

The university in the innovation system. A case study on the interactions between university and biotechnology industry in Cuba

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Abstract

This paper is related to two subjects that literature on national innovation systems has considered relevant. One is the relations between public research organizations and industry, and the other is the role of universities in the economic and social development.

In this paper we study a particular case of university-industry interaction. The Center for Protein Studies of the University of Havana is a research institution with relevant scientific results, well connected with international networks, that has established a bi-directional interchange channel with the Center of Molecular Immunology, one of the most important high tech enterprises of the biotechnological industry of Cuba.

We studied the characteristics of those interactions: drivers and motivations, barriers, channels, benefits and risks. At the end we summarize the lessons learned. We assume that they are important for Science, Technology and Innovation's Policy in Cuba.

Key words: university, industry, biotechnology, science-based innovation.

Introduction

This paper is related to two subjects that literature on national innovation systems has considered relevant. One is the relations between public research organizations (PROs) and industry, and the other is the role of universities in the economic and social development.

An issue which is becoming very important in the literature regarding these subjects is if innovation can generate not only economic benefits, but most of all inclusion, equity, and social justice.

This contribution is related also with a practical matter: the transformations that are taking place nowadays in Cuba regarding the national Science, Technology and Innovation Policy (STIP), and particularly the debate on the role of universities in STIP.

These topics are examined through a case study about the interactions of a research Center of the University of Havana, the Center for Protein Studies (CEP) and the Center of Molecular Immunology (CIM), an enterprise of the biotechnology industry in Cuba.

Both CEP and CIM are part of a process of building scientific and technological capacities that has been taking place in Cuba during the last five decades. To understand this we have to take into account the transformations that experienced higher education in the 1960's, in which the University Reform played a very important role by incorporating research and high-level training into the university life and thus establishing the institutional basis of university science.

This occurred in the context of profound political and economic transformations with high popular support. The scientific community took as its own the purposes of the political project that science should contribute to the economic and social development of the country. As we will demonstrate further on, these shared values are relevant to the interactions between CIM and CEP.

At the late 80s and the 90s important transformations occurred in the National Science and Technology Policy (Núñez and Montalvo, 2014) that affected both organizations.

On the one hand, university science shifted towards innovation in order to create new groups, new incentives increasing the interactions with the productive sector and on the other the country gave an extraordinary impulse to biotechnology oriented to the medical-pharmaceutical industry, in order to satisfy internal demands of the Cuban health care system and to increase their share in national exports with high added value.

The development of both Centers has taken place in a complex context of Cuban economy, where the financing for research has been very scarce.

Finally they participate on the debate about STIP mentioned oriented to support a national innovation system capable of satisfying social demands and economic

development. There are very few studies on Cuban experiences on science, technology and innovation. This is why we envisage that this paper could be of interest to policy makers.

Can developing countries generate science-based innovation, through interactions between university and industry? What are the characteristics of those interactions: drivers and motivations, barriers, channels, benefits and risks?

It is difficult to generalize, but this case offers some evidence that allow us to propose some useful lessons for the current debate.

Our work is a descriptive research based on documentary studies, interviews, and, most of all, the authors' participant observation; given that some of them are researchers directly involved in these institutions and the other an academic scholar on social studies of science, technology and innovation.

The paper presents the conceptual and methodological references in which we based our work. Then we characterize the two institutions involved and later we identify the motivations, drivers and motivations, benefits, barriers and risks we observed in the interaction process. Finally we identify some lessons learned.

The role of university in the innovation system. Conceptual framework and policy debates

In Cuba innovation was included as part of the Science and Technology Policy in 1994 with the creation of the Ministry of Science, Technology and Environment. Some political definitions were adopted that emphasized on innovation and reinforced the role of research institutions to attain a recovery of the country's economy. It was expected that increasing the use of science and technology Cuban enterprises would increase their efficiency, productivity and competitiveness, so as to modernize Cuban economy and improve its position internationally.

The model was named "System of Science and Technological Innovation (SCIT)" and conceded great importance to the sector of research and development (R&D). This is an example of what has been called as a narrow perspective of innovation systems (Lundvall, 2007;Lundvall, Jang and Chaminade, 2009¹).

¹ "Innovation system research has taken two different perspectives, a narrow one, equating innovation to science and technology, and a broader one encompassing learning, innovation and competence building at different levels of aggregation" (Lundvall et.al,

The most relevant advances were obtained in the biotechnology industry. In other sectors and institutions they are fewer².

In Cuba universities play an important role in the innovation system (Núñez, et. al, 2011a). They carry out an important part of the country's R & D activities, provide university graduates, contribute to support local development strategies, and ensure postgraduate education in relevant areas for the country's development. For example, around 20% of the PhD's that University of Havana (UH) graduates annually, are of interest for the biotechnology sector. Hundreds of scientists, technicians and other university graduates of the biotechnology industry have been trained and graduated in masters programs offered by UH, as well by other universities. Higher Education has designed and implemented training programs to response needs of the biotech industry, as Biomedical Engineering. Great amount of university graduates in Chemistry, Biology, Biochemistry, Microbiology, Pharmacy and related engineers are working in biotech institutions.

However, there are very few studies regarding the interactions between industry and universities (Pérez y Núñez, 2009; Núñez, et.al, 2011b).According to Dutrénit (2010) there is a lot of evidence of the benefits that the interactions between public research organizations (PROs) and industry produce for both of them. But, as Arza (2010) has mentioned, the majority of the theoretical and empirical studies are based on developed countries experiences (Perkmann and Walsh, 2007;Bekkers, and BodasFreitas, 2008) and there are less studies related to developing countries³.This explains Globelics (Global Network for Economics of Learning, Innovation and Competence Building Systems) interest in developing the comparative project: "Interactions between universities and firms: Searching for paths to support the changing role of universities in the South". This paper contributes in some way to that purpose.

2009, p.2). These authors criticize the Triple Hélix approach because it contributes to a narrow understanding of the innovation system.

²An evaluation of the results of SCTI in Cuba might be found in Núñez y Montalvo, 2014. It is mentioned that the results of two innovation surveys taken place in 2004 and 2006 reveal a weak interaction between the enterprise sector and the knowledge production sector.

