UniDev

The Evolving Role of Academic Institutions in Innovation Systems and Development

University, innovation and society: The Cuban University in the national innovation system

Jorge Núñez Jover, Luis Félix Montalvo Arriete,
Isarelis Pérez Ones and Aurora Fernández González

LUND UNIVERSITY

Research Policy Institute

UniDev Discussion Paper Series Paper no. 10

ISBN: 978-91-86113-09-4
Published online at http://developinguniversities.blogsome.com/
by Research Policy Institute, Lund, Sweden, 2008

University, innovation and society: The Cuban University in the national innovation system.

Jorge Núñez Jover
Luis Félix Montalvo Arriete
Isarelis Pérez Ones
Aurora Fernández González

INTRODUCTION......4
BRIEF OVERVIEW OF THE EVOLUTION OF THE CUBAN ECONOMY......7
CHARACTERISTICS OF THE INNOVATION SYSTEM IN CUBA......12
THE SCIENTIFIC AND TECHNOLOGICAL EVOLUTION......12
THE SYSTEM OF SCIENCE AND TECHNOLOGICAL INNOVATION IN CUBA (SSTI)......15
SSTI MAIN PLAYERS......16
ENVIRONMENT IN WHICH THE SYSTEM OPERATES......19
PRIORITIES OF THE SYSTEM OF SCIENCE AND TECHNOLOGICAL INNOVATION (SSTI)......21
INDICATORS SELECTED FROM THE SYSTEM OF SCIENCE AND TECHNOLOGICAL INNOVATION......24
THE SYSTEM OF SCIENCE AND TECHNOLOGICAL INNOVATION: A PRELIMINARY ASSESSMENT......29
THE HIGHER EDUCATION SYSTEM......32
TRAINING AND EDUCATION OF PROFESSIONALS......33
TYPES OF COURSES......33
NEW PROGRAMS, NEW PROFILES, NEW UNIVERSITIES.......34
THE "AIDED DISTANCE EDUCATION" AND THE PRODUCTIVE ENVIRONMENTS......35
SCIENTIFIC RESEARCH AND ON-THE-JOB TRAINING......36
PROFESSIONAL TRAINING AND EDUCATION AND THE INNOVATION SYSTEM......37
THE NATIONAL SYSTEM OF POSTGRADUATE EDUCATION......38
CONCEPT OF THE SYSTEM......38
POSTGRADUATE EDUCATION IN ITS SETTINGS......40
THE SYSTEM EXPANDS......41
TRENDS OF POSTGRADUATE EDUCATION AND INNOVATION SYSTEM......42
UNIVERSITY, SCIENCE, TECHNOLOGY AND INNOVATION......44
CHANGES IN THE NATIONAL SCIENTIFIC AND TECHNOLOGICAL POLICY AND NEW DEVELOPMENTS IN THE RESEARCH AGENDA......46
INNOVATION AND ITS LESSONS......47
THE MOST RADICAL INNOVATION: BUILDING "ROBUST DESIGNS"......49
INNOVATION AND ENERGY SAVING......51
FINAL COMMENTS......52
BIBLIOGRAPHY......56

Introduction

The Cuban University of the last five decades has carried out its work in a context of deep social changes which have had an outstanding impact on the life of the university itself as well as on the University-society relationship[1].

This intense University–Society relationship —and very likely unique, as regards the experiences of other developing countries— transpires in all functions performed by the academic institutions in Cuba[2]. These functions usually include: professional education, postgraduate education, research and university extension[3].

The University–Society relationship in Cuba is not considered a function, among others, but a quality of all the functions performed by the University. In order to designate this close tie of academic institutions with society, the concept of social pertinence is used, understood as the multiple relations that are built between the university and the environment, linkages, bonds, interactions in which both the university and society undergo profound transformations.

The issue of social pertinence was one of the major questions at the World Conference on Higher Education, convened by UNESCO in 1998 and also the Regional Conference on Policy and Strategy for the Transformation of Higher Education in Latin America held in Havana (1996), as part of the preparatory process for the World Conference[4].

Social pertinence, as a principle that governs university policy, is oriented towards the multiplication of the linkages of professional education, postgraduate education, research and extension with the productive system and the society as a whole. Probably, an appropriate insertion of the University in the innovation system is only possible if the University promotes this type of interaction.

---

1 Studies on innovation systems usually incorporate a historic perspective which enables to understand the evolution of the political, educational and cultural dimensions influencing the innovation processes. We assume that in the case of Cuba, it is sufficient to consider the last five decades. Before then, the university scientific research was virtually nonexistent, there were very few universities and the access of students was quite limited. In keeping with a profound revolutionary process, the last five decades of social, economic, political, cultural as well as international relations underwent dramatic transformations. Consequently, the university—society relationship also changed radically.

2 The Republic of Cuba is located at the entrance of the Gulf of Mexico, between North and South America, with an area of 110,920 km2, and a population of 11 177 743, according to the last Population and Housing Census of 2002, it has a life expectancy of 76 years. The official language is Spanish and the currency, the peso. The country is divided into 14 provinces and 169 municipalities (ONE, 2005 y CEDISAC, 1999).

3 Unlike other concepts which call “extension” the university function concerning the University – Society relationship, in Cuba extension has a different and more limited meaning. It fundamentally refers to the involvement of the university in socio-cultural projects, arts, sports, informal educational campaigns (sexual education, drug consumption, etc.) among other activities. Extension is also occasionally called the “third mission”. At times, this “third mission” is used to designate the relationship with economic growth and commercial objectives. Etzkowitz, H y Leydesdorff, L (1997).

4 Commission No. 1 was called Pertinence of Higher Education. The main contributions are included in *La Educación Superior en el Siglo XXI. Visión de América Latina y el Caribe*, Ediciones CRESAL/UNESCO, Caracas, 1997. It includes the works of Garcia Guadilla (1997) and Sutz (1997), among others.

The idea of social pertinence should be adequately rationalized. A market-oriented approach —like the sort that has invaded social relations in the last 20 years in many countries, by turning almost everything into a product— can lead to viewing the university as a company trading educational or other services.

In the current context of knowledge capitalization, the so-called "third mission" has often been construed along an economic key: basically as the interaction between the university and the enterprise, which is guided more by profit than providing a social service.

Compared to other approaches, we would rather highlight the role of the University as a knowledge-producing institution, able to provide a high-level education and commit to knowledge and Society. This concept does not rule out the commercialization of products and technology created by the University; it assumes, though, that society is much more than the market and any knowledge can be potentially useful for development.

The university knowledge is committed to social development in its every dimension, with the purpose of moving towards a knowledge-based model of social development, which has been called the "new development" (Arocena, R. y Sutz, J., 2005).

The priority given to social pertinence has resulted in the model of university-society relationship that has been built since the Higher Education Reform in Cuba, passed on 10 January 1962 (Higher University Council, 1962), being basically a model which we call “interactive", where research agendas and educational processes are built in interaction with the social environment.

The “interactive model” title underscores the social orientation of the model and the impossibility of resorting to any other designation used in the literature, such as the so-called “linear model”.

Since the 1962 Reform, with variable intensity according to the stage, the agenda for education and research has been developed in direct interaction with the productive sector and has inserted itself in the national development programs.

This paper shall describe the participation of the Cuban universities[5] in the national innovation system. It will be noted that the participation of universities in the system benefits from the outlined principle of social pertinence.

We shall begin by outlining the more salient features of the Cuban economy and the trend to improve its performance after the serious crisis which began in the early 1990’s. Then, we shall characterize the innovation system in Cuba, called “Science and Technology Innovation System” which is a stage in the evolution of the national Science and Technology Policy.

[5] In particular, those grouped under the Ministry of Higher Education, as it will be seen below.

Then, the participation of universities in the National Innovation System (NIS) shall be assessed from a three-angled perspective: the education and training of professionals, the postgraduate education, including the education of leaders, and activities of science, technology and innovation. The active participation of universities in the national innovation system will be noted. In the end, the many challenges that need to be overcome shall be identified.

Brief overview of the evolution of the Cuban economy

For Cuba, the early 1990s were characterized by a quite complex economic situation. It resulted, primarily, from the disappearance of the Union of Soviet Socialist Republics (USSR) and the loss of the trade linkages established with the rest of the socialist countries in Europe[6].

The negative impact on the Cuban economy brought about by the change in Eastern Europe was compounded by the effects of the growing globalization process and the existence of an economic blockade imposed by the U.S., which was tightened by the implementation of the Torricelli Act[7] (1992) and later the Helms-Burton Act[8] (1996).

Under the influence of extreme changes and the conditions that characterized the domestic situation, the government initiated a process of transformations aimed at halting the decline of the economy and preparing the country to take up growth again on new basis. In this connection, a national emergency program called “Special Period" was put in place; as it set out to face the new challenges through the promotion of sectors where some capacity had previously been built. So a boost was given to non-traditional sectors with hard-currency earning potential, such as international tourism and the high-tech industry involving the production of biotech and pharmaceutical products and medical equipment. Likewise, the export capabilities of traditional sectors were bolstered on the basis of restructuring the sugar agribusiness and the expansion of the nickel industry. A program for the production of food for the population was also introduced.

In 1994, after a long economic decline[9], Cuba began a process of small economic recovery which can be seen in Chart No.1 Notice how the country's sum of productions and services began to pick up, reaching in 2004 a 46% increase compared with 1994. In the year 2005, the economy grew by 11.8%, the highest growth since 1959 (Rodríguez, J, 2005) In the first quarter of 2006, the Cuban economy had surpassed the growth achieved in 2005, and in May its growth pace was estimated at 12.5% (Castro, F. 2006)

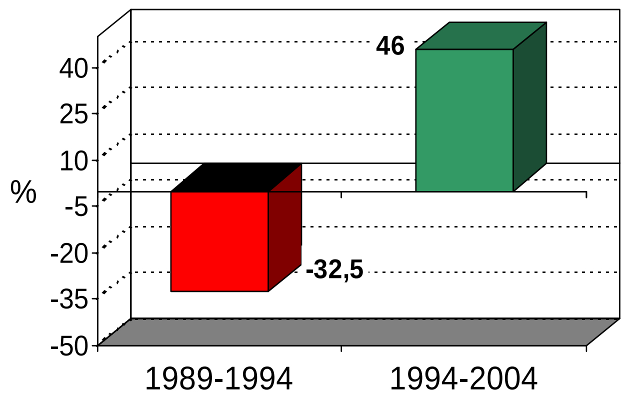
6 The breaking-off of integration relations in effect for years with these countries led to Cuba’s drastic fall of imports —by more than 70%—, the loss of safe markets for her exports, fast decline of imports and the inability to have access to soft loans from international financial institutions. In these extremely difficult circumstances, the continuity of the social and economic development that had been achieved in the late 1980s was compromised.

7 Act whose objective was geared towards preventing Cuba from trading with US subsidiaries based in third countries.

8 Act geared toward slowing down foreign investment in Cuba and stopping the supply of products out of concerns from companies or suppliers.

9 Technological supplies from the USSR were stopped between 1989 and 1992. In three year, imports fell by 72% and exports by 67%, the investment rate was 7% down from 26%, the gross capital formation dipped by 60% and oil imports dropped in over 50%. In 1993, the GDP sank by 35 % compared with 1989.

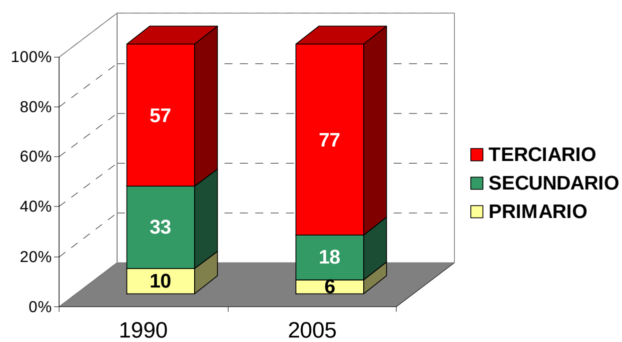
Chart No. 1. GDP variation (1997 prices)



Source: Center of Studies on the Cuban Economy (CEEC), 2006[10]

In the period 1990-2005, Cuba continued to turn into a service economy based in the policy of giving priority to foreign exchange-generating activities that save energy and reduce energy dependence, use qualified human resources and make their productions in dynamic markets. The effect of this behavior can be seen in the shift of sectors share in the GDP structure. See Chart No. 2.

Chart No. 2. GDP structural changes

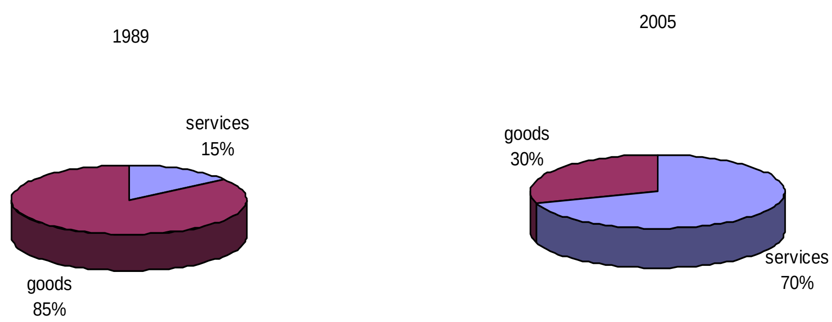


Source: Center of Studies on the Cuban Economy (CEEC), 2006

As can also be seen in Chart No. 3, the share of these sectors in the Cuban exports underwent a significant modification.

[10] Our thanks go out to Dr. Anicia García Álvarez, Director of the Center of Studies on the Cuban Economy (CEEC) for the information about the Cuban economy made available for this paper.

