (R&SH)
110. Centro Provincial de Epidemiología y Higiene, Habana, CPHE-H (R&SH)
111. Centro Provincial de Epidemiología y Higiene, Villa Clara, CPHEVC (R&SH)
112. Centro Provincial de Epidemiología y Higiene, Ciego de Avila, CPHE-CA (R&SH)
113. Centro Provincial de Epidemiología y Higiene, Santi Spíritus, CPHE-SS (R&SH)
114. Centro Provincial de Homeopatía, Granma, CPH-G (S)
115. Centro Provincial de Homeopatía, Holguín, CPH-H (S)
116. Centro Provincial de Genética Médica-Habana, CPGM-H (R&S)
117 Unidad Prov. de Vigilancia y Lucha Antivectorial, Sancti Spíritu, LAV-SS (S)
118. Unidad Prov. de Vigilancia y Lucha Antivectorial, Santiago de Cuba, LAV-SC (S)
119. Centro Municipal de Higiene y Epidemiología de Bayamo, CMHE-Ba (S)
120. Centro Municipal Vigilancia y Lucha Antivectorial de Boyeros, CMLA-H (S)
121. Centro Municipal Higiene y Epidemiología de Guanabacoa, CMHE-G (S)
122. Centro Municipal de Higiene y Epidemiología de Holguín, CMHE-Ho (S)
123. Centro Municipal de Higiene y Epidemiología de Regla, CMHE-R (S)
124. Centro Municipal de Higiene y Epidemiología de Habana Vieja, CMHE-HV (S)
125. Centro Municipal de Higiene y Epidemiología de Centro Habana, CMHE-CH (S)
126. Centro Municipal de Higiene y Epidemiología de Boyeros, CMHE-Bo (S)
127. Unidad Prov. Vigilancia y Lucha Antivectorial, Cumanayagua, Cienfuegos, LAC-Ci (S)
128. Centro Municipal de Higiene y Epidemiología de Playa, CMHE-Pl (S)
129. Centro Municipal de Higiene y Epidemiología de Isla de la Juventud, CMHE-IJ (S)
130. Grupo Empresarial Agromin, GEA (P)
131. Empresa Importadora y Exportadora de Medicamentos y Equipos Médicos, MEDICUBA (S)
132. Laboratorios Biológicos Farmacéutico, LABIOFAM (P)
133. Laboratorios Farmacéutico, AICA (P)
134. Laboratorios MedSOL, MEDSOL (P)
135. Laboratorio de Anticuerpos y Biomodelos Experimentales, LABEX (P)
136. Centro de Química Biomolecular Antígenos Sínteticos, CQB (R&D)
137. Grupo Empresarial de Producciones Biofarmacéuticas y Químicas, GEPBQ (R&D)
138. Laboratorios Farmacéuticos LIORAD, LIORAD (P)
139. Centro de Investigaciones Científicas de la Defensa Civil, CICDC (R&S)
140. Instituto de Investigaciones de Raíces Tropicales, INIVIT (R&D)
141. Instituto de Investigaciones de la Caña de Azúcar, INICA (R&D)
142. Instituto Nacional de Investigación de Sanidad Vegetal, INISAV (R&D)
143. Instituto de Investiagciones del Tabaco, IIT (R&D)
144. Cooperativa Agrícola "Osvaldo Sánchez", Güines, CAIOS-G (P)
145. Estacion Experimental Apícola "El Cano", EEA (R&D)
146. Instituto Nacional de Ciencias Agrícolas, INCA (R&D)
147. Centro Nacional de Epizootiología, Diagnóstico e Investigación, CNEDI (R&D)
148. Institute de Medicina Veterinaria, IMV (R&D)
149. Centro Nacional de Parasitología Animal, CNPA (R&D)
150. Parque Zoológico Nacional, PZN (R&S)
151. Instituto de Investigaciones para la Industria Alimenticia, IIIA (R&D)
152. Centro de Investigaciones Pesqueras, CIPq (R&D)
153. Centro de Investigaciones del Petroleo, CIPt (R&D)
154. Grupo para el Desarrollo Integral de la Ciudad, GGIC (R&D)
155. Centro de Investigación y Desarrollo del Comercio Interior, CIDCI (R&D)
156. Empresa Nacional de Geofísica, ENGf (P)