³In the case of universities there are interesting contributions, for example: Simón Schwartzman (ed.): Universidad y desarrollo en Latinoamérica: experiencias exitosas de centros de investigación .IESALC, Caracas, 2008.

Arza (2010) correctly states that these studies in developing countries must take into account some particularities. For example, if those interactions contribute or not to attend socio-economic needs proper of those countries as poverty, inequity, deficient education and health systems, among others. As it is known, market demands frequently differ from the most urgent social needs of the majorities. This is an important worry of studies on innovation nowadays (Bortagaray, I y Ordóñez-Matamoros, 2012; Cassiolato, J y H. Lastres, 2013; Sutz, 2010; Johnson, B. y A. D. Andersen, eds., 2012).

Furthermore, the average technological dynamism of firms in developing countries is much less (Arza, 2010). They have reduced absorptive capabilities and prefer to import technologies, instead of creating them. This is an old problem which includes economic but also political and cultural issues (Sabato and McKenzie, 1982).

Another peculiarity of developing countries is that frequently universities are not directly involved in the economic and social development of their countries, for instance, by means of R&D agendas correctly oriented towards that objective. In Latin America, for example, since the 90s university-enterprise linkage is being emphasized, but still with minor results.

In our study we will explore whether some of these characteristics are present or not.

The other conceptual subject that encourages our work is “models of universities”. Regarding this issue, authors related to Globelics (Brundenius, Lundvall and Sutz, 2009) have defended the concept of “Developmental University System”. These authors prefer this concept instead of others like “Third Mission” and “Entrepreneurial universities”. 'Third Mission' is related to different ways of conceiving the relationships of universities and the society to which they belong. They argue that notion of third mission has a strong normative bias: it has not yet been naturalized as the other two university missions” (p. 312). On the other hand, “Entrepreneurial universities”, although with various meanings, is usually related to the idea of ‘capitalisation of knowledge’, proper of the model of “Triple Helix” (Etzkowitz, 2004; Etzkowitz and Leydesdorff, 2000)

The Developmental University System (DUS) is related to a broad view of innovation system that not only considers R&D activities and their institutions, but includes knowledge, interactive learning as different type of organizations do, named as DUl: Doing, Using and Interacting mode of innovation (Ibid). DUS must be an open system, which interacts with society. Its guidance cannot be profit and its main objective must be to contribute to the economic and social development.

Its objective is to promote innovation with justice, equity and inclusion. It needs to be conceived as a tool for development. The authors suggest it should not be restricted to developing countries.

Even though in this approach named DUS the universities play different roles it is always important to differentiate their contributions with respect to those played by other institutions. On the one hand, the approach suggests the need of a differentiation between universities: some may be hubs in a global knowledge network while others can be hubs in national and regional networks, more oriented to the solution of local problems (Ibid, p.326).

Furthermore universities should be capable of responding in a short term basis to the societies needs and also keep some degree of autonomy with long term objectives.

Finally, DUS should be sustained in the commitment and motivations of its teachers and researchers. Shared values are a key factor. The most important is that the academic and scientific community feels socially useful (Ibid p.331) and that the institutions support them.

In Cuba, our idea of the role of universities in the innovation system is very close to the DUS approach. Universities are oriented to satisfy development needs.

Our model is based on the conjunction of attaining academic excellence, combined with social relevance, which is social impact. Only then we can talk about high quality university performance, the one that proves to be pertinent and oriented to satisfy social needs.

Universities plan their goals, objectives, and activities in the long, medium and short term plans. One of the key factors in this projection is the economic and social impact of universities, including the impact of science, technology and innovation, as well as training of human resources, among others.

We have identified the following roles of university in the system of innovation:

- Provides university graduates.
- Ensures postgraduate education.
- Carries out an important part of the country's R & D activities.
- Participates in the construction of the country's economic and social policies
- Undertakes the training of executives
- Contributes to support local development

In this paper we study a particular case of university-industry interaction. The Center for Protein Studies (CEP) of the University of Havana is a research institution with relevant scientific results, well connected with international networks, that has established a bi-directional interchange channel with the Centre of Molecular Immunology (CIM), one of the most important high tech enterprises of the biotechnological industry of Cuba. It is, then, a science-based innovation.

In the study we used the framework developed by Arza, 2010; Dutrénit and Arza, 2010) that suggests the study of the interactions through motivations, barriers, channels, and benefits as well as risks and their relations.

In Cuba we are currently designing a new STI policy in order to favour the connections between research centres and the productive sector. In this context a very interesting debate has taken place about the role of universities (Blanco ed., 2013). The lessons learned as a result of this case study can be useful to that purpose and particularly to policy makers, as it has been already mentioned.

Additionally, this study has several peculiarities regarding international experience. Frequently the studies are based on the relations among universities and the private sector. In our case, the industry is state property. Another peculiarity is referred to the relationships between channels and benefits. The framework used points out the following: 1) service: economic benefits for public research organisations (PROs) and short term (production) for firms; 2) traditional, intellectual benefits for PROs and short term production for firms; 3) Bi-directional: intellectual benefits for PROs and long-term (innovation) for firms, and 4) commercial: economic benefits for PROs and long-term (innovation) for firms.(Arza, 2010, p.477).

The case we present confirms the importance of the bi-directional channel and shows a more complex scenario on the relationships between motivations, channels, and benefits.

Our case refers to an industry that has a high tech dynamism and combines economic benefits with attending important health care problems.

Our case also offers useful information for the debate of the role of universities in development and the role of commitment, motivation, individual and institutional values, when they are shared by the university and the productive sector.