Chart No. 3. Structure of Cuban exports

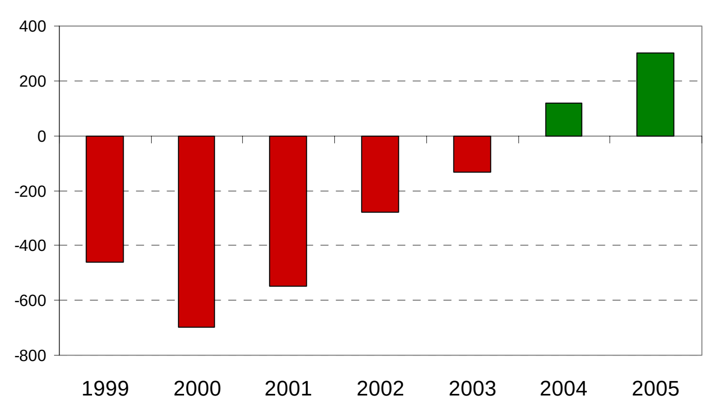


Source: Center of Studies on the Cuban Economy (CEEC), 2006

As can be seen, the recovery process began in the mid-1990s was accompanied by a diversification of the sources of growth. Thus, the Cuban economy went from an economy where the key factor of growth was centered on a pattern of low technology-intensive[11] specialized production and export of goods (namely sugar and tobacco) to an economy where the production of services with high added-value, such as health related, education and tourism, prevailed.

The measures taken by the government in a numbers of areas of the economy allowed that for the end of 2004, the current accounts of the balance of payments (Chart No. 4) showed a positive balance.

Chart No. 4. Balance in current accounts (MM USD)



11 Kelly typology, extending technological intensity as the relation between the total expenditure (current plus investment expenditures) allocated to R+D and the value of production of an economic activity. The critics of this typology points out, among other limitations, that an industrial branch can directly qualify as low technology intensive, while being an indirect user of technology generated in other branches by way of inputs. Its advocates justify the use of this classification on the basis of empirical evidence, in many industries, between the intensity of R+D expenditure and the technological complexity (Fernández, C. 1994)

Source: Center of Studies on the Cuban Economy (CEEC), 2006

That year the Cuban economy made a significant progress in its development. Although the industrial production suffered various impacts[12], 10 branches grew out of a total of 22, being mining and non-ferrous metallurgy the most outstanding ones with 10.7% and electronics industry with 4.0% (Rodríguez, J, 2005). Furthermore, the conditions were created to advance much more in coming years. Some of the additional factors that shall have a bearing in this advance, which characterize the current economic situation include:

1.- Development of the high-tech industry. The emergence of a new high-tech industry, the biotech-based medical-pharmaceutical industry[13], with investments over the last three years amounting to 120 million dollars and the intent of developing the software industry[14], also highly technology-intensive, somewhat modify the actual Cuban production structure.

2.- Major donations, loans and investment from China. Including a loan of 6.1 million USD —to be repaid in 15 years with a grace period of 5 years during which no interests shall accrue— for material and inputs and spare parts for the health sector; deferment of 10 years of the beginning of repayment of financial obligations under government loans for the sum of 50 million dollars; the granting by Chinese banks of a loan of 500 million dollars for the establishment of a joint-venture which will build a ferronickel plant with a production capacity of 22.500 tons of nickel and the granting of credits for the development of infrastructure in Cuba, such as port equipment, railway improvement, telecom, machinery for shipbuilding, oil extraction and nickel mining, among others.

3.- Significant agreements with Venezuela. Cuba signed agreements included in the Bolivarian Alternative for the Americas (ALBA)[15], including the establishment of PETROCARIBE and the signing of agreements to refine

---

12 Due to its geographical position, Cuba is frequently hit by meteorological events causing million-dollar losses to the Cuban economy. In 2005 hurricane Dennis ravaged 10 provinces bringing about considerable damage, losses caused by this hurricane were initially estimated at 1.4 billion dollars. It was also affected by hurricanes Rita, with losses estimated at 704.2 million dollars, and Wilma, with losses estimated at 207 million dollars.

13 The production of drugs by the pharmaceutical industry grew more than 26% in 2005, and should rise more than 18% in 2006 (Rodríguez, J, 2005).

14 The University of Informatics Sciences reached 8 000 students in 2006. In addition to the mass teaching of computer science in the entire educational system, the strategy devised to promote the software industry includes 26 computer science polytechnics, part of which are new or have been completely renovated. They train more than 40 000 mid-level technicians, which is compounded by more than 11800 higher education students, 8000 of which from the University of Informatics Sciences. In addition, more than 847,782 people have taken training courses over the last 18 years at the Computer Youth Clubs. In 2005 the available pool of computers grew by 14% (Rodríguez, J. 2005)

15 The ALBA is an integration proposal which is based on the creation of mechanisms providing cooperative advantages among nations to allow for the compensation of the existing asymmetries between the countries of the hemisphere. It is based on the cooperation of compensatory funds in order to rectify the disparities that place weak countries in disadvantage vis-à-vis the top powers. This is why, the ALBA proposal gives priority to Latin American integration and the negotiation in sub-regional blocs, opening new spaces of consultation to deepen the knowledge of our positions and identifying the common spaces of interest enabling to forge strategic alliances and presenting common positions in the process of negotiation.

Venezuelan crude oil in Cuba. The agreements also include: Venezuela's funding of productive projects and infrastructure work, prioritizing asphalt for roads and facilities for the supply of domestic fuel; a proposal for building — together with Canada's Sherritt— a coal-fired power plant in Mariel municipality; the possibility of setting up a tripartite company (Cuba-China-Venezuela) for the production of stainless steel in Venezuela. Under consideration is an economic association to exploit the supertankers facility in Matanzas, among others. In the context of ALBA, Cuba exports scientific and technical services (i.e., medical services and the handling of the associated technology). In 2005, trade between the two countries was in excess of 2.4 billion dollars and in the first quarter of 2006, it was more than 1.2 million dollars. Perez, E. (2005).

4. Program aimed at energy saving, developing alternative sources of energy and improving the management of these resources. Domestic extraction of oil and gas should be noted, as it has enabled to significantly reduce imports. In 1989, 94% of oil was imported and only 6% was domestically produced. In 2005, these figures were 56% and 44% respectively (CEEC, 2006). Since 1995, production of domestic crude oil has been on the rise. In 1995, the domestic production of crude oil was 1.4 million tons, reaching 3.3 million tons in 2004 (AEC, 2005). All of these advancements are part of an energy revolution that the country has embarked on, achieving significant results[16].

5. Cooperation agreements with other countries. Brazil gave an important loan to purchase foodstuff required in 2005, to be repaid in 3 years after each shipment and with an annual interest rate of 2.5%. Iran gave a credit of 20 million euros, it will cooperate in the production of food in the land released by the sugar industry and also will contribute with inputs and equipment in the combat against the effects of drought in Cuba. (Ibid; p3).

6. - The high prices of sugar and nickel in the international market and the signing of sale agreements for the latter. For example, China will purchase 4,000 tons per annum from 2005 to 2009.

Consequently, it can be said that the Cuban economy is coming out of the profound crisis which affected it for over a decade and that the economic transformations taking place are frequently associated with varied intensity to economic activities demanding knowledge, learning and innovation. Cuban

[16] In the first four months of this year, the domestic production of crude oil and gas reached around 1.244 million tons, that is to say, four times more than what was produced in 1991. Hard work is currently under way to complete 36 new oil wells, some of them wildcat wells and others development wells. Until April this year, a reduction of 3.7% of actual consumption of energy carriers have been achieved essentially due to the reduction of fuel to generate power and the decrease in the use of kerosene and liquefied gas. The savings amount to more than one kw/h of billed electric energy, thanks to, *inter alia*, the supply of different types of energy-efficient appliances and accessories. The country has allocated 262 million dollars to upgrading the power grid. When these investments are completed the quality of service will increase and the total loss due to distribution of electricity will be down approximately to 11% from 18%. Furthermore, gensets have been installed in the country, with a capacity to generate 903,000 kw/h and work is under way to install back-up gensets in vital socio-economic facilities to be used in emergency situations like catastrophes and meteorological events, among other (Castro, F. 2006: 4-8) The country is increasingly conducting studies, research and tests on the use of wind energy. The universities are participating in the preparation of the first eolian map and it is expected that the first wind power plants be generating and contributing power to the national power grid within the next two years.

President Fidel Castro stated on 18 January 2002 that "this country will live on intelligence and intellectual property", which means that the political commitment to bet on knowledge, education and science, remains.

Below are examples of the role of the universities in such processes, namely in training human resources for the oil and tourist industries, as well as the medical-pharmaceutical and software industries which also enjoy much support from the universities in scientific and technological research. The universities are strongly linked to the development of renewable sources of energy and strategies for energy saving and production.

Characteristics of the Innovation System in Cuba

The scientific and technological evolution

Cuba is a developing country that has bet heavily on knowledge. For more than four decades, the country has pushed for what has been called a Social Knowledge Policy (SKP), understood as the deployment of deliberate strategies aiming at the production, appropriation, diffusion and application of knowledge, strengthening its institutional basis and defining agendas that project objectives and priorities with a broad and favorable social impact. A first and major boost was the massive Literacy Campaign of 1961, which eradicated illiteracy in the country. A privileged attention to the educational system has been an important part of that policy.

A key moment in this evolution was the abovementioned University Reform, which set up research and postgraduate education as basic roles of universities and turned them into the daily work of our higher education centers, strongly articulating them with the education of students and professors as well as the country's social life.

Also in 1962 was enacted Law 1011 of the Revolutionary Government, creating the National Commission of the Academy of Sciences of Cuba and placing it under the Council of Ministries. That year marks the beginning of the emergence of research institutes at the Ministry of Industries, under the leadership of Ernesto Che Guevara. This became another milestone in the foundation of the national science and its coordination with the priorities of the economic and social development.

It can therefore be considered that the efforts to develop a science and technology policy in Cuba began in the early 1960s, stemming from the priority that the top political leadership attached to knowledge, education, science and technology. Its purpose was always promoting social development in favor of the large majorities. Education, science and technology were oriented to the goals of social transformation driving the whole revolutionary project.

Starting out from underdevelopment and dependence, the goal of promoting science and technology and putting them at the service of development, called for decisions to be adopted at the highest level of government. The relationship between Science and the Government of Cuba is probably a rather unique feature among developing countries, in particular in Latin America.

The Cuban science and technology policy has gone through three main stages since 1959. The first stage could be called "guided promotion of science" (García Capote, 1996 p. 149), i.e, a policy that set out to develop a previously nonexistent research sector. In Cuba this translated into creating scientific institutions and the training of researches that shall man them. In keeping with this, many of the main research institutions that the country has nowadays were founded in the 1960s. And most of the programs of science, engineering and scientific research were introduced in the universities. Since then, a remarkable process of international exchanges began through the coming of foreign scientists to Cuba and the training of Cuban professionals abroad. All of these advances notably transformed the universities.

If we take into account the exiguous background, it can be said that the advance in the guided promotion of science in the sixties meant an extraordinary leapfrog in the Cuban scientific development.

The existence of the science and technology policy has long come hand in hand with the notion that scientific advances fail to fully translate into the practical use of its results. So in the mid-1970, evidence started to mount indicating that the practical use of scientific results to solve the problem of production and services was a matter of greater complexity. This brought about a number of changes in the science and technology policy establishing what has been called the "model of centralized direction" (1977-1989), whose objective was to complete the efforts from the supply end[17] with a deliberate strategy to use scientific and technological results; this was called the "introduction of results".

It was supposed to be achieved through a very centralized model relying on the identification of "research problems" to direct research towards issues of high priority and the use of results in the fields of production and services. Although the use of results was emphasized, this staged was based on the same lineal concept towards scientific research as a triggering element in the relationship between science, technology and production (Núñez, J. 2003).

Problems of concept were compounded by a very relevant practical circumstance. In parallel with the emphasis on science and the expectations that it would increase its contribution to development ran an implicit technological policy which was characterized by generalized imports of technology, quite frequently from the European socialist countries. They were characterized, *inter alia*, by being moderately modern technologies with low energy efficiency and environmentally aggressive. The tendency of assimilating, rather than producing, technologies and the frequent lack of

17 Until 1985 the quantitative and qualitative growth of the national scientific and technological potential reached significant levels. That year, the workers involved in this activity totaled approximately 40,000, which represented a 35% increase as compared with 1981. The total amount higher education graduates devoted to R&D in 1985 was, roughly, 14,000 physical workers and 9,700 in full-time work equivalent. This is a 39% increase regarding 1981, of 2.4 times regarding the existing amount in 1975 and almost a tenfold rise compared with 1970 (Sáenz y Capote, 1989: 186).

interest to innovate shown by the entrepreneurial segment of the agents of technological change explain why the scientific development and the human potential achieved were not expressed in the expected practical results (García, E. 1996).

This situation justifies the critical view that was formed around this issue throughout the 1980s, a discussion that was included in a broader debate on the praxis of the socialist transition in Cuba and, particularly, the economic efficiency of the country.

This critical view was combined with other factors. The concept that the advance of socialism worldwide would largely depend on its ability to develop science and technology as social productive forces, became another important element[18]. Coupled with this was the need to increase the country's ability to face the biological aggressions it had been subjected to, a priority given with great emphasis from the early of the 1980s, as well as the efforts to continue improving the Cuban health care system with the creation of state-of-the-art technology in this field. Also considered was the creation of new exports items, capitalizing on the potential offered by the revolution in biotechnology, a process the country decided to actively engage in (Núñez, J. 2003).

Although incomplete, this range of reasons determined that since the mid-1980s the country introduced changes in its science and technology policy. The more pointed changes include the re-launching of university research, now with a more applied orientation, the definition of new priorities for scientific and technological development (i.e.,biosciences, biotechnology, pharmaceutical industry, high-tech medical equipment); the creation of the productive scientific parks —true networks of integrated cooperation where research, creation of technologies, production and commercialization of products are part of a continuous process led by unique strategies, the enhancement of the Science and Technology Forum, a unique Cuban experience geared towards increasing social participation in the scientific and technological development and its applications (Ibid, 2003)

It is important to note that in the 1980s, in a context of most uncertainties and at the verge of an economic crisis which eventually turned out to be very profound, the government's decision was to promote science and technology as leverage for economic and social development. Biotechnology was the biggest bet.