Science at the University: the evolution of the Center for Protein Studies

The Center for Protein Studies (CEP) is a research institution belonging to The University of Havana devoted to the isolation, purification as well as the structural and functional characterization of protein and peptides mainly purified from marine

organisms. Its staff comprises around 25 full-time teachers and researchers as well as graduated students that share their time between teaching and scientific research. In terms of teaching, CEP has a tight connection with the Biochemistry Department of the Biology Faculty and takes part in the formation of the future Cuban biochemists and molecular biologists, and jointly develops postgraduate programs on Master in Science in Biochemistry and the PhD in Molecular Biosciences. CEP's staff is mainly composed of biochemists collaborating with biologists, physicists, and chemists, rendering a multidisciplinary ensemble that has provided a more integrated vision of the scientific performance. Organized around two main research directions-laboratories: *proteases and protease inhibitors* and *liposome and toxins*; CEP has also a young laboratory on Bioinformatics that complements the theoretical approach that supports the *wet* laboratories findings. Protein Immobilization and antimicrobial peptides are additional researches focuses of CEP with interesting results. Linked to these research themes, undergraduate and graduate students carry out their Diploma, Master in Science or PhD. Thesis.

CEP has enrolled in several international networks to support its activities such those CYTED-supported actions on *Enzyme technology*, *Antimalarial agents*, and more recently coordinates one network on *Toxins of interest to biomedicine*. CEP is in Cuba, the main node responsible for the network on biotechnology *Isla Negra* belonging to the *Pablo Neruda* Program, also and Iberian-American collaborative network focused on graduate education in biotechnology. Besides, CEP has developed over these years an international strategy aiming to collaborate in research and postgraduate education with top academic institutions in Europe, Canada, and Latin America. Additionally, the Center has also shown a certain efficacy in obtaining funds for research from international agencies such as the International Foundation for Science (IFS, Sweden), the International Union of Biochemistry and Molecular Biology (IUBMB), among others.

CEP as all the scientific research at the University finds its roots in the University Reform of 1962 that incorporated scientific research to the academic activity and created those science studies/careers oriented to the formation of researchers and launched the first documents on scientific policies at universities (Nuñez, 2010)

Those changes experienced by the institutionality of scientific research at universities and its orientation to a stronger connection with the productive sector can be illustrated by CEP. Its strategy and evolution has been different to other university research teams. CEP is an organism that since its very birth has focused its efforts on linking its research lines with those of the national biotech industry – nowadays gathered under the so-called Higher Organization of Enterprise Direction (OSDE) BioCubaFarma- by developing strategic research projects together with an academic formation with the highest standards.

CEP was built on the bases of the experience and research results obtained, from the beginning of the 70's, by a team of teachers from the Biochemistry Department at that time School of Pharmaceutical Biochemistry –subsequently Biology Faculty of The University of Havana, Cuba. Over this and the next decade, the development of the projects allowed accumulating experience and results on Protein Biochemistry of interest to biomedicine and biotechnology. This can be categorized as a first stage, where CEP developed novel methodologies for the purification and characterization of proteins valuable for industry, and of intense learning. An important outcome of this stage was the consolidation of experimented teacher-researchers with a clear concentration on research goals in problems of social interest, even though in the beginning we could consider this as an endogenous development stage of the group. In the 80's Cuban policy in science and technology gave a turn to innovation and in the universities this was translated into new organizations whose main mission was to establish links with the productive sector and their contribution to innovation. In 1986, the group of professors around these tasks were organized under the *Priority Objectives Group of Proteins* (GOP, in *sp*), this new organization led to a growth in scientific personnel and goals and focused to obtain novel bioproducts relevant to the society. From this point, a new stage can be defined in the development and performance of the research ensemble. In fact, over the fifteen years of GOP existence, the projects led to discovering novel proteins mainly, but not exclusively, from marine organisms with potential applications in biotechnology and biomedicine, rendering several national patents.

GOP developed a large and multidisciplinary study focused on the molecular and functional characterization of proteins, such as protease inhibitors and proteases belonging to different mechanistic classes as well as toxins with membranotropic activity that altogether contributed to the introduction of advanced technologies and to expand the knowledge in this field. This progress allowed getting national and international research projects funded, publication of scientific papers in periodicals of the mainstream, presentations in several international meetings in Cuba and abroad, as well as a strong and bi- and multilateral collaboration with research centers in Cuba including those of the biotech sector (gathered under the cluster called *Scientific Pole of Western Havana*), a growing number of institutions during this and the next decade.

The group during its development was achieving the capacitation of professionals with a high specialization level and offered several scientific-technical services. These services were carried out adjusting priorities and in a due time representing a change in the mentality and mode of assuming the scientific activity according with the nature of this "commissioned work". CEP was engaged in different tasks as the production of bio reagents for the Cuban public health system (such as enzymes

and other composites for diagnostic laboratory kits) or immobilized protein A for the purification of immunoglobulin, among others.

Improving postgraduate education was other of the missions of GOP from the beginning with particular emphasis in the qualification or re-orientation of those professionals of different profiles to the field of protein and enzymes. This stage was characterized by an intense postgraduate educational activity since the Faculty, and particularly the Biochemistry area was the natural scenario where many doctoral theses from specialists coming from the centers of the Scientific Pole were defended. This activity had two important implications, on the one hand, the contribution of the academic experience to the doctoral defense processes and on the other, the mandatory updating of academicians in frontiers and impact themes for the nascent Cuban biotechnology industry.

Furthermore, the academia became through these activities an essential link in the qualification of the personnel directly related to the biotechnology industry and contributed to reach a certain level of professional recognition. In other words, this foundational stage can be characterized by:

- Consolidation and concentration of the scientific research objectives by a group of university academics.

- Orientation of research towards the solution of social problems, but keeping focus and efforts in basic research. This stage was not exempt of mistakes related to non-well defined priorities by the social organisms or enterprises that demanded the occupation of the University team.

- Start of links with centers of the biotechnology industry through research projects.

- Contribution of Academy to postgraduate training of personnel linked to the biotechnology industry.

- The biotech industry was in its initial phase, concentrated in its own endogenous development. Their interest for the University was mainly focused on the postgraduate formation of their specialists, most of them young people.

In summary, this stage can be considered of a mutual approach, exploratory, with no long-range project consolidated yet. Perhaps, the existence of a substantial gap in the own culture of the University as how to understand the triad science-technology-innovation as compared to the biotech productive sector and the own endogenous urgencies of the productive sector performances lowed down a more dynamic and stable flow between both type of institutions.