In the1990s policy making-related changes were introduced. The loss of the reference provided by the bloc of socialist countries regarding the organization of the system of science and technology, as well as the productive changes at

18 Based on this rationale, the socialist countries promoted a process of scientific development, with particularities in each country, focusing on research institutions as a prior condition for social and economic progress. Such concentration was different from the process taking place in the capitalist societies in terms of the R&D links with production. As pointed out by Salomón, the R&D activities were more radically separate from production than in the capitalist economies (Salomón, 1974: 50).

the international level, led to an update of the concepts on the organization of the science and technology activities[19].

Up to 1993, the Cuban system of science and technology received wide state support in human resources, expenditure and short- and long-term investment for its development and strengthening. However, the system worked like a sort of "black box", to which significant amounts of resources were allocated, without getting the expected results. In other words, it seems there was not a correlation between the "inputs" and "outputs" of the system. Besides, its operation failed to eliminate the relative distancing between R&D and the productive sector. This is why, one of the main problems continued to be the introduction of results into practice (Montalvo, L. 1998:148).

So, in 1994 the new System of Science and Technological Innovation (SSTI) was devised, with a view of distancing itself from the former system of science and technology, not only in the name but also in its essence, approach and content[20].

The main purpose was to put at the core of the system the production of goods and services, on the basis of efficiency and competitiveness leading to a good modern economy and its advantageous insertion into the international market (CITMA, 1995:7). This concept took into account several aspects including: the contemporary trends in the organization of science and technology —trends that usually emphasize innovation—; the role of the enterprise in the innovation processes, including their involvement in project funding; boosting effectiveness and competitiveness in productive organizations in a context which includes market elements; recognizing the multiplicity of sources and agents that participate in the innovation process; favoring the funding of project as opposed to institutional financing (Capote, 1996: 157-159).

Thus by the end of 1995, the first steps were taken for the setting up of a System of Science and Technological Innovation. Some of its characteristics are featured below.

The System of Science and Technological Innovation in Cuba (SSTI)

In this paper we have assumed the concept of "innovation system" as a "group made up by organizations, institutions, interactions between different collective authors and the general social dynamics having a greater influence on the

19 The scientific and technological activities are considered those directly related with the development of R&D, the scientific-technological services, interface activities, as well as other complementary efforts.

[20] Transition in Cuba to an innovation-centered stage of the scientific and technological policy was basically due to the reasons previously mentioned in this paper. The denomination used was undoubtedly influenced by the theories of innovation systems and their political expression of many countries. However, this one underscores the role of scientific research and the organizations driving it forward. Consequently, in the programmatic formulations (CITMA, 1998: P.22) more emphasis is placed on the role of the universities as provider of research than as trainer of professionals and specialists. This paper has a broader view, highlighting the contribution to training.

available capacities for research, experimental development, technological innovation and the diffusion of technical and productive advances" (Arocena, R and Sutz, J, 2003, p.96).

Often times, these systems are more sectorially-, regionally or locally-oriented than they are nationally, although the concept of innovation systems emerged very closely linked with the term national (Freeman, Ch. 1988) (Lundvall, B.A. 2000) and the expression "national innovation systems" is frequently used in the theoretical discussions about these topics (Arocena, R and Sutz J. ibid).

At any rate, it held that in innovative processes there is a strong national imprint through the unique array of historic, economic, cultural and educational circumstances which pertain to national spaces.

In order to characterize the SSTI we shall comment on the actors considered to be key, the environment in which the system operates, its priorities, its main indicators and some noteworthy limitations.

SSTI main players

An important role is played by the Central State Administrative Bodies (OACE). They are divided into two, the bodies with a global reach and those of branch reach. The global organizations (i.e., Ministries of Economy and Planning, Foreign Trade) are regulatory institutions and are in charge of the functioning of the issues involving all activities and organizations and institutions of the State. Regarding SSTI, their roles basically relate to activities of planning, funding, evaluation and control of science and technology. Particularly, the Ministry of Science, Technology and the Environment is the governing body for the activities of science and technological innovation. It is also responsible, *inter alia*, for designing the policies of promotion and development of innovation according to strategic projections to optimize the available investment, as well as for regulating and facilitating the actions between the actors taking part in the process of innovation.

By contrast, the branch organizations are in charge of leading and managing one or various branches of the economy and their role regarding SSTI is twofold. First, to bring about the scientific and technological development with a view to constantly increasing the efficiency in the relevant area and activity, in accordance with the outlined policy and plans. Second, to evaluate the process of development and technology transfer in the activities in their charge, the functioning of the kynetical and technological entities, as well as the effective use and development of their scientific and technological potential[21].

As previously mentioned, an outstanding role is given to enterprises producing goods and services. Their part is important within the SSTI because of their

21 The scientific and technological potential (in the case of a branch) is the total of available resources to research, innovate and study problems of national or international scope raised by science, technology and the innovative process.

duty to generate and increase the contribution[22] to society and as an important innovation player. There are currently over three thousand companies in the country, 715 of them have undertaken a process called “Business Management Improvement”[23]. The rest of the enterprises shall join this process gradually. The benefits for the enterprise and society are obvious[24].

Universities play a decisive role in the creation, diffusion and application of knowledge. They conduct a sizable portion of the national scientific research; they train university graduates and have a decisive bearing on the postgraduate education, notably in education at the doctorate level. At present, the university system has been largely decentralized through a process of creation Universities Venues[25] at the municipalities, a process that has opened up the opportunity to connect more effectively the knowledge with the needs of local development.

The entities of Science and Technological Innovation (ECIT), that is, centers for research, centers for scientific and technological services and units for scientific and technological development, are essential in the system. The main mission of these entities is scientific research, the technological development and delivery of scientific and technological services. Nowadays, the number of entities is estimated at more than 200. Two important characteristics stand out in the network of entities. First, a shift towards services[26] and interface consultancy can be observed. Second, in most of the research institutions the number of researchers is small, which may become a limitation to tackle complex problems (OCCyT, 2005: 19).

The main mission of the financial institutions in the system is to provide funding through the different modalities, trying to enhance the capacity of the key players of the system. Now there is a group of institutions helping the entities in this regard[27].

---

22 Contribution is meant to be understood as the total monetary contribution to the State, the generation of useful products and services improving the people’s lives, the jobs created, the organizational and technical contributions, the new products and services, the patents, innovations and anything increasing the efficiency of the socialist society.

23 Program for the renovation of structures and work methods in the Cuban enterprise whose main objectives seek to reorganize the flows of production and services, modernize the productive processes on the basis of economic rationality, looking for the maximum efficiency, effectiveness and competitiveness possible and observing a due protection to the environment and the fair treatment of the situation of work resources.

24 For example, in 2005, the enterprises in the Business Management Improvement System boasted a productivity increase of 54.55% compared with those which are not in the system. The contribution in foreign exchange was 1618.76 as opposed to 480.86 and the profit of the enterprises in the system was 14.50% greater than the rest. (Betancourt, A. 2005). The Cuban business landscape has both companies that from the point of view of their performance indicators are on the same level of their peers at the international level (23%) and others who need a change to respond to the demands of the Cuban economy and society of gaining more productivity and efficiency.

25 The Municipal Universities Venues are centers of higher learning located in the most varied places (municipalities, hospitals, penitentiaries, among others) providing full access to university studies of all the young, with major implications for the purpose of justice and social equity that characterize our social project.

26 In 1998 this fact was perceived by CITMA when it pointed out: “In practice, a number of institutions which continue to call themselves research centers have reoriented themselves towards scientific and technological services or towards activities of assimilation and technology transfer (CITMA, 1998: 21).

27 They include the following:

The Cuban System of Science and Technological Innovation incorporates organizational forms and organizations whose goal is to promote and integrate efforts, in particular, to interconnect the scientific and technological research with the productive sectors. That is the case, for instance, of the productive-scientific Pole, the National Forum on Science and Technology, the National Association of Innovators and Rationalizers.

The productive-scientific Poles are instruments of coordination and integration whose main goal is to link up, in the most efficient way, the results of the R&D entities with the needs of the sector producing goods and services. There are presently 14 Poles, two of them in the country's capital and the rest spread across the other provinces. The territorial poles constitute a setting where universities, research centers, productive sectors, the government and social organizations interact.

The most outstanding scientific-productive pole is the West Pole, because of its role in the creation of the new, biotech-based, medical-pharmaceutical industry. It also serves as a space promoting interactions and consensus among the actors linked with its development.

The National Forum on Science and Technology is a movement promoting a broad social participation in the process of innovation; it favors the interactions between the key actors in these processes and enables the dissemination of results. Originally it was geared to finding solutions to the shortages generated by the lack of spare parts but then it also took on board the sector of science and higher education. The Forum allows looking for useful solutions to daily problems of production and services, including the appropriate application of science and technology. It is organized from the local up to the national level. At all levels discussions are held and prizes are awarded to the best solutions derived from the "Problem Banks"[28]. Like ANIR and BTJ, which are going to be explained right away, the Forum is a way to promote the country's innovative imagination.

The ANIR is an organization covering the entire productive fabric whose members contribute through different ways to enhance the technological performance of enterprises and improve their efficiency and competitiveness. Further to what has been indicated, its importance within the SSTI lays in the

---

Banco Central de Cuba. Governing body of the banking system; its roles include, among others, proposing the monetary policy to allow reaching the targets the country needs.
Banco de Inversiones S A. It is oriented to the production of financial services specialized in matters of investment, identifying and mobilizing available resources, both in the domestic and the foreign markets, channeling to the prioritized and more productive sectors of the economy.
Banco Internacional de Comercio S A. Provides a wide range of services to Cuban, foreign and joint entities. Their main activities include, among others, foreign trade-related transactions and transfers from and to Cuba.
Banco Financiero Internacional. Conducts operations in foreign exchange as a commercial bank, it enjoys a solid reputation and has correspondent banks in several countries.
28 "Problem Banks" list important difficulties of technical, economic and organizational characteristics facing entities of production and services in the performance of their main duties, which must be resolved through different ways.

fact that their work within enterprises enhance the use and tacit knowledge and the release of technological creativity.

The BTJ is a youth's participatory movement looking for solutions to problems that usually demand scientific and technological knowledge. Its goals include import substitution and the creation of new export products, influence the introduction and generalize scientific results and their dissemination.

However, the mechanisms through which research and training agendas are defined and these, connect to the economic and social strategy of the country; they are not just limited to the abovementioned organizational forms and organizations.

There are a number of mechanisms of exchange at the highest level of government, ministries, enterprises, universities and research centers that generate many joint initiatives influencing research, the exchange of specialists and training. Below are examples of university-generated innovation (i.e., biomaterials, alternative sources of energy) whose paths are linked to several exchange mechanisms in a plethora of actors.

Account should also be taken of the role of the government bodies in the discussion on science and higher education. The Administration Councils, at the provincial and municipal levels, have incorporated these matters into their strategic projections and they are part of the issues being discussed periodically. These councils include representatives from the sector of science and higher education. This, of course, works with a variable efficiency but there are quite interesting examples[29].

Generally speaking, the bodies of the People's Power in Cuba and the highest hierarchy of the Cuban State, have incorporated into their agendas the issues relating to science and higher education. For instance, the National Assembly of the People's Power (ANPP) has at least 20 deputies from this sector. The ANPP has a commission on Education, Science and Culture whose work agenda reviews these matters periodically. This commission convenes hearings to which representatives of social institutions and organizations are invited.

Environment in which the system operates

There are several environments acting directly or indirectly over the System of Science and Technological Innovation which can have a positive or negative influence in its functioning. We shall refer to the current situation of some environments we believe to be important.

[29] The best-known case is the municipality of Yaguajay, in the province of Santi Spiritus, whose local government has an office for project management. The projects enable tackling the main economic, social and environmental problems. These projects have given rise to the creation of networks with universities and research centers that facilitate the flow of knowledge allowing to address the identified problems. It is an interesting experiment of knowledge-based local development.

The first to be considered is the economic-productive environment. As seen before, the Cuban economy has been taking steps towards the transformation of its development pillars for the last 15 years. Until the early 1990s, the key factor of growth rested upon the capitalization of the production capacity related to comparative advantages —sugar, nickel, tobacco. Subsequently and with the clear purpose of moving to an economy that raises the leading role of knowledge, the predominance of production of services associated with health, education and tourism was noticeable by early this decade. The rapid development of the biotech-based medical-pharmaceutical industry and the beginning of the development of the software industry, are important modifications in Cuba's production structure and pose challenges to the System.

The technological environment has been adversely affected by two main reasons. The first is the collapse of the socialist bloc, which was the primary provider of technology to the country[30]. Not only the flow of technology was abruptly severed but also the supply of inputs for the normal functioning of the country's scientific-technological infrastructure.

The second cause has been the complex financial situation with an extraordinary restricting effect in terms of acquiring technology to renew the technological base[31]. Thus, the current Cuban technological landscape is characterized by a technological diversity ranging from the so-called traditional technologies up to state-of-the-art.

The sociocultural and educational environment is favorable to the SSTI. Cuba has a good educational system ensuring access with equal opportunities to all and allows the continuous training of the human capital[32]. The literacy rate between 15 and 24 years of age is 99.96%; the enrollment rate in primary education is 99.4% (98.5% continue to fifth grade) and the average schooling level of workers is 10.8 grades of education (higher than Taiwan, Chile, China, Brazil, *inter alia*). The population between 25 and 64 years of age with university education is 11% (similar to France, higher than Italy and Portugal, for example). Education is compulsory up to the ninth grade.

According to UNESCO, the ratio of students per teacher at primary and secondary education is 14 and 12 respectively (in the US is 15 for both levels). In 2005, 62.7% of the television broadcast was devoted to educational programming (Rodríguez, J. 2005). The characteristics of the higher education system will be commented further down.

---

[30] In spite of belonging to an old paradigm with the deficiencies already mentioned, the technology coming from that country allowed the functioning of the production sector, with guaranteed energy resources and spare parts.

[31] Since 1993, the boost given to foreign investment has contributed to stop the process of undercapitalization in those branches where it takes place, contributing technology and ensuring spaces in the international market. In this connection, the expansion of economic associations with foreign capital have been an important expression of incentives to foreign investment.