CEP was founded in December 2000 on the bases of the teaching and research experience accumulated for more than twenty years by the group of teachers and researchers devoted to the study of protein and enzymes with the aim to expand its goals from obtaining and characterizing protein and enzymes to incorporate other advanced technologies in molecular biosciences according to the new challenges of the scientific-technical development.

In this way, it was possible to obtain chimeric or modified proteins with pre-established or improved properties to be used in biotechnology or biomedicine.

Additionally, CEP also engaged more deeply into the protein engineering techniques particularly those related to the modification of their microenvironment by immobilization.

The introduction of high throughput techniques for the identification of molecules based on protein-protein interaction and development of basic studies, essential for the structural and functional characterization of proteins, were goals after the Center foundation. From this new era, CEP becomes one of the most important reference centers of the Ministry of Higher Education in connection with the Cuban biotechnology industry.

A characteristic of CEP performance has been to focus research of the kind that Stokes (1997) included in the "Pasteur's Quadrant" which he calls "basic research oriented to application" - others prefer the term "strategic research" . This approach has allowed consolidating some leadership in certain topics and technologies and has helped to manage material limitations. In order to maintain a high scientific level, compared to the depressed growth in material resources of universities, the strategy implemented combined concentration of efforts on research lines, personnel growth and accelerated education of the newly graduates. These activities were carried out in collaboration and partnerships with centers of the so called Scientific Pole and international cooperation with institutions of high scientific standards.

It is important to note that the concentration of research efforts in those directions with social priority did not dismiss the importance of basic research as an essential support of the formers.

At this stage, the establishment of research links between the University and the representatives of the biotechnology industry begin to be more frequent, mainly from an informal perspective. However the dynamics of the industry that is working to find its own ways of self-sustenance in response to the government investment does not place among its priorities this collaboration.

One of the motivations that mobilized CEP in this approach to the productive sector was, on the one hand, the necessity of alliance with those centers centrally supported equipped with cutting edge technology and supplies to develop these and other research projects and, on the other, the transfer of experiences with potential technological outputs that did not exist in Cuba and academics had pioneered their introduction in the country, foreseeing its possible impact on the industry.

There is a long history of these meetings where efforts bearing fruit were associated not only with the potential or actual success of scientific-technological cooperation but also with the will to endorse this collaboration even in unfavorable conditions.

The Centre of Molecular Immunology in the Cuban biotechnology industry: science- based innovation

As we said before, biotechnology occupies a relevant place in Cuba's Science and Technology Policy (STP)⁴. The interest for biotechnology did not decrease in spite of the economic crisis of the 90s and the reinforcement of the blockade by the USA Government.

The highest priority has been given to biotechnology applied to the medical-pharmaceutical sector. There are also important projects oriented to agriculture, food production, livestock and environment preservation. The outcomes of biotechnology benefit the Cuban health care system and represent an increasing part of the country's exports (Núñez, et. al, 2011b).

The locus of Cuban's Biotechnology has been the Scientific Pole of the West of Havana.

According to Lage (2008), the Pole was: "an ensemble of more than 40 organizations comprising about 12,000 employees, including 7,000 scientists and engineers".

The biotechnology efforts were powered by two fundamental objectives: meeting the social needs, particularly the progress of the Cuban health care system; searching for sources of revenues from foreign markets for the national economy.

⁴ The origins of the Biotechnology Industry in Cuba and the role played by the government can be found in Limonta, 2002 and Herrera, 2008.

This explains the formidable take-off of biotech research, essentially in association with the medical-pharmaceutical sector (Núñez, et.al, 2011b). Several papers have documented this achievement (among others, Lage, 1994, 1999, 2006, 2013; Kaiser, 1998; Majoli, 2002; López et. al., 2006; López, 2007; Núñez, et. al, 2011b).

As a result of the updating of the Cuban Economic Model, in November 2012 BIOCUBAFARMA Companies Group was created clustering production and services companies from the Cuban biopharmaceutical sector, including the former Scientific Pole. This group is mainly integrated by pharmaceutical labs and plants devoted to produce drugs and chemical reagents and its objective is to produce drugs, medical equipment and offer high tech services in order to improve Cuba's health system and to create new exportable goods and services with high added value. It owns more than 40 companies and 78 production plants all over the country.

Starting from the demands of pharmaceutical products for the Cuban health care system and for foreign markets, BioCubaFarma conducts its research and development of new drugs and other products and services. They also decide their international projection, their foreign trade activities, the imports and exports of products, the technological transfer and the development of products and services⁵ (Núñez and Figueroa, 2014).

The Centre of Molecular Immunology (CIM), founded in 1994, is one of the most outstanding companies in the BioCubaFarma Group. By the end of 2014 CIM had 1136 workers, among them 514 university graduates and 406 technicians. CIM staff includes 441 PhD, 150 masters and accumulates 350 patents. In 2014 staff training achieved around 70.5 h per worker. CIM exports have increased 926 times in 20 years and its market expanded to 31 countries. They have its own commercial firm (CIMAB) registered in the Cuban Chamber of Commerce. CIMAB has shares in three joint ventures, in Spain, Singapore, and China. The annual income is over 100 million dollars due to the export of products and royalties from joint ventures abroad. There is a strong collaboration with Brazil, China, and India and a strategy to diversify the markets.

How to explain the advances of CIM?

A review of some basic ideas of the CIM work model can help us not only to understand the characteristics and advances of Cuban biotechnology, but rather to

⁵ Ministerio de Justicia de Cuba (2012). Gaceta Oficial de la República de Cuba, No. 052 Extraordinaria de 07 de diciembre de 2012.

extract interesting regularities for countries of the South who try to build economic sectors based on knowledge. Let us see some of the factors of this success (Núñez and Figueroa, 2014):

CIM emerges and develops as a social property company, in a socialist economy. Initial investment came from the government becoming the patient capital every high tech and high risk company needs to mature. In fact, in its first decade CIM worked as a budgeted organization until its economic operations brought it near to management economy.

The state intervention protected CIM from domestic competitive pressures and short-last focuses (that so much damage has caused to other countries of the south). Nevertheless, at the same time, its export strategy avoided the easygoing (that could have been possible due to excessive protection) and exposed it to the quality requirements and external competitive pressures. CIM developed a two way business strategy, on the one hand representation and commercial distribution in the markets of the South and on the other, pre-commercial agreements of licensing and co-development with the countries of the North.

Currently CIM has two clinical trials ongoing in Europe and Japan and hopefully these two products will reach the market before 2020.

The close ties with the health system allowed it to build a strategic program for therapeutic products in which, the use of those innovative products are inserted in Cuban health programs (as the cancer program) of wide covering in the country. This insertion also permits to evaluate its products by its impact in these programs.

The Director of CIM has written: "Biotechnology filled the void between immunology research and the health system. Eleven vaccines, more than 40 therapeutic biological compounds (including monoclonal antibodies and recombinant proteins) and immunodiagnostic systems (including micro- ELISA machines) are manufactured in Cuba. The 'pipeline' has 91 new potential products now being investigated. More than 60 clinical trials are ongoing with the participation of 65 hospitals" (Lage, 2008, p. 110).

The Centre of Molecular Immunology, like other Cuban biotechnology centres, takes into account the needs of the national health care system to build their R&D agendas. This interaction with the health system favours the learning process and open new technological paths. This link between high tech and health care programs is a good example of technology and innovation that solves social problems, promoting social inclusion and health care. As we know, the connection between innovation and social inclusion is one of the relevant topics in Globelics' agenda (Dutrénit, G. and J. Sutz eds., 2013).

The State accompaniment was also projected toward the exterior. In other words, the Cuban biotechnology products were inserted in several countries through the intergovernmental agreements framework of more reach.

In the internal strategy of the organization, CIM created a line of products that combines generic biological products (as the erythropoietin) with more radical innovative products of own patent, as several of its monoclonal antibodies and therapeutic vaccines. This strategy generates a combination of projects of short term and low technical risk (bigger commercial risk) that are vital for the operation of the organization, with projects of medium term and high technical risk, but with more future commercial possibilities.

Even inside that mixed strategy of "me too" projects together with innovative ones, CIM did not give up basic scientific investigation, maintaining a generation of ideas and completely original products. From this a corollary can be derived: good science is not opposed to the objective of innovating and even of imitating when it has been convenient.

The subjective component of the attitude and the motivation of the workers (not only of ~~the~~ researchers and professionals) has been very important in the discussed outcomes. As described along this epigraph CIM was founded and has developed under very difficult conditions. The workers know that the economic advance of the country, the continuity of its development project, the sovereignty and the invigoration of the health system partly depends on the success of Cuban biotechnology and the success of the CIM in particular, too. Those have been irreplaceable motivations.

Work in this centre is based on some basic ideas (Pérez, 2008). First of all the articulation of science and economy: ensuring that its products generate sustained economic results. In this connection, the clear identification of objectives and rapid results become indispensable characteristics. The economic goal is an important driving force of research. Secondly: competitiveness based on innovation. Competitiveness ranges from the technological capability to scientific capacity and the added value provided by new knowledge. The novelty of products resulting from research is what allows taking market positions, which is called differentiation strategy. Thirdly: the advance of the institution through cooperation networking. Networks encourage connectivity between institutions, which becomes a factor of competitiveness and integration. Fourthly: motivation as a fundamental element of human capital. The scientific community that works at CIM shares values like dedication, team work spirit and well defined public service vocation. Upgrading, masters and doctoral programs, recruitment and selection of new staff as well as obtaining academic ranks in the field of research and teaching are essential.

CIM undertakes different types of projects. Depending on the characteristics of the projects universities have a greater or lesser level of involvement in their development. An important feature that was discussed in general terms in the biotech sector can also be noted at CIM: the ability to work simultaneously on issues at the scientific and technological cutting edge and on more traditional products, thereby generating economic opportunities for the country (Núñez, et.al, 2011b).

Currently CIM develops various research themes in collaboration with several universities, such as the development of a vaccine against breast cancer, adjuvants for therapeutic vaccines, studies of complex systems, simulation of biological systems and fermentation of mammalian cells. The universities most involved are the University of Havana, the Instituto Superior Politécnico José Antonio Echeverría, the University of Informatic Sciences, among others.

CIM is also a “Teaching Unit”, where undergraduate students from the above mentioned universities develop practical abilities and skills at the labs and production plants; some of them, upon graduation, can potentially become CIM workers. At the same time the involvement of researchers and technologists as faculty members contribute to their academic development and is opposed to the entrepreneurs’ frequent pragmatic course of mind. This contradiction stimulates creativity.

Links between CEP-CIM: motivations, barriers, channels, benefits, and risks

The motivation driving links between researchers and enterprises for the formers are usually classified into two groups: intellectuals and economics and those for the latters have been associated with short-term production interests and innovation strategies in the long-term (Arza, 2010).

Let us consider the motivations for this study case.

Facing the threat over the university science mainly due to the scarcity of a stable financial support by the government, one way of survival and to alleviate the impact of the 90’s crisis was to find alliances with the centers of the Cuban biotech industry that had been favored by governmental financial sources due to the role this productive sector was expected to play in the national economy; a strategic projection that was confirmed over time.

From its side, CIM, interested in fostering novel R&D projects, where protein understanding is a key factor, and knowing the potentialities of CEP in that field decided to strength its connection with this to build bi-directional channels (Íbidem).

From the CEP perspective, there was –undoubtedly-the interest for getting resources that would allow carrying on its research projects. But another key factor in this approach was the professionalism and knowledge of its CIM counterparts that CEP staff had realized along the education process of CIM researchers.

CIM was interested in a long-term alliance and the knowledge of CEP researchers gave the confidence to strengthen the ties. One important antecedent in the history of these relationships, before CIM or CEP foundation, was that those researchers that would be part of both institutions later had obtained a joint European patent (1997)⁶.

But probably, the key factor was that both CIM and CEP share values that served as a unifying element and support to this effort: the willingness to work for the health of the Cuban people without receiving back any personal benefits even being immersed in extremely difficult conditions. The social vocation of both parts was a key factor in this alliance.