32 In the year 2004 Cuba allocated 25.8% of the budget to education (AEC, 2005)

Priorities of the System of Science and Technological Innovation (SSTI)

The priorities for the scientific and technological activities can be divided into four large thematic groups.

Group 1 refers to the areas where excellence and international competitiveness can be achieved or maintained on the basis innovative products and technologies.

The priorities in this group relate to the development of new vaccines and innovative technology for their production; new drugs based on natural and recombinant products, including monoclonal antibodies for therapy, and new application of innovative drugs developed in Cuba[33]. Similarly, they are linked with the development of high-tech medical equipment and diagnostic kits for exotic disease in humans and animals, using molecular biology techniques as well as other cutting-edge technologies in diagnosis and medical treatment.

This group also comprises research for obtaining new plant varieties through biotechnology and other advanced techniques, or new technologies for their reproduction and propagation, as well as wok related with transgenic plants and animals and the development of diagnostic kits for quarantine plant diseases.

As it will be addressed later on, a significant part of the university scientific research is involved in these priorities. Important groups are working in the university on the production of vaccines, drugs, vegetal biotech, among other fields. This agenda is associated with the training of professionals through numerous university degree programs and also postgraduate education, including the education of doctors.

Group 2 takes into account the key areas related with more traditional productions, where important technological changes are needed to ensure the competitiveness of products, increase of efficiency, diversification of production and ensuring the observance of the established environmental standards.

The priorities of these groups have been linked to the production of sugar and derivatives; production of food for the population and animal feed based on national raw materials; agricultural and fisheries products for tourism and exports; diversification and optimization of industrial productions destined to exports and the domestic market in foreign exchange; activities of development, transfer and adaptation of technologies for the gradual digitization of the country over the coming years. The universities are present in all these efforts. In particular, under higher education are agricultural research centers and training

33 It should be noted that Cuba has had important results in this area, both in the generation and the commercialization of medicines and products. For example, obtaining recombinant streptokinase; interlucina-2 which inhibits tumors metastasis; the vaccine against the meningococcal meningitis type B, unique in the world; the recombinant vaccine against hepatitis B; vaccine against haemophilus influenzae type B, first vaccine totally obtained by synthesis for human use. In addition, 24 products have been registered including biomedicines and vaccines, 49 advanced generic drugs; 5 products for AIDS treatment; over 900 patents have been granted, and full vaccination coverage is provided (13 vaccines, most of them produced in Cuba). These topics are elaborated on later.

programs of a high level, some of which have three or four decades of operation.

This group covers activities of research and innovation necessaries for the defense and security of the nation, also with the involvement of the universities.

Special attention is paid within this group to energy and the development or assimilation of materials and processing technology needed to support the rest of the priorities.

Since last year, the issues of energy, energy saving and creation of new energy sources have been identified to be an important priority. The country has embarked on what has been called "the energy revolution". Later on, an example will be shown of technological innovation associated with process of training and learning generated by the university. Universities are also working on the development of alternative sources of energy, like wind and solar energy.

Group 3 refers to the areas involved in the study of Cuban nature and society.

These include the studies related with biodiversity, soils, marine and inland waters, coast management, air pollution as well as the influence of global changes on the Cuban environment. Special attention is paid to the care of the environment.

The study of Cuban history and traditions is a priority, as well as the development of research and renewed theoretical approaches on Socialism.

Special attention is attached to the economic research, including the study of the world economy and its impact on our country.

Universities play an important role in this group. For instance, there are research centers and programs linked to marine investigations and the integrated management of coastal zones. The environment is a cross-cutting issue, present in every university program; universities have centers devoted to the study of the environment and there are various postgraduate programs on it.

Training and education at all levels and history research are well represented in higher education.

The same is true for social sciences and economy. There are programs in these areas supporting other priorities, such as programs of the sugar industry, scientific education, training for innovation, among others.

Group 4 is for the advanced scientific and technological areas where certain level must be achieved or maintained to facilitate the advance of the other groups and ensure the continuity of the future development of the country.

It groups a number of activities which are more strategic. These include research linked to basic sciences, primarily Mathematics, Physics, as well as areas of Chemistry and Biology, and multidisciplinary combinations thereof, which are not part of Group 1.

It also incorporates activities of advanced technology such as new materials, electronics and informatics, whose aspects are not considered within Group 2 (Codorniú, D. 1998: 17-22).

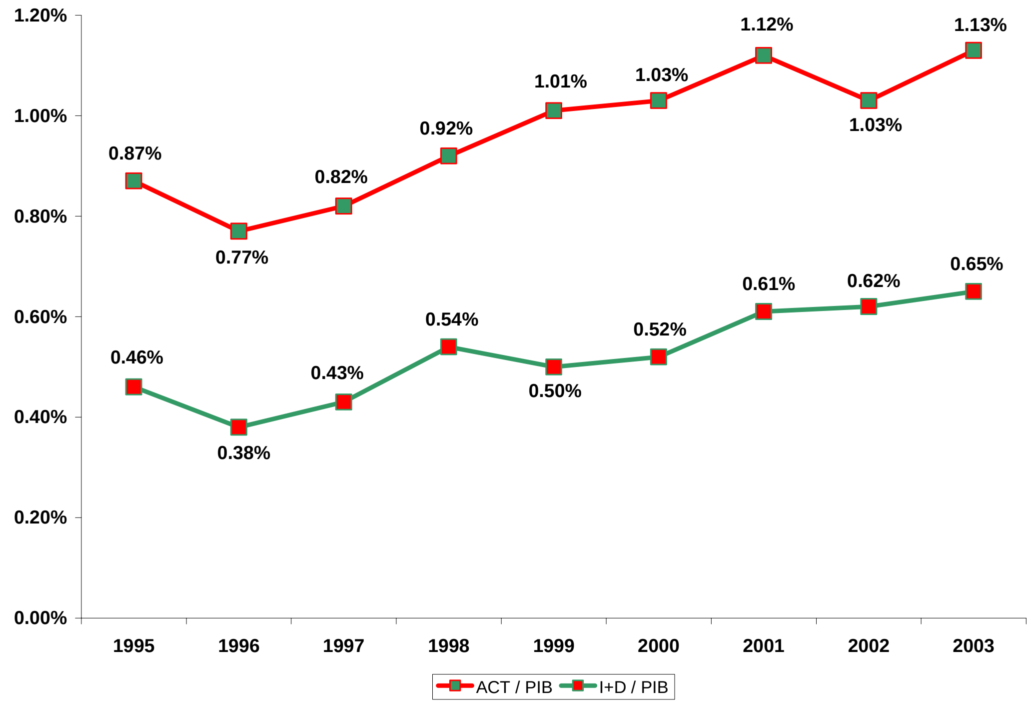
The deployment of the software industry, oriented to support the programs for the digitization of the society and generate exports, basically rests upon the universities. Several universities have programs for university degrees and postgraduate education on computer science and informatics. One of the greatest bets of the country in terms of higher education was the creation of the University of Informatics Sciences, which shall be elaborated on later.

In the field of basic sciences and others included in this group, universities are the most important actors due to their training programs and research. Material shortages caused by the adverse economic situation of the past decade have dealt a strong blow to the infrastructure for training and research. However, training programs and research persist, almost always very much articulated to international cooperation.

Indicators selected from the System of Science and Technological Innovation

The efforts carried out for years by the government to promote science and technology activities (ACT) can be best seen through some of the selected indicators shown below. Note on the Chart No. 5 how, as of 1991 in spite of the financial difficulties that the country went through in the 1990s, the total expenditure in ACT as GDP percentage showed an upward trend.

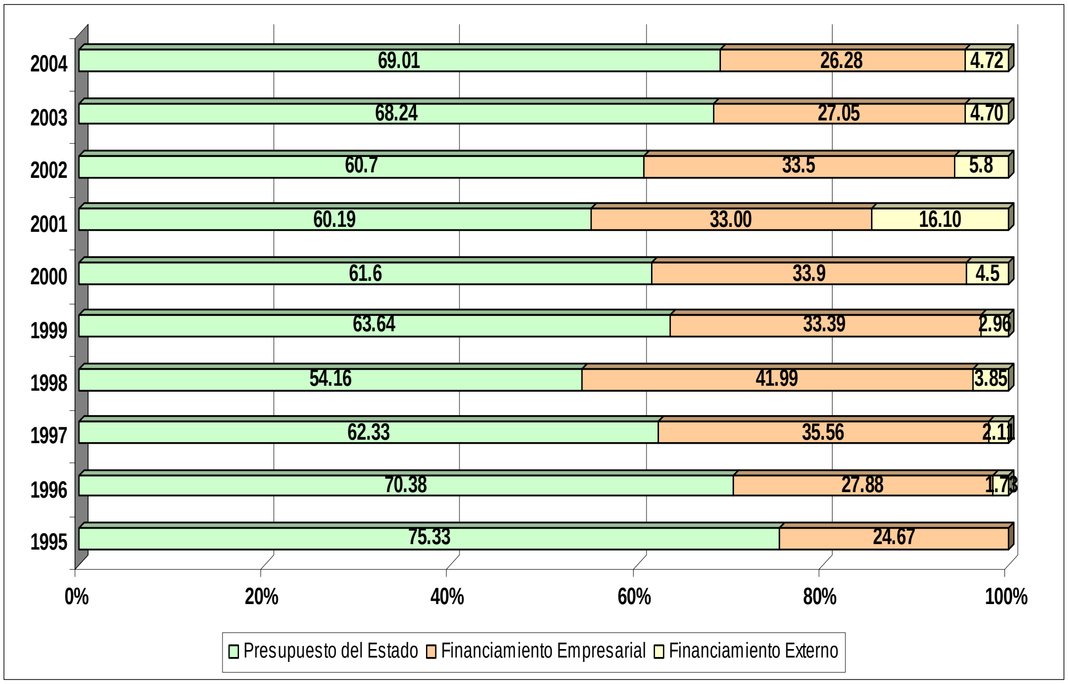
Chart No. 5. Total Expenditure on ACT and R&D as GDP percentage



Source: ONE / CITMA (Planning Division)

Chart No. 6 shows also the efforts in ACT, identifying the sources of funding. It shows the relative participation of the government, enterprises and the external funding in these efforts. As is known, private business in Cuba have a limited scope and maybe except in areas where foreign capital is involved, they are enterprises which do not carry out ACT, so when a company funding is discussed, it refers in most of the cases to state-owned enterprises. So, however it is calculated, the State appears as the almost absolute financier of ACT efforts in Cuba.

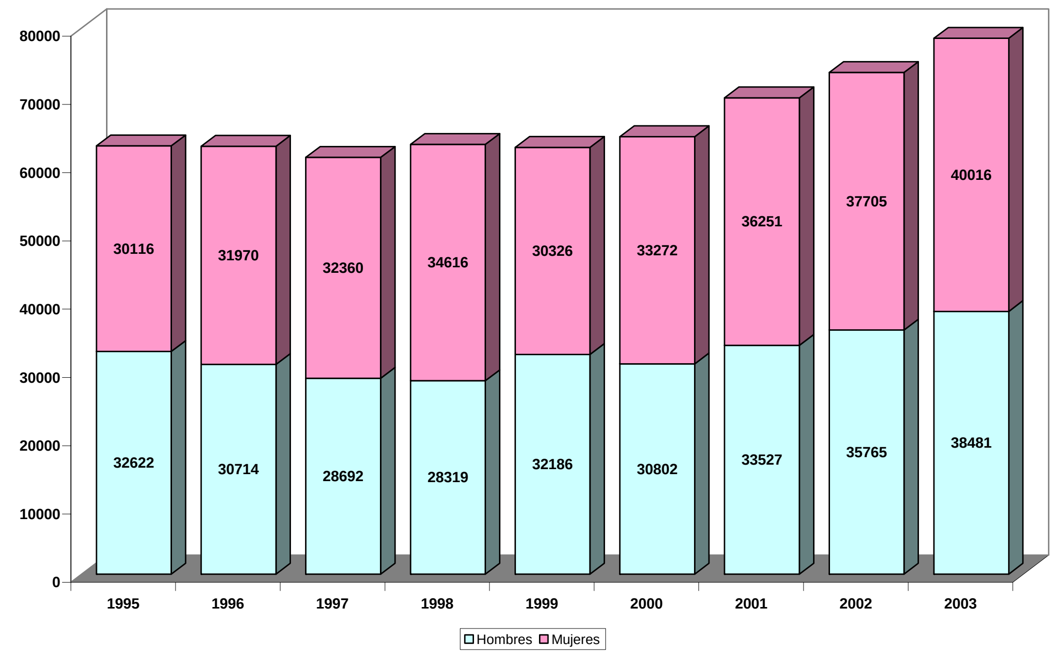
Chart No. 6. Current expenditure in ACT per source of funding (%)



Source: Calculated based on information CITMA (Planning Division)

Chart No. 7 shows the level of participation of women in the country's scientific and technological activities. As can be seen, combined, women make up the majority in the ACT.