Usually, the aforementioned literature assumes that the bi-directional channel is set when the intellectual benefits of both centers are associated with firms pursuing short term benefits. In this case, the intellectual and economic benefits (from the university research center side) have run together, and on the firm side, when they exist, include well settled and a strong researchers team (quite frequent in the biotech sector), also with intellectual aspirations but concentrated in projects with application aims. The publication of joint papers demonstrates this statement. Note that we are talking about practical ends but not only economic aims, since the assistance to the Cuban health system, and not only competitiveness and profit, is a central motivation in the development of their projects.

Without any doubt, the high spirit to be better every day worked as a motivating driving force for both partners.

⁶ Anti-ganglioside monoclonal antibodies, antiidiotype monoclonal antibodies and their use in the specific active immunotherapy of malignant tumors. Vázquez A.M. et al. CU 109.12.93/CU 11443F 1048 (03.94) Receiving section 70030006 No. 22 500, Cuba, 1997; European patent.

Both of them, had reasons to consider that interactive learning of both teams could discover new ways to research, to the solution of health problems and to the economic advances that the country needs.

This bi-directional articulation has been supported by the following mechanisms:

- ✓ Incorporation of CEP projects of relevance for CIM in the project folder of the latter. This is the case for instance: the combination of liposome technology and the highly cytolytic toxin isolated and extensively characterized by CEP as tool to modulate the immune response or as delivery agent of nucleic acids.
- ✓ The development of a Master in Science and doctorate programs devised with a joint vision taking into consideration the needs of the biotech sector. The MSc. in Biochemistry of the Havana University has an Immunology mention that is jointly coordinated by CIM and the University staff. Most of its faculty comes from CIM. Furthermore, CIM is one of the Centers promoters of the curricular collaborative PhD program in Molecular Biosciences led by the University of Havana.
- ✓ Insertion of researchers from the productive sector as teachers in university disciplines. For instance, personnel from CIM, CIGB, among others, have devised optative subjects for *Biochemistry and Molecular Biology* students or even have participated in the regular curriculum of this undergraduate program.
- ✓ Joint design of under and postgraduate subjects.
- ✓ CIM works as a *Teaching Unit*² of the Biology Faculty with its implications in the third educational level.
- ✓ The co-supervising of academic thesis with the participation of researchers from both institutions.
- ✓ The joint participation in projects and networks of national and international character.
- ✓ The laboratories and facilities of CIM are crucial for carrying out the research projects of CEP, ranging from basic scientific problems to those more focused on novel products or technological platforms of mutual interest. That is for instance the use of the pore-forming toxins of CEP used in different ways to explore possible platforms for product development.
- ✓ Publications and joint patents. As a fruit of the maturity of this relation, in 2014 there appeared a second patent in collaboration but in this case the main authorship lies on the specialists of the University of Havana⁷.

³Vaccine composition based on sticholysin encapsulated into liposomes. M.E. Lanio et al., USA patent. US 8,697,093 B2 April 2014

- ✓ Organization of scientific workshops to follow the course of current or promising scientific projects.
- ✓ The representation of specialists from both institutions in the other's scientific council.

The benefits obtained are diverse. CEP strengthened its research capacity by using the facilities and resources of CIM, under and graduate education of the university was improved with the expertise and high qualification of CIM professionals, and under and postgraduate education in the Havana University was updated with the own problems of the biotechnology industry.

On the other hand, CIM was benefited with the educational programs of the University in order to qualify its personnel, it was connected with the international networks where CEP was already inserted, and incorporated in a more structured way under and graduate students to its research programs.

The literature analyzing the university-productive sector links frequently makes reference to obstacles and risks.

We could say that the main obstacle in our case is derived from the own fragilities of innovation policies in Cuba limiting the direct resource transfer from the public sector firms to universities. This situation does not allow to university teams receive the same wage treatment than those working in institutions of the productive sector that could considerably increase their incomes depending on the economic results of the firm.

The same happens with university researchers, even though they have contributed to those economic results. Altogether this is part of the nowadays discussion that takes place in Cuba on STI policies.

That is why we have pointed out that the shared values and other subjective values are relevant elements to the case here discussed.

Literature on risks stresses among others some factors that could be present in cases as that discussed here. It has been suggested for instance that in clinical trials the interactions could lead researchers to hide or modify results; the power of the market can distract research to certain lucrative goals not paying the necessary attention to others relevant for the majority.

²A Teaching Unit is a research or productive institutions where university students carry out their pre-professional practices.

Costs of opportunity are also mentioned when a joint research takes up time to investigate and teach or when the abandoned research for favoring the interaction puts aside other more promising project. Finally, it is also mentioned the risk of privatization under patents, secrets, etc. limiting the access to information generated by public institutions.

Interrogated on these aspects actors involved in this relation consider that these anomalies were not present. For example, the existence of scientific abilities both in CEP and CIM and the permanent scientific exchange as well as the regular activity of submitting joint papers to be revised by peers decrease substantially the possibility to manipulate results.

Other interesting and particular feature in Cuba is that patents are not the property of researchers neither of the firm but of the state; and accordingly revenues derived from them are distributed with a social purpose and not privately. For instance, a large part of the income from the biotech industry sustains the Cuban public health system.

Researchers also consider that there has not been a problem related to *cost of opportunity* because those projects carried out have been satisfactory and did not interfere with others or even the teaching commitment of CEP. From the CIM side these dangers are minimum due the mechanisms this institution have created to conveniently interrupt those projects that could look initially promising but eventually did not render the expected outputs.

As already pointed out these projects are oriented not only to economic ends but also to satisfy needs of the Cuban health system.

In summary, motivations and channels have contributed to adequate benefits, the potential risks have not appeared while obstacles have not prevented these links. Anyway, it is easy to presume that in the absence of the obstacles herein described, the results could be higher.

In the opinion of the actors this has been a good experience. The results so far obtained and the robustness of the alliance built confirms this statement.