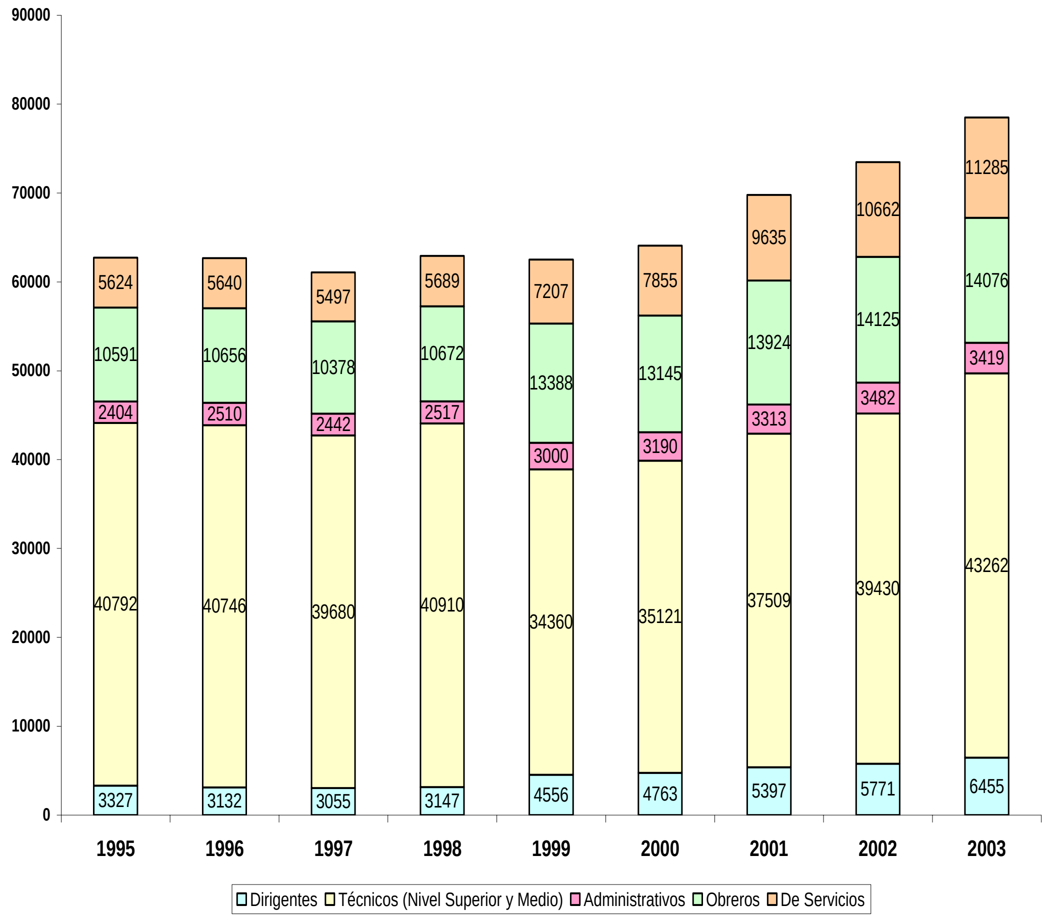
Chart No. 7. Labor force in Scientific and Technological activities (ACT) per gender



Source: CITMA (Division on Human Resources)

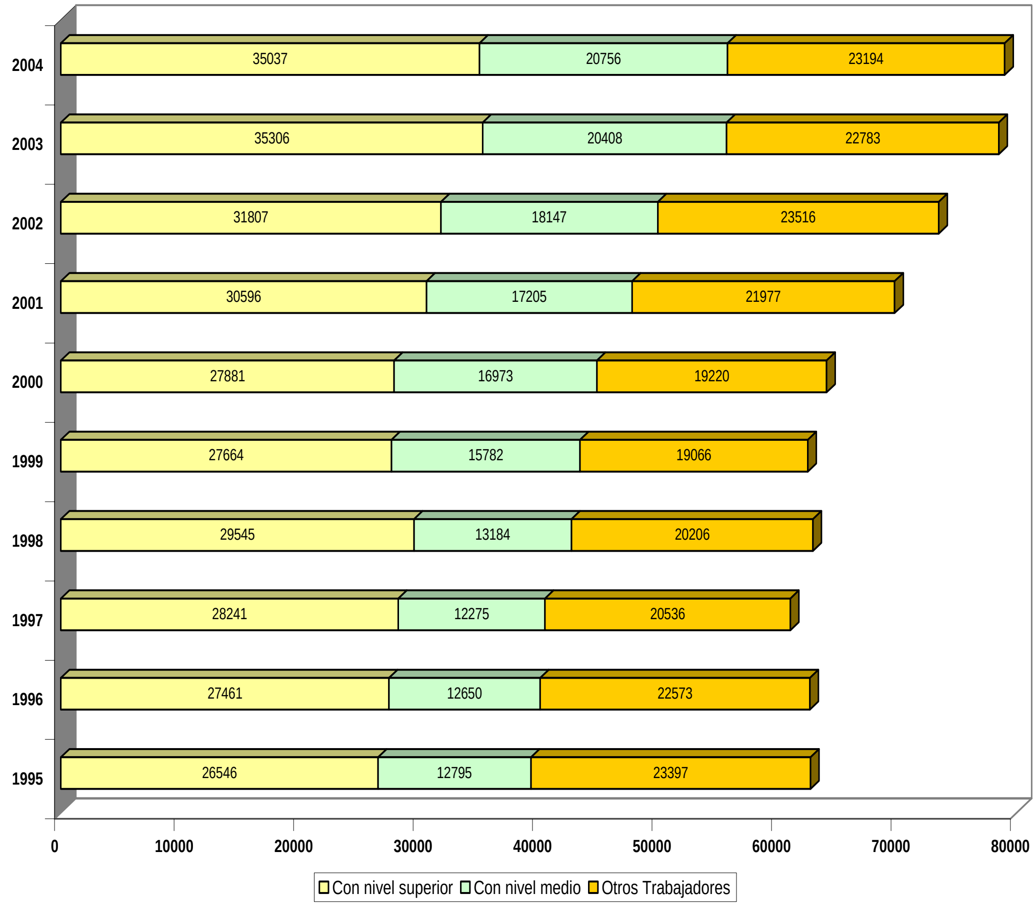
Charts No. 8 and 9 show the break-down of labor in ACT according to occupational category and educational level respectively. Chart No. 8 also shows that the bulk is for technical personnel, both university and middle level. Chart No. 9 shows that most of the technical personnel are university graduates.

Chart No. 8. Labor force in ACT per occupational category



Source: (AEC, 2005)

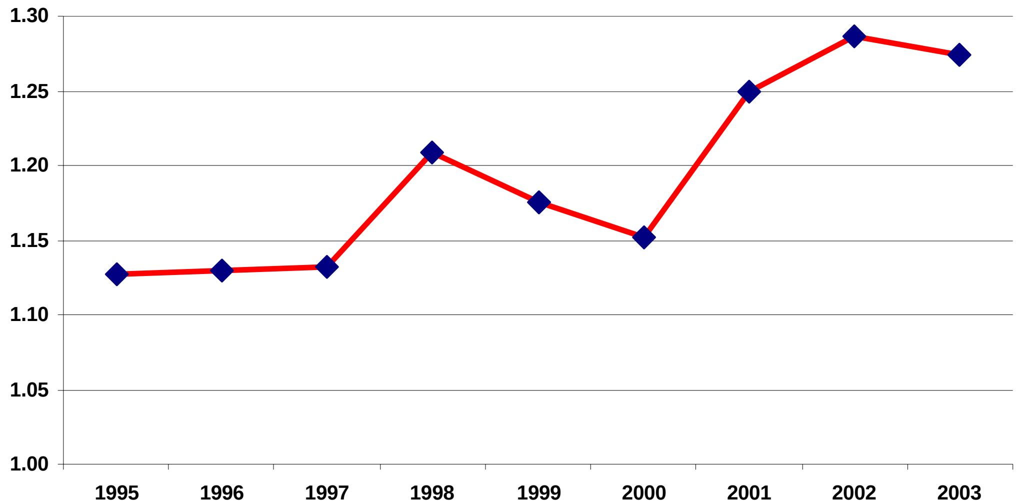
Chart No. 9. Physical workers in ACT per educational level



Source: (AEC, 2005)

Finally, Chart No. 10 shows the number of researchers per 1000 inhabitants of the employable population. Note that by the end of 2003, the country had 1.27, showing an important human potential for R&D if compared with countries like Chile (1.17), Colombia (0.52), Panama (0.35), Latin America and the Caribbean (1.02) (RICYT 2003).

Chart No. 10. Number of researchers per one thousand inhabitants of the employable population



Source: (RICYT, 2004)

The System of Science and Technological Innovation: a preliminary assessment

The building of the system of innovation is still an unfinished process. The foundations have been laid, progress is being made, but the SSTI has limitations curbing its effective functioning.

As pointed out earlier, the undercapitalization of the productive sectors was accentuated when the country began the so-called "Special Period" in the early nineties. Many enterprises were operating with obsolete technology and with a high level of inputs and energy carriers[34]. This situation somewhat remains and has an influence in the productive development and the innovation capacity.

The lack of funding is another major problem. The policy of the Cuban government of preserving and supporting the R&D efforts has led to keeping the institutions operating with the existing resources in spite of the severe economic restrictions. State support to R&D funding allows ensuring basically the salaries of the staff involved in the activity, as well as covering other domestic currency expenses.

The most negative effect in R&D funding relates to the State's supply of foreign exchange. The considerable shortage of foreign exchange has led to allocating

34 The impact this had on the country in energy terms is illustrated by Figueras, by highlighting that in 1978 Cuba consumed 1,111 kg of energy (in terms of oil equivalent) for every million dollars of the GDP. Due to the economy downsizing efforts, the figure was reduced to 848 kg by 1987.. However, in the referenced years, the value of that indicator was brought to 323 down from 407 in Spain, 259 down from 322 in Italy and 205 down from 286 in Japan (Figueras, 1994:46).

these resources with much selectivity, with a view to ensuring the appropriate functioning of institutions and R&D efforts of specific sectors involved in high-priority work. The inability to cover the foreign exchange needs of all R&D institutes, universities and enterprises, among other actors of the system, creates great difficulties for acquiring materials, specialized inputs, international mobility, equipment, as well as limitations in the access to national and international information networks and Internet.

These limitations are compounded by organizational difficulties. In spite of the statements contained in the SSTI documents, R&D continues to take place predominantly outside enterprises. Enterprises are not the axis of the system. The technological efforts of the business community have failed to secure effective linkages between R&D and production. The specialized entities in the interface services have focused their work on organizational development and have given less attention to technological management.

It is also very likely that in various sectors, training of workers, technicians and professionals does not live up to the industry's development needs.

The systematic follow-up and evaluation mechanism for SSTI has not worked ideally. In some cases, there is no precise information providing assistance in the decision making process (OCCyT, 2005).

The limitations identified indicate, *inter alia*, that the effective implementation of SSTI still requires a long and complex process of maturation. However, success stories of innovation efforts with a major social impact can be identified in sectors of the Cuban economy and society. Let us mention some examples:

The sectorial system of the biotech-based medical-pharmaceutical industry can be considered a success story of knowledge-based economy (Lage, A. 2000). It is based at Havana's West Pole, a cluster with more than 40 institutions and 12 000 workers, seven thousand of which are scientists. These institutions operate in a "closed cycle": research, design, product development and product manufacturing and marketing.

This sectorial system of innovation incorporates other actors such as universities, research institutes, the health care system and, very importantly, the government. The system works under the leadership of the State.

The State has made the investment and property is social, although research and commercial agreements are entered with foreign companies. Only the State can make that this technological and scientific development have the following characteristics, among other: strategic importance, large scale, high risks and high costs (Arocena, R and Sutz, J, 2003, p. 105).

The impulse to the industry depends on the combined effect of two major driving forces: the country's health needs and exports. The positive impact on the health care system is extraordinary; for instance, all children get the benefits of 13 vaccines for free, almost all of which are Cuban. Biotech in Cuba, in particular its health-related applications, enjoys a very favorable public perception which facilitates the industry's performance. An example is the conduction of clinical trials with the support of the population and social participation.

The biotech industry operates with a positive cash flow[35], it has generated over 900 patents and its importance within Cuban exports has risen. For example, in 2002 foreign sales of medicinal and pharmaceutical products were valued at 50 million dollars (CEPAL, 2003:5) and in 2005 they are estimated at between 100 and 200 million, becoming the country's second export category. Cuba is probably the main exporter of medicines in Latin America with exports to over 50 countries. There are technology transfer agreements and commercial negotiations underway with hundreds of countries.

Agricultural and livestock biotechnology seem very promising for the country's development. It is possible to speculate that the sectorial biotech-based system of innovation is becoming a "guiding system of innovation" in Cuba (ibid, p. 103) (a role played by e-commerce in other countries, for instance) with a major influence in the rest of the technological areas (such as informatics, let us note the great demand generated by bio-informatics), the economy and higher education.

A great social impact has been achieved by urban agriculture[36] whose main objective is to mobilize the existing productive potential in every locality to produce food all-year-round, even in exceptional conditions. In this regard, an infrastructure has been created[37], with a great job-generating capacity (308 000 workers in 2005) and good performance indicators.

Ten thousand university professionals and 45 000 technicians work in urban agriculture. Urban agriculture has a branch research program to evaluate and systematize the experiences learned. International organic agricultural conferences are convened periodically. The National Research Institute of Tropical Agriculture (INIFAT), a research center with a century-old tradition, supports the urban agriculture-related research and extension program.

The urban agriculture enables to increase biodiversity and promotes the conservation of the environment in keeping with the urban setting. It can

---

35 In the US and Europe, barely 20% of biotech companies are able to finance themselves with their sales of products. They are funded, above all, by venture capital and speculations in the stock exchange (Lage, A. 2005 : 35p). As can be seen, the experience of the Cuban biotech is radically different to the one in the US and Europe. Maybe the crucial different lies in the ownership regime. In Cuba ownership is social and society receives the benefits. A fundamental role is played by the moral motives of scientists and other actors.

36 A productive movement with a deep popular sense and marked character of organic production on the basis of sustainability. Food is produced within the urban and peri-urban perimeter by applying intensive techniques, and taking into account the man-crop-animals-environment interrelation and the facilities of the urban infrastructure providing labor stability and diversified production of crops and animals all year round, based in the sustainable management allowing for the recycling of waste.

37 The National Program of Urban Agriculture has an infrastructure made up by a network of municipal seedbed farms, centers and microcenters of organic manure, people's nurseries, municipal veterinary clinics, centers for the reproduction of entomophagous and entomopathogenous (CREE) and comprehensive centers for animal feed.

therefore be characterized as a group of eco-innovations (Arocena, R and Sutz, J, 2003, p.105).

Its development is based on the intensive and rational use of the cultivation area, the permanent training of the labor force as well as on the combined use of modern and traditional techniques. It is characterized by remarkable energy savings. Some productions have a proven therapeutic value and, in coordination with the Ministry of Public Health, they are being used to that end. (Companioni, N., 2005).

Urban agriculture is a national movement, notably integrated and organized, mobilizing various ministries, scientific institutions and both national and local social organizations and relying on public participation. Researches often act as extensionists, which guarantees the communication of tacit knowledge (passed down through interactive learning) and a close relationship between scientists, producers and consumers.