The University in the innovation systems: lessons learned and final remarks

As we mentioned earlier, the CEP-CIM channel is bi-directional. CEP has generated new knowledge, formulated new and relevant questions and contributed with a heuristic thinking. Furthermore it has fostered a common working environment with the presence of theoretical work and scientific criticism. CIM,

meanwhile, has not been limited to absorb a potentially interesting finding for the industry, but in its interaction with CEP, by different more or less formalized routes and supervision of joint thesis at different levels of academic training, has been approaching the university to industry without blurring the edges and social missions that differentiate them.

The innovative interest closer to the CIM's goals assesses over all novelty, innovativeness and industrial applications patent-oriented. Therefore this activity demands an environment of business development.

One might wonder now if the limits between both institutional activities may get blurred. However in our experience the hard core of one or the other alternative remains in academia, more concerned with the *whys*, and industry more concerned with the *hows* and the *what for*.

This story emphasizes the importance of university research which operates within the "Pascal's quadrant ". But in no way suggests that all university research should be of this nature. Our own experience indicates that product-oriented research acts as a driver for innovation but would only be sustainable over time if it is supported by a set of other types of research. Researchers immersed in border-basic scientific problems add, at the due time, new value to products, technological platforms and enrich the theoretical framework in which new products are evaluated.

Our experience shows that at least in biotechnology and other fields where innovation is based on science, it is important that the productive sector also performs research, including theoretical (eg via doctors training). This would facilitate interactive learning between both stakeholders.

The commitment of university and productive sector with society is essential to understand the experiences narrated here. Both started from shared values and it should be stressed the remarkable willingness to undertake these alliances that strengthen academia and industry bi-directionally. The academy was nurtured by the demands of industry and modeled its efforts in this direction, thus the terms: proof of concept, feasibility, scaling, pre-clinical studies, and clinical trials became

part of the categories' set to be incorporated in the academic thinking. Also, the periodical control on projects' progress as well as definitions of their important critical points and even the decision of when to stop or redirect an investigation were features translated from industry to academia and used in both institutions for project performance control.

Actually the experience narrated here cannot be considered characteristic of the university-biotechnology industry links in Cuba. There are other experiences of collaboration but the construction of a bi-directional stable, lasting cooperation is- so far- less frequent than desired. In the case studied the links were established through a gradual process that allowed building over time the channels already mentioned. To reach this point a permanent and long communication as well as the slow work of building shared agendas were required. Certainly the university and the biotech industry would benefit greatly from the multiplication of similar experiences

The case addressed shows that it is necessary to promote research activities and high-level education in universities. Both are very important for innovation systems. It is also essential to build connections with the productive sector through an interactive university-society relationship.

Values and motivation of the participants are very important for the progress of these linkages.

The university is a locus where teachers and undergraduate and graduate students abound. They are a very important human potential for innovation.

The university hosts a disciplinary diversity that is more difficult to achieve by the industry.

The university participates in international academic networks that allow the flow of knowledge and technologies that foster innovation.

The atmosphere of scientific debate that characterizes university encourages critical thinking that in turn benefits innovation.

The experience here narrated, despite its particular features, can help to devise cooperation policies between the universities with other productive sectors. Certainly biotechnology is a sector where links with university research are very

important. However if we assume the broader innovation systems approach earlier discussed incorporating the innovation mode DUI: Doing, Using and Interacting, the role of the university, through various channels and for various purposes, can be considerably enlarged.

As mentioned earlier, a new Policy on Science, Technology and Innovation is under construction in Cuba. Its hold comprise the potential of universities to a greater extent than any previous formulation and must create mechanisms that encourage their linkages with the productive sector.

On the other hand, universities should encourage their vocations as "developmental universities", giving greater priority to their research and innovation agendas and promoting their links with the productive sector.

The case studied here, although singular, illustrates that progress may and should be made.

Referencias bibliográficas

Arocena, R. y J. Sutz, 2003: *Subdesarrollo e innovación: Navegando contra el viento*, Madrid: Cambridge University Press y Organización de Estados Iberoamericanos (OEI).

Arza, V, 2010: Channels, benefits and risks of public-private interactions for knowledge transfer: conceptual framework inspired in Latin America Science and Public policy, Volume 37 Number 7 ISSN 0302-3427, August 2010, 473-484

Bekkers, R and I M Bodas Freitas 2008: Analysing knowledge transfer channels between universities and industry: to what degree do sectors also matter? *Research Policy*, 37 (10), 1837-1853)

Blanco, F (comp.), 2013: *La ciencia universitaria en el contexto de la actualización del modelo económico cubano*, Cátedra CTS+I, UH/Editorial Félix Varela, La Habana

Bortagaray, I. y G. Ordóñez-Matamoros, 2012: "Innovation, innovation policy, and social inclusion in developing countries", *Review of Policy Research*, 29 (669).

Brundenius, C, B.A Lundvall, J. Sutz, 2009: "The role of the universities in innovation systems in developing countries: developmental university systems-empirical, analytical and normative perspectives". *Handbook of Innovation Systems and Developing countries. Building Domestic Capabilities in a Global Setting*. Edited

by: Bengt-Ake Lundvall, K. J Joseph, Cristina Chaminade and Jan Vang. Published by Edward Elgar, Cheltenham, UK; Northampton, MA, USA, ISBN 978 1 84720 609, 311-333

Cassiolato, J y H. Lastres, 2013: "Sistema Nacional de Innovación de Brasil: Desafíos para la sostenibilidad y el desarrollo incluyente", Dutrénit, G. y J. Sutzeds, Sistemas de innovación para un desarrollo inclusivo. La experiencia latinoamericana, Foro Consultivo Científico y Tecnológico, AC; LALICS, México, 2013, ISBN: 978-607-9217-28-0, pp 65-95

CIM, 2014: La historia del CIM contada por sus trabajadores, Documento interno.

Dutrénit, G, 2010: "Introduction to special issue: Interactions between public research organisations and industry in Latin America: a study on channels and benefits from the perspectives of firms and researchers". Science and Publicpolicy, Volume 37 Number 7 ISSN 0302-3427, August 2010. pp 471-472

Dutrénit, G. y J. Sutzeds, 2013: Sistemas de innovación para un desarrollo inclusivo. La experiencia latinoamericana, Foro Consultivo Científico y Tecnológico, AC; LALICS, México, ISBN: 978-607-9217-28-0

Dutrénit, G and V. Arza, 2010: Channels and benefits of interactions between public research organisations and industry: comparing four Latin American countries. Science and Public policy, Volume 37 Number 7 ISSN 0302-3427, August 2010.541-553.

Etzkowitz, H, 2004: "The evolution of the entrepreneurial university", International Journal of Technology and Innovation, 1(1), 64-77.

Etzkowitz, H, L, Leydesdorff , 2000: "The dynamics of innovation: from National Systems and "Mode 2" to a Triple Helix of university-industry-government Relations", Research Policy, vol. 29, Elsevier Science, Netherland,pp. 109-123.
Gibbons, M., Limoges C., H., Nowotny, S., Scharzman, and M., Trow (1994).The new production of knowledge.The dynamics of science and research contemporary societies.Sage. London.

Herrera, L. (2008). El camino hacia el éxito está lleno de fracasos. Entrevista concedida a Enrique Ubieta para La Calle del Medio, Prensa Latina, No. 5, noviembre, La Habana.

Johnson, B. y Andersen, A. D. (Eds.), 2012: Learning, Innovation and Inclusive Development: New perspectives on economic development strategy and development, Alborg, Denmark: Alborg University Press.

Lage, A, 1994: Biotechnology: Offering new opportunities for developing countries. Biopharm 7(No.5) 18-19, June.

Lage, A, 1999: Las biotecnologías y la nueva economía: crear y valorizar los bienes intangibles, Disponible en: http://www.nodo50.org/cubasigloXXI/economia/lage1_310502.htm

Lage, A, 2006: La economía del conocimiento y el socialismo: ¿hay una oportunidad para el desarrollo? Disponible en <http://www.cubasocialista.cu/cs41/cseconomia.html>

Lage, A, 2008: Connecting immunology research to public health: Cuban biotechnology, Nature Immunology, Volume 8 Number 1 January, Nature Publishing Group <http://www.nature.com/natureimmunology>, pp. 109-112

Lage, A, 2013: La Economía del Conocimiento y el Socialismo, Editorial Academia, La Habana.

Limonta, M, 2002: Historia exitosa de una visión de futuro: la biotecnología médica en Cuba. Disponible en: www.catedradh.unesco.unam.mx/catedradh2007/SeguridadHumana/prospectiva%206/revista

López, E., et. al, ,2006: “Biotechnology in Cuba: 20 years of scientific, social and economic progress”, Journal of Commercial Biotechnology. Vol. 13. No 1. 1–11 octubre.

López, E., et. al, 2007: “Taking stock of Cuban biotech”, Nature Biotechnology, Vol. 25, No. 11.

Lundvall, B.- A 2007: “Innovation system research: where it came from and where it might go”Globelics Working Papers, no 2007-01, available at www.globelics.org

Lundvall, B.-A, V. Jang, Joseph, K. J, C. Chaminade, 2009: “Innovation system research and developing countries”, Handbook of Innovation Systems and Developing Countries. Building Domestic Capabilities in a Global Setting. Edited by: Bengt-Ake Lundvall, K. J Joseph, Cristina Chaminade and Jan Vang. Published by Edward Elgar, Cheltenham, UK; Northampton, MA, USA, ISBN 978 1 84720 609.

Majoli, M, 2002: Ciencia y Desarrollo en Cuba: aspectos del desarrollo científico y tecnológico cubano, FLACSO, La Habana.

Núñez, J, 2010: Conocimiento académico y sociedad. Ensayos sobre política universitaria de investigación y posgrado, Editorial UH, La Habana, 222 pp.

Núñez, J; L. Montalvo; I. Pérez, I; A. Fernández; J. L García, 2011a: “Cuba: University, Innovation and Society: Higher education in the National System of Innovation” pp.97-118 Universities in Transition. The Changing Role and Challenges for Academics Institutions; Goransson, B. y Brundenius, C. (editors),

International Development Centre, Springer, Ottawa, ISBN 978-1-4419-7509-6, 366 pp.

Núñez, J., I. Pérez y L. Montalvo, 2011b; "Biotechnology, university and Scientific and Technological Policy in Cuba: A look at progress and challenges". In *Biotechnology and Innovation Systems. The Role of Public Policy*. Göransson, B. y Pålsson, C.M. (editors), International Development Research Centre, Ottawa, 2011, ISBN 978-1-55250-538-0, pp.80-107.

Núñez, J y G. Figueroa, 2014: *Biotecnología y sociedad en Cuba: el caso del centro de inmunología molecular*, TRILOGÍA. Ciencia, Tecnología y Sociedad No. 10 / ISSN 2145-4426 / enero-junio / 2014 / pp. 11 – 24

Núñez, J y L. Montalvo, 2014: "Science, Technology, and Innovation Policies and the Innovation System in Cuba: Assessment and Prospects", *No More Free Lunch. Reflections on the Cuban Economic Reform Process and Challenges for Transformation*, Claes Brundenius and Riocardo Torres, editors. Springer, Switzerland, 2014.

Pérez, I J. Núñez, 2009: "Higher education and socioeconomic development in Cuba: high rewards of a risky high-tech strategy", *Science and Public Policy*, 36(2), march, 2009.

Pérez, R. , 2008: *Inmunoterapia. Artillería anticáncer*. Entrevista concedida a *Revista Bohemia*, Año 100, No. 26, Diciembre.

Perkmann, M and K. Walsh, 2007: *University-industry relationships and open innovation: towards a research agenda*. *International Journal of Management Reviews*, 9(4), 259-280

Sábato, J y M. Mackenzie, 1982: *La producción de tecnología*. Autónoma o Transnacional, Editorial Nueva Imagen, México.

Sutz, J (2010) *Ciencia, Tecnología, Innovación e Inclusión Social: una agenda urgente para universidades y políticas*. *Psicología, Conocimiento y Sociedad* Número 01 / Año 2010. *Revista de la Facultad de Psicología*.