The Higher Education System

The Cuban higher education system[38] plays a significant role in the system of innovation. It provides the university graduates that the country needs, contributes most of the continuing and postgraduate education, conducts a sizable part of scientific and technical research and is incorporated to the main social programs (education, energy, etc) which the country is carrying out, which frequently incorporate technological innovation.

Higher education is not, however, an isolated player (Arocena, R and Sutz, J., 2005), at least as it is in other developing countries. There are relatively important R&D+innovation institutions under other organizations such as, productive ministries (Agriculture, Transport, etc), academic institutions (namely, the system of the Academy of Sciences) and R&D+innovation labs working in tandem with enterprises. A significant case is the already mentioned sector of the medical pharmaceutical and biotech industry.

The system consists of 65 higher education institutions[39], all of them public, with a relatively fast expansion. Prior to 1975-76 there were five higher education institutions (IES): the University of Havana, founded in 1728; the universities of Oriente and Las Villas, founded in 1947 and 1952, respectively. The Military Technical Academy was created in the 1970s and the University of Camaguey in 1975.

In 1976 the Ministry of Higher Education (MES) was established. The decision was made to turn into IES some schools and institutions that were part of the

38 General information on Higher Education were provided by the Statistics office of the Ministry of Higher Education.

[39]All higher education institutions carry out continuous education, postgraduate training and research, with variable intensity and depending on their academic profiles. Some ten universities carry the main burden of research and doctoral training.

major universities, resulting in a network comprising 27 IES. Other nine institutions were established in the same decade. In the 1980s, there were six, and in the 1990s, an additional seven.

Six more institutions have been established since 2000. Most of these IES are locally oriented, rather than nationally, and an important fraction of them have a single profile to train graduates. In terms of the number of students enrolled, those in the teaching and health sectors stand out. In total, Cuban IES offer 94 university degree programs.

The process of "Universalization of Higher Education" in effect for the last five years, has led many IES to establish university venues in all 169 municipalities of the country. There are 3150 venues[40]. And three hundred and sixty five thousand youths study 46 different university degree programs in them.

Such process of universalization has provided access to higher education to 510 thousand students, amounting to more than 50% of the youth aged 18 to 25. This represents that three in 100 people study at the university. Sixty four percent of students are women and 36%, men.

Higher education employs a little over 32 thousand full-time teachers and around 84 thousand part-time teachers.

Over 800 thousand students have graduated over the last five decades. That is, seven out of 100 Cuban citizens hold a university degree. For the academic year 2009 – 2010 the estimated figure of one million graduates will have been reached. The graduates in this period include some 22 thousand foreigners from 125 countries. Of them, 45% are women.

Training and education of professionals

Types of courses

There are two modalities of study in higher education: full time or part time studies. The former includes regular day courses and responds to a plan of matriculation in higher education approved by the country, depending on the envisaged demands in the socio-economic strategy. These types of studies require a certain time for its completion (usually five years) and a similar progress pace for all students. Upon completion of these studies, the State guarantees all graduates a job in accordance with the title conferred. These courses are fed by young high-school grads that, in most cases, must take and pass entrance exams for higher education. Full time studies are characterized by a greater presence of students in the classroom and are usually conducted

40 Of which, 340 are under the Ministry of Higher Education; 2361 under the Ministry of Public Health; 209 under the Ministry of Education and 240 under the National Institute of Physical Education, Sports and Recreation. They have 96,500 teachers.

in the main campuses and teaching units[41] of the universities. During academic year 2005 – 2006 enrollment in this type of course amounts to 145 thousand students.

Enrollment per branches of study. Full time study

	%
Technology	16.0
Natural Sciences and Mathematics	2.9
Medical Sciences	21.6
Agricultural Sciences	2.8
Economy	6.3
Social Sciences and Humanities	7.0
Pedagogy	38.0
Physical Culture	5.0
Arts	0.5

Part time studies are offered to everyone with completed higher secondary level, without age limit, and are geared to ensure full access to higher education. It is conducted after hours. There is no commitment by the State to guarantee these students an appropriate job in accordance with the profile of their studies, although very frequently these studies are chosen by people who are already working[42]. Students move at their own pace, without time limit to complete their studies, they have less demands in terms of class attendance and these studies are mainly offered at the municipal university venues or other training spaces.

New programs, new profiles, new universities.

In order to illustrate the relationship between the training and education of professionals and the evolution of the productive and social needs of the country, it can be said that in 2005 the program of engineering in Informatics was offered in five new provinces, making it available for study in 13 provinces, and the program of Law was made available to 12 provinces. These programs were also available in the Special Municipality of the Isle of Youth. The program of Physics Engineering, recently approved, will train all professionals that the health network needs to tend to the large amount of medical equipment that have been recently installed in hospitals, polyclinics, rehab centers (which

41 Those working entities with the appropriate scientific and technological development in the field of the specialty at hand, the sufficient amount of specialists for the required attention to students, the general conditions to favor the teaching of classes, study practices, on-the-job training and term and diploma papers, the extracurricular scientific research etc, which may contribute to the development of professional skills and habits. These units must guarantee the development of systematic or concentrated teaching activities with or without the presence of students there.

42 Account must be taken of the fact that in Cuba the unemployment rate is below 2%, which technically is considered “full employment”.

become in themselves, university training spaces for doctors and other health-related specialists). Likewise, Biomedical Engineering will respond to the medical-pharmaceutical needs of the country. The programs of Engineering in Meteorology, Bachelor of Tourism and Agro-industrial Engineering will also respond to the needs of the economic, scientific and technological and national defense development of the country. The program of Bachelor in Restoration of the Built Heritage will be made available as a response to the work of recovery and maintenance of the Cuban architectural heritage.

On the other hand, existing programs offer their professionals training in more specialized profiles during their senior year. The programs of bachelor of Physics, Biochemistry, Chemistry, Computer Sciences and Biology have placed emphasis on bioinformatics, very close to the needs of the Cuban biotech industry. The programs of Chemical, Geophysics and Geology Engineering have emphasized oil. Furthermore, the engineering programs of Automation, Telecom and Mechanics offer in their senior year a diploma course on Optometric and Lasers in order to tackle the needs of the country's health network.

The most recently established IES include the University of Informatics Sciences (UCI), with over eight thousand students, reflecting the government's efforts to develop the informatics industry, connect it to the country's development needs and increase the presence of its products in the country’s exporting portfolio.

The UCI is an innovative institution having a “productive infrastructure” centered in the production of software that caters to the demands of numerous sectors (namely, health, education, among others) both to meet the national demand and for export. Exports amount to tens of millions of dollars.

The UCI model links production, training and education and research. Students, together with the teachers, work in the production of software as they go about their studies. Research activities are largely subordinated to the production efforts and they are part of the training. The work includes market studies, industrial property studies, quality control, etc.

The training, production and research activities are located at the UCI but they are possible, *inter alia*, thanks to the remarkable Government support, the networking with other institutions in the country, especially other universities contributing professors and researchers. Indeed, a significant number of Cuban universities have programs of informatics and computer sciences. Research groups and training programs of several universities are actively cooperating with UCI.

The “Aided Distance Education” and the productive environments

In the efforts to universalize higher education and train its workers, more than 25 bodies and organizations in the country have implemented the aided distance education. This is a modality of the traditional distance education[43] in response to the requests of many entities that need to train their technical and high-school level workers as university-level professionals. Training takes place in cooperation with these entities and the university and the venues are the workplaces themselves, as they become university classrooms. More than 50% of their teachers are the professionals involved in the sector and the rest the professors teaching at the universities. For example, the West Scientific Pole of Havana currently has classrooms to train workers in Accounting, Finances, Informatics and Chemical Engineering with specialization in Biotechnology. The Ministry of Construction has requested that the programs of Architecture and Civil Engineering are made available in all 14 provinces of the country, due to the need for university level professionals commanding the advanced construction techniques that have been recently introduced in the country.

Scientific research and on-the-job training

Scientific research is part of the university curricula since the early years of study. Students carry out scientific tasks, participate in students scientific fora, and many programs complete their studies with a diploma paper which is based in a research and shows the student's abilities for the activity (Horruitiner Silva, 2006).

This relationship with research during the whole program largely happens through the on-the-job training. Linking study and work is one of the guiding principles of higher education in Cuba. Its main objective is to ensure the training and education of a professional that is suitable for its performance in society, through the students' involvement in the solution of real problems of production, services and research from very early on in the program. This principle is taken into account in the curriculum design. The student performs professionally, incorporating modalities of scientific research into their professional activity. This is called, as a whole, research-work activity. This activity amounts to a third of hours of lesson in the programs of Natural Sciences, Social Sciences and Humanities, Economic Sciences, Agricultural Sciences and Technical Sciences. (Horruitiner Silva, 2006)

All universities have linkages with enterprises, production centers and they have their students working in tandem with the professional activity carried out in them. This is a generalized practiced in university programs in Cuba. Teaching units play a fundamental role in it. At present, there are 821 teaching unites employing 4788 professionals. In the 2004 – 2005 academic year, 76% of the enrollment in the regular day course conducted activities in these institutions.

---

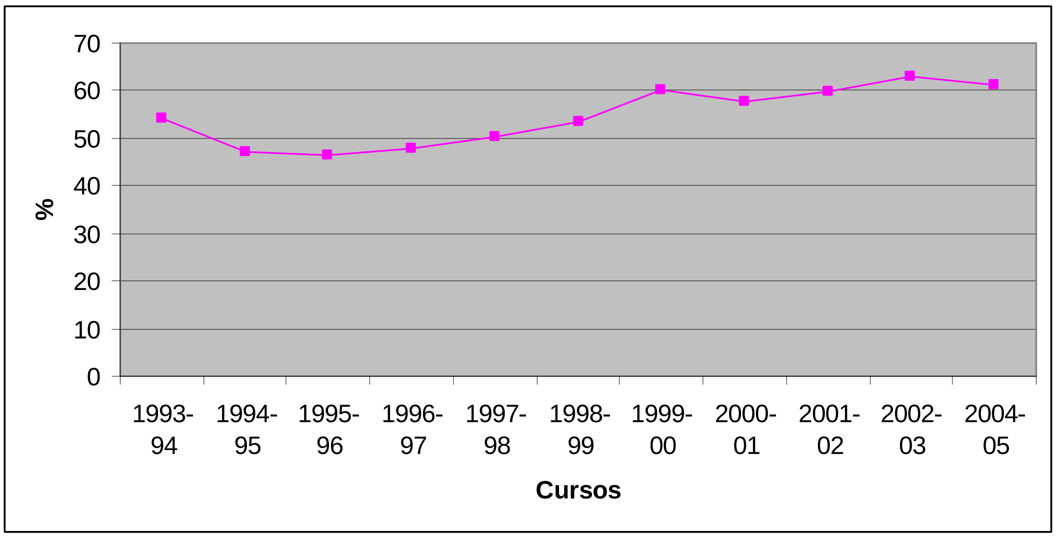
43 Distance education was established in Cuba in August 1979 with a view to expanding the possibilities of higher education studies for the population without interfering in their work or social activities and irrespective of their place of residence. It is open because it does not fix a time limit and the student decides its own learning pace in accordance with their personal possibilities. It is called distance education because it allows the development of studies outside the university premises, independently, without taking classes, although methodological advice, bibliography and other supplementary means are made available. The term "aided" means that it is an intermediate modality between full time and distance education, which includes activities in the classroom.

The professional training courses include a plan for highly performing students[44], through which students with a better performance join prominent scientific teams within or outside the university. These students are part of the pool of young scientists and during the process their curriculum is modified so as to expedite and deepen their training and come out better prepared as researchers. Currently, 10% of full-time university students are part of this program.

Professional training and education and the innovation system

Professional training and education plays an important role within the innovation system. It contributes the university graduates, develops practically all major university programs and does that with a 60% efficiency (students who complete their studies versos those who enroll) as shown by Chart No. 11.

Chart No. 11. Students who complete their studies versus students enrolled (%)



Source: Drawn up based on the data made available by the Statistics Office of MES.

This is compounded by the above-mentioned aspects.

- Curricula integrate activities of teaching, production and research.
- University education and training is fully spread, reaching a significant part of the youth and workers wishing to continue their studies.
- University studies are closely related to the socio-economic strategy of the country and, above all, at the end of their program full-time students have a guaranteed job in keeping with the completed studies.

44 These are special plans for those students with faster assimilations rates and favorable aptitudes for learning and scientific work, who stand out due to their academic performance, creativity and independence in the carrying out of their academic, work and research activities, and that are able to take up tasks supplementing their curriculum.

- The IES, with their municipal venues, span across the whole national territory, enabling for proximity of professional training and local needs.
- The process for the establishment of university programs, modification of curricula, conducting on-the-job training, students research, creation of training spaces in enterprises and other organizations, and even the founding of universities is directly associated with the solution of social, economic, cultural and environmental demands. Thus, the knowledge involved in the education and training of professional is closely related to the development of the country.

The national system of postgraduate education

Concept of the system

Cuba is among the Latin American and Caribbean countries which have been able to structure a national system of postgraduate education. The postgraduate education strategy in Cuba is based in the priority of education understood as continuing education or lifelong education. It is considered as the opportunity offered for free to all university grads to continue their training process throughout their work lives, and even after that. It is aimed at updating, qualifying, retraining and reorienting graduates in sync with the demands of their work performance: in the academic, research and professional fields.

The system is national because it is guided by the same criteria in all institutions of the country. There is a Regulation of Postgraduate Education of the Republic of Cuba. The Ministry of Higher Education conducts the national policy in this field and several national bodies exist: the National Commission on Scientific Ranks, the Advisory Permanent Commission for Postgraduate Education and the National Accreditation Board, all of which are in charge of the policy and quality management of the postgraduate education.

The idea of a system also refers to the articulations of different forms of production, diffusion and application of knowledge. These forms are grouped in two sub-systems of the postgraduate education. The first is professional advanced studies, which includes short courses, trainings, diploma courses (equivalent to specialization in many countries) and even activities such as conferences, workshops and debates, among others.

The other sub-system includes master’s programs, specialties and doctoral programs. In the beginning the former had an essentially investigative orientation (master’s degrees in science) and presently they are also oriented towards innovation. The specialties have always taken care of the needs of learning, updating, deepening, improving or expanding the working competence of the graduates and are articulated to the innovation processes.

Put differently, in Cuba postgraduate education includes what other countries call continuing education, as well as master’s degrees and doctoral programs, and specialties leading to new degrees.

In 2005, the number of participants in postgraduate activities reached 600 000 grads, out of a total of 800 000 in the country[45]. These are carried out not only in universities but mainly in the enterprises and other settings where the effective work takes place. Hence, postgraduate certificates contribute to improve qualitatively the work performance of the mass of professionals and the process of innovation.

The master's degree programs are essentially generated by initiative of the universities and some research centers, in accordance with the needs of economic, social and cultural development. The specialty is conceived as a joint undertaking by demanding entities and the universities. In both cases the interaction between the universities and sectors of production and services are encouraged. However, specialties of the latter play a more leading role, contributing not only the demand, the physical space and resources but also part of the teachers and tutors of the programs. The academic committees (bodies where the programs are conducted) of the specialties are mixed, including university teachers and professionals from the production and services. Specialties devote no less than 50% of credits to work (oriented and supervised) and master's degree programs allocate the same percentage to research, innovation and artistic creation activities.

The length and intensity of the postgraduate training is determined by the academic credits. In the past, the credits were associated with activities in the classrooms in front of the teachers. This approach has proved very limited vis-à-vis the needs of professionalization, the linkage with production, distance education and the ideals of continuing education and self-managed learning promoted by postgraduate education.

Looking at several experiences, especially from Europe, the credit equals 48 hours of the student academic work. For every hour of teaching in front of the professor, at least 3 hours are allocated for the student's independent work as well as activities of study, practice, research, publications, text drafting, and preparations of exams among others[46].

The doctoral program is thought of as a process of educating researchers of the highest level. Two basic variants coexist nowadays, one more unstructured and individualized, that is tutor-led, without obligation of completing courses. The other is more group-oriented, including some courses and other activities of a collective nature, always under the watch of the tutor and other instructors, favoring their immersion in cooperation networks.

---

45 All data on postgraduate education has been made available by the Postgraduate Division of the Ministry of Higher Education.

46 Under this approach, the minimum length of masters programs and specialties is 70 and 100 credits respectively.

At any rate, the primary research nature of the doctoral program is preserved, although the concept of research fluctuates according to the different fields of knowledge.

The evaluation of the doctoral thesis incorporates the judgment of people and institutions which may give a legitimate opinion on the quality of the results, their practical applicability and social impact. Thus, the idea of peer evaluation is preserved. Nonetheless, it bears in mind the usefulness, efficacy and efficiency, which are not always taken into account by the academic peers. Very frequently, the evaluation opinion takes into account the consideration of its impacts.

Postgraduate education in its settings

To understand the functioning of our postgraduate education as a national system and its insertion into development, it is worth briefly commenting on the settings in which it occurs.

One setting is that of ministries, bodies and enterprises that, according with their technological, productive, social and cultural strategies, require the training of the people working for them. These institutions usually have HR representatives in charge of this activity. Ministries usually have "branch schools" in charge of that training role.

Universities cooperate actively in determining the organizations' needs for advanced studies and, of course, in meeting them. This is the setting where specialties occur primarily. The growth of the number of specialties suggests an improvement of the organization's response to the need of training their human resources.

Another relevant setting is that of the territories. Each territory has its own economic, social and cultural strategy, as well as a need to train their professionals. Universities, in close relation with the governments, engage in determining the learning, research and innovation needs of the territories and how to address them. The universalization of higher education has brought about the universities' offering new opportunities in knowledge management and innovation for local development.

The last setting is the academic. It covers postgraduate activities taking place within universities in order to promote teaching and research capabilities. The permanent academic improvement of university teachers is part of their contractual obligations. The main efforts are geared to the training of doctors. Among the universities with the greater traditions doctors represent 40% to 50% of the faculty. The other 20% is in the other end. The most encouraging data is that around 50-60% of teachers without a doctorate are currently working to get one.

The drive to train doctors is shaped by a strategy of the Ministry of Higher Education mainly expressed in the granting of scholarships for research development in the country's best universities and research centers. The strategy also consists of improving the possibility to study abroad in order to complete the national training.

In the above-mentioned settings, continuing and postgraduate education pays special attention to the people holding leadership posts in ministries, enterprises, the government and other organizations, as well as the people getting ready to hold those responsibilities[47]. There are specific strategies of education and training incorporating various components: modern management techniques, technical and professional advanced studies, economic training, as well as training for the defense of the country and political education. These processes of education include the highest leaders of the State and Government up to executives operating at the grassroot levels of the organizations and territories. This enables that people in leadership positions, most of them university graduates, are qualified for the duties of their post, improving their performance. In addition, quite often they are also involved in other postgraduate education and training programs.

The system expands

The system has taken several decades to build, although the greater expansion and institutional consolidation can be seen in the last 15 years. Let us look into the causes.

- The relatively high number of university grads the country has, some 800 thousand, as mentioned earlier. They make up little over 7% of the current Cuban population. This amount of professionals can only become a strength as long as they remain updated.
- In the 1980s, the country adopted a training strategy of university graduates with “broad profiles” (for example: general training in chemistry without specialization in polymers, organic chemistry, etc.) whose training ought to be completed in the postgraduate phase in order to successfully deal with the job's demands. Postgraduate education then becomes the necessary continuation of preceding studies.
- The higher education centers, together with other social players, have captured one of the messages clearly being sent by worldwide changes, associated with the new highly knowledge-intensive technological paradigm: development will increasingly depend on the professional, intellectual, scientific and technological capabilities.
- The Cuban society is going through economic and social transformations requiring new skills and work profiles, renewed economic practices.
- The 1990s kicked in with a rupture of the traditional linkages that postgraduate education in Cuba used to rely on. A sizable part of the training of doctors and other expressions of postgraduate education took place in Europe’s socialist countries. These linkages were severed for reasons all too well-known and together with a process of reconstructing higher education institutions’ (IES) international linkages, national

[47] They are officially called cadres and reserve, respectively.

strategies had to be devised for the development of postgraduate education ensuring through different means what could previously be obtained in the socialist bloc.

- For decades, IES cultivated scientific research as one of their basic projections. Consolidated groups operate especially in IES of greater development in order to push forward lines of research with known results serving as basis for postgraduate education.
- The changes that took place in the National Scientific and Technological Policy since the mid-1980s re-launched university research and modified its institutional forms.

Trends of postgraduate education and innovation system

Some trends can be observed in the Cuban system of postgraduate education:

1. The volume of postgraduate education in the country has increased significantly, measured both by the number of people and the number of programs and institutions involved. The annual growth of participants is around 20%. Some 99 thousand people are involved in the 844[48] master's degree programs in effect in the country. Master's degree programs are distributed per field of knowledge as follows:

Table No. 1. Master's degree programs per field of knowledge

	Total	%
Agricultural Sciences	34	9,3
Technical Sciences	72	19,6
Pedagogical Sciences	58	15,8
Natural and Exact Sciences	41	11,2
Biomedical Sciences	59	16,1
Economic Sciences	53	14,4
Social Sciences and Humanities	50	13,6
	367	**100%**

In 2005 some 1800 people graduated from master's degree programs. In total, 21,344 people have graduated. The end efficiency of this type of studies can be still improved on very much.

Some 14 thousand people participate in some 800 Specialty programs.

Currently there are 55 medical and 114 non-medical specialties, whose break-down per field of knowledge is as follows:

48 There are 367 different programs approved but some of them were developed during the year in different institutions.

Table No. 2. Programs of specialties per field of knowledge

	Total	%
Agricultural Sciences	15	8,8
Technical Sciences	35	20,7
Pedagogical Sciences	25	14,9
Natural and Exact Sciences	1	0,6
Medical and Biomedical Sciences	56	33,1
Economic Sciences	20	11,8
Social Sciences and Humanities	17	10,1
	169	**100%**

It must be noted that most of the Central State Administrative Bodies and other relevant institutions in the country are developing programs for the training of specialties or preparing to do so.

The country trains 300 to 400 doctors every year. The number of people holding doctoral degrees in Cuba to date is 8494[49]. The distribution of doctors per field of knowledge is shown in the following table.

Table No. 3. Distribution of doctors per field of knowledge

	Total	%
Natural Sciences	1547	18.2
Technical Sciences	1790	21.1
Biomedical Sciences	912	10.8
Agricultural Sciences	1090	12.8
Social Sciences and Humanities	1179	13.9
Pedagogical Sciences	1319	15.5
Economic Sciences	581	6.8
Military Sciences	76	0.9
Total	**8494**	**100.0**

Most doctors work at the university and it is there, in addition to research centers, where there is more interest to train more. However, master's degree students and even more, specialties students, come from the most diverse working backgrounds.

2. International cooperation on postgraduate education has been expanded and diversified. For the abovementioned reasons, the 1990s required a process of international reinsertion of the universities through existing linkages and the establishment of new relations. The most intense linkages between universities are with Europe, Latin America and Canada.

49 Information on the doctoral degrees were made available by the National Commission on Scientific Ranks of the Republic of Cuba.

3. The last decade, in particular the last five years, has given birth to a concept of quality management of postgraduate education very close to the national needs, as well as adjusted to international experiences. Quality is very much linked with the problem of innovation. In Cuba the concept of quality includes not only what is understood as academic excellence, i.e., the one which is determined by the peer review of publications, thesis and other products of knowledge. Quality also incorporates a central concern over social pertinence of the programs of postgraduate education. A socially relevant postgraduate education is being developed, in accordance with the needs of production, services, research and with a good academic level at the same time. This relation between postgraduate education and social demands favors the role of postgraduate education as a driver of innovation.

University, science, technology and innovation

The 17 IES directly linked to the MES[50] stand out because of their contribution to the national scientific development. They get over 50% of the awards handed out by the Academy of Sciences of Cuba (ACC) every year to the main scientific contributions in the country and 50% of the Cuban articles registered in the Science Citation Index; they train over 50% of doctors in sciences and get around 20% of the awards associated mainly with innovation. That includes four gold medals by the World Industrial Property Organization in this last area.

These IES employ some 5807 teachers, 620 researchers, 254 young graduates primarily working on research (scientific pool) and 787 youth (work trainees) carrying out several training activities, including a research component, who can start to work in other organizations upon completion of their training. A little over twenty-one thousand students do some kind of research incorporated in their training curriculum, of which thirteen thousand are seniors and around four thousand are considered top academic performers whose involvement in research is usually important. Generally speaking, the organization of research tends to incorporate young graduates and students into the research teams.

Research in IES takes various institutional forms. Teaching departments are the most traditional. Around 80% of faculty is involved, with varying degrees of intensity, in some kind of research, some times associated with their master's degrees and, especially, doctoral programs. There is an institutional policy and incentive mechanisms favoring the doctoral training, emphasizing the youth.

Quite often scientific work is organized in the departments through the research teams. The research team thus associated with the so-called "Mode 1" of knowledge production (Gibbons, et al.1994) usually in a disciplinary way, takes place in the academia, basically generating publications, thesis and is evaluated by academic peers.

50 Other IES fall under the Ministry of Public Health, Ministry of Education, Ministry of Culture, Ministry of the Armed Forces, etc.

There are also over 50 “Entities of Science and Technological Innovation” made up by some twenty research centers (the bigger ones may total around one hundred researchers) and around 30 Units of Scientific and Technological Development, usually smaller and with less economic autonomy than the research centers. Frequently, they both had moved to alternative forms of knowledge production similar to the ones described in “Mode 2” of knowledge production (Gibbons, et al, ibid): the “application context” determines the course of the research, which is organized multi-disciplinarily, there are interactions with enterprises and productive organizations, it is subject to a different kind of quality control and generates products and technologies which can be commercialized both domestically and internationally.

A little over 90 “Centers of Study” conducting postgraduate education and doing research, operate within the IES.

The more significant fields or research include, inter alia: Medicines, vaccines, diagnosis kits, medical equipment, agricultural biotechnology, animal feed, educational and medical informatics, hydraulics, agribusiness, new materials, neurosciences, electromagnetism, enzyme technology, fine chemistry, computer chemistry and social and human sciences.

The presence of universities in the national scientific efforts is revealed in the fact that 43% of their research projects are directly involved in the top priorities of the country organized through the national, branch and territorial scientific and technological programs.

The greatest weight of research lies in the University of Havana, the Jose Antonio Echevarría Higher Technological Institute, the Agrarian University of Havana, the National Center for Plant and Animal Health, National Institute of Agricultural Sciences, the Institute of Animal Science, the Central University of Las Villas, and with less specialties and with a more regional approach, the Universities of Ciego de Avila, Matanzas and Camaguey.

Since the 1980s, within the context of changes in the National Scientific and Technological Policy, higher education has been striving to increase the linkages between their research and the productive sector, and even commercialize its results, including exports of products and technology, preferably to Latin America, Europe and Asia.

In order to facilitate this undertaking, interface institutions were created in the second half of the 1990s under the name of Office for the Transfer of Research Results, as well as mechanisms for the specific funding of product development efforts with revenue-generating capabilities (Núñez, J. y Alonso, N., 1999).

To illustrate the turnaround of the linkages between research and the productive sector, we shall present some examples taken from the University of Havana, the most important research university in Cuba.

Changes in the National Scientific and Technological Policy and new developments in the research agenda

The changes in the National Scientific Policy during the 1980s and 1990s have already been mentioned. They were associated to the government and other actors' view that science was not producing the expected practical benefits. As a result, in the 1980s new signs of the context were sent to the University, demanding greater social contribution, particularly productive, from university research. Ever since 1985 the links of the UH with the main national development programs were on the rise. Against this background, new research centers emerged, generally from already existing groups, in order to provide them with better capacity to apply their scientific results. Thus, “new type” centers emerged directly linked to national programs of industrial development demanding a major scientific and technological support. These centers, based on a multi-disciplinary organization of research, were geared to close the research-production cycle. In this connection, new production capacities were incorporated or very close linkages were created with the industry. For instance, the University of Havana saw the emergence of the Institute of Materials and Reagents (IMRE), the Center of Biomaterials, the Center of Synthetic Antigens, the Center of Natural Products, the Center of Protein Biochemistry and the Institute of Pharmacy and Food. All of them have received, in different stages, significant investment and special attention from the Central Government.

The working style that these centers took on entailed a high level of devotion to the scientific activities considered important to the country. All these centers are immersed in a fabric of relations incorporating various social actors and posing more direct demands to research, plotting new social and technological paths (vaccines, lasers, biomaterials, medicines, etc.). In this way and in a greater degree than before, the relevant fields for research were defined out of the exchange of academic and non-university actors.

As the economic crisis of the country worsened after the collapse of the USSR, the intent to increase the practical effects of research connected with the idea of using this way to get financial resources for the university.

From the policy discussion that was held then, ten chief lines of work defining the new research agendas emerged: medicines, diagnosis kits, biomaterials and medical equipment; new materials, biotechnology and food; environment, computer science, economic studies; history and culture; society and politics; human health and studies on education and science. Each of these directions defined lines of research of priority in order to use more efficiently the limited resources, concentrate the university scientific production and maximize its impact on the more important problems of the country. Guidelines were established for recruiting material and financial resources on the basis of the sale of scientific and technological services, software and high added value specialized small productions as well as technology transfer. It is no exaggeration to say that a sort of "second academic revolution" was in the making (Etzkowitz, H y Leydesdorff, L 1997).

The commercial dimension has forced groups and research centers to learn about topics they had not dealt with before: market studies, cost analysis, project evaluation, quality management, marketing strategies, contracts, intellectual property, licenses and advertisement, among many others. Thus a transformation took place in the thinking and culture of a number of leading scientists and researchers. Multidisciplinary work with economists, legal experts and marketing specialists, working in the university itself, has become an important support.

Innovation and its lessons[51]

Some interesting technological and scientific breakthroughs are going to be mentioned in this section.

Tisuacryl, for instance, is a product created at the UH's Center of Biomaterials, founded in 1991. Since the 1980s, work had been done in the School of Chemistry on the research and development of material for clinical use with a high domestic demand and difficult availability due to high prices in the international market. Biomaterials are usually very much sought after in developed countries. The world market for these products was worth over 120 billion dollars in 2001.

The Center of Biomaterials focuses its work on the technological development and production of biological polymers and ceramic materials. Tisuacryl is a synthetic nonsuture adhesive used to bond tissues and seal wounds in the skin and the mouth as a result of trauma or due to surgery. This so called "biological glue" advantages include saving time and surgical suture, no need for treatment, more aesthetic as scarring is minimized, less risk of infections, it is biodegradable and avoids inflammation and keloids. This product is ISO 9002 certified and registered in the European Union. The same is true with APAFILL-G, a synthetic ceramic granulate of hydroxyapatite for bone restoration in maxillo-facial surgery and dentistry.

The center has completed some 6 products and 9 are in the pipeline. The work done there exemplifies very well the advantages of the coordinated, networked and multidisciplinary efforts where lab research, escalation, evaluation, production and commercialization are conceived from the beginning as elements of a single process. The whole process is governed by the context of application and a concept of the scientific work as proposed by the "Mode 2" theory. Biomaterials are a good example of technological and scientific activities (Núñez, 1999, Echeverría, 2003) where the entire process was characterized by the interactive work between scientists, engineers and health personnel.

Biobras-16 is a high added-value product belonging to a family of stimulators of vegetal growth. It was obtained by organic synthesis specialists of the School of Chemistry from the chemical modification of natural products. Biobras-16

51 The information was made available by the leaders of research teams: Rubén Alvarez, Francisco Coll and Carlos Rodríguez. An article written by the last author (Rodriguez, 1997) helped to understand the evolution of the university scientific policy.

improves crop quality and increases yield by 10 to 25%, it favors plant development in adverse conditions such as saline, water and heat stress and can replace, in various processes, several phytohormones already known.

The context of application is also a determinant throughout the production process of knowledge. The quality assessment of this research includes the classic peer review; and several master's and doctoral thesis and publications have made possible that the synthesis of the likes of brasinoesteroids. But the evaluation of these research activities incorporates the phytosanitary registration, optimization and scale of synthesis, the establishment of methods for quality control, design and start-out of a small production capacity and the production license. It also includes the design of a strategy to apply the product in the Cuban agriculture and for export, which has required market studies, registration of brands and patents, export licenses, exchanges with entrepreneurs, agreements with commercial firms, etc.

Laser technology has been developed at the UH's Institute of Materials and Reagents for 20 years. Young physicists graduated in the USSR began to explore different applications in the areas of surgery, ophthalmology, and laser cutting engraving and soldering. Since 1996 they have taken up again the development of laser systems and manufactured a piece of equipment to cleanse works of art, which has been registered by the European Union and sold to several countries. In 1999, the works began to create a business set up with a view to obtaining components in Mexico and selling the equipment in that country. As part of an agreement with the National Polytechnic Institute of Tampico a laser lancet was developed for blood extraction, which is less painful and makes the process more asceptic. Once registered in Cuba, it could be used in our health system. Work is underway in projects for laser applications for the removal or cleaning of prickly pear thorns and its fruit, both highly consumed in Mexico. The next applications are going to be biotechnology, biomaterials and nanotechnology.

What is common to the abovementioned examples is the following:

- All innovations have been possible thanks to the existence of a "pre-innovation" accumulation (Núñez, J y Castro, F., 2005) expressed in the high level training of human resources, and a process for the institutionalization of science spanning several decades.

- The "context of application" guides the entire process of social production of knowledge. The starting questions include: ¿Science for what? ¿Science for who? ¿What is the economic feasibility? ¿What benefits/revenues is it going to produce?

- The interactions between the various actors and the incorporation of different rationales (scientific, commercial, social, etc.) have shaped the technological and scientific path. The changes examined are not going in the direction of the "entrepreneur scientist" because the goal is not individual profit making. Instead, they lean towards a scientist assimilating an integrated vision of the process of research, production, commercialization and social use of the products, accepting a concept of quality assessment of the scientific work that is far from traditional.

- The chief actors have been the community of university researchers (who are also engaged in teaching and other activities) and the State, on the basis of a community of shared values and objectives.

- Research, innovation and learning go together. And that's in several senses. Firstly, the quality of tertiary scientific and technological training and postgraduate education have made these innovations possible. Secondly, because the dissemination of these products in the society (namely the application of biobras-16 in the vegetable crops) require the social learning by the producers. All these innovations are accompanied by a learning which, in turn, feedbacks research and innovation.

The most radical innovation: building "robust designs"

The most recent and probably the most brilliant success of science in the UH has been the creation of a new vaccine against Haemophilus influenzae type b (Hib) based on a synthetic antigen[52].

A Hib bacterium is the first cause of invasive disease in children under 5. Vaccination against Hib began in the 1970s with a vaccine that proved to be effective from the age of 18 months. It was followed by a new generation of vaccines called conjugates, where a process called conjugation was used to chemically bond the same capsular polysaccharide to a protein of bacterial origin. In the late 1980s the clinical trials with Hib conjugate vaccines of different configurations were completed. All of them proved to be very efficient, highly safe and with little adverse effects. These vaccines are successfully used in developed countries. However, a decade after the introduction of the conjugate vaccines, only 38 thousand out of the estimated 2.2 million cases every year are protected by vaccination, that is to say that only 2% of the children in the world with risk of catching the disease are protected. Prices limit a greater accessibility.

In the 1980s Dutch scientists proved the scientific possibility of obtaining the vaccine through synthetic means. The challenge lied in turning the academic possibility of obtaining a small amount of synthetic antigen into a technology able to produce the antigen for millions of vaccine doses and that such process could compete with the existing one. In the 1990s several universities and laboratories of vaccine producing companies tried that, without being able to go beyond the phase of clinical trials in humans.

The project looking for an alternative to conjugate vaccines began in the UH in 1989. In this connection, a close cooperation was established between the laboratory of synthetic antigens of the UH and the National Center of

[52] Our thanks go out to Dr. Vicente Verz Bencomo, director of the Center for Studies on Synthetic Antigens and collaborators for their valuable information.

Biopreparations of the West Pole of Havana. The Finlay Institute and the University of Ottawa, Canada, joined in afterwards. Then the Center for Genetic Engineering and Biotechnology, the Pedro Kourí Institute of Tropical Medicine and the delegation of the Ministry of Public Health in the Province of Camaguey followed suit.

Little by little, the optimization of the technological process was achieved (chemical reactions were brought down to 23 from 65) and clinical trials showed favorable results and they were done in children with excellent results.

These efforts, with the cooperation of several institutions, led by a small lab in the University of Havana, were completed after 15 years. They proved that the Hib vaccine developed from a totally synthetic antigen is very safe and effective. The registration took place in Cuba in 2003.

At present work is underway in the production of this vaccine at large scale which will save the country 3 million dollars every year, previously used to import Hib vaccines. A Cuban pentavalent vaccine is also incorporated, probably the second pentavalent vaccine in the world. The exports envisaged are for the Latin American and Asian markets. The results were published by the journal Science [305,522(2004)] and the UN Task Force which prepared the document “Innovation: Applying knowledge in development” (2005) reflected it extensively. It was also given an award by the World Industrial Property Organization in 2005.

From the experience of the UH, at least regarding the abovementioned examples, some conclusions can be drawn. Let us look at some of them:

- Development-relevant research must take its application very much into account. It does not reduce the scientific value of the development. The context, the fabric of relations into which the scientific practice is inserted, can generate research agendas and technological and scientific paths allowing for new explorations of the scientific and technological frontiers. These research projects can have a scientific relevance and their application go beyond the limits of the context which generated it. The Hib vaccine proves it clearly. This example reveals the convenience of university research overcoming the basic-applied, science-technology, academic evaluation-context-based dichotomies, among others. Social pertinence can be placed at the core of our values without hurting academic quality.

- The relevant research demands high academic level and requires a good level of scientific education, including postgraduate education. Learning is essential.

- Multidisciplinary, networked work in cooperation is also indispensable.

- The evaluation system of university science must go beyond the exclusive privilege of peer review and should take on board diverse criteria, stimulating the work for the solution of social problems.

Unfortunately we still do not have indicators describing the significance and social appropriation of knowledge.

- Society is much more than market. Science tends to commercial demands but must also tend to social needs. Research agendas must also be led to the goal of promoting the broadest social appropriation of knowledge and its benefits. Knowledge can be a source of social justice and equity.

Innovation and energy saving

The preceding examples illustrate the breakthroughs in research, more or less innovative from the scientific point of view, which have generated production capacity and even business on the basis of science and technology. These are innovations produced by a University with a tradition of five decades of research, hundreds of doctors among its faculty, tens of research groups, master's degree and doctoral programs. Particularly, the case of Hib can be considered to be a result of world level.

We shall mention a relatively different case now: the Total Efficient Energy Management System (TGTEE). This is a result which received the Innovation Award 2005 in Cuba. The award comes after several years of research and postgraduate efforts, including doctoral thesis. The main authors are from the University of Cienfuegos (UCF) and other specialists also contributed. The UCF is a small university showing more modest scientific indicators than the UH but with a significant course on technological and scientific development in the field of energy, having a center of study to this purpose.

The issue of energy —critical worldwide— sparks in Cuba the highest economic, political, social and technological interest. Advancing in a program for energy saving and generation of new sources of energy is a central objective that is shared by all relevant actors in the innovation system.

This is the context in which the TGTEE innovation emerged. It is about a suite of procedures, tools and specialized software that, applied continuously and based in the total quality management, allows an organization to establish new habits in the management, control, diagnosis and use of energy, aimed at using all energy saving and conservation opportunities and at the reduction of energy costs and the associated environmental pollution.

The TGTEE’s essential objective is to increase the technological and organizational capabilities of institutions and enterprises so that they can develop a process of continued improvement of energy efficiency.

Its implementation is carried out through a cycle including training, testing, energy diagnosis, socio-environmental study, design of an action plan, organization of human resources, supervision, control and evaluation among other processes.

The TGTEE is integrated to the management of the enterprise or the institution as a sub-system subordinated to the top management.

This technology has already been implemented in 132 enterprises and now is being disseminated across the country to generalize its use. To this end, a macro innovation project has been put together involving several actors, learning processes and various forms of social participation. In addition to universities, the system involves various ministries, municipal and provincial governments, enterprises and a numerous number of social workers that will supervise the implementation of the system in the organizations. The municipal university venues are cooperating in this project. The central government is in charge of providing the necessary resources. It is an example of working in networks where actors share the same objective. The total cost is estimated at around a quarter million dollars.

In this project, the training of the people who will use the technology covers all municipalities in the country. Cooperation is very important in this connection. The universities under the MES have centers and groups working on the issue of energy in nine of the 14 provinces of the country; some of them employ specialists who co-authored the abovementioned award-winning innovation. The training includes the holding in various territories of a Master's degree program in Energy Efficiency, which already exists in the UCF.

Final Comments

We have given an overview of the role of the Cuban university in the Cuban context of social and scientific and technological development, showing the most visible features of its performance in the National Innovation System.

This report argues that the Cuban university occupies a significant place in the national innovation system. We have considered the contribution of the university in three fields: the education of professionals, continuing education and postgraduate education, including the training of executives and technological and scientific research. All these activities take place within policies giving privileges to the program's social pertinence.

This paper underscores the decisive role played by the Cuban State in establishing national and sectorial policies which have brought about a broad social demand for technology, products and services. The biotech industry is a success story. Its significant progress has been based on the broad social demand of technologies generated from the needs of the national health programs, the high qualifications of human resources involved in the field and the high priority attached to its development.

Social pertinence, as a principle that governs university policy, is oriented towards the multiplication of the linkages of professional education, postgraduate education, research and extension with the productive system and the society as a whole. Probably, an appropriate insertion of the University in the innovation system is only possible if the University promotes this type of interaction.

The Cuban universities are closely related to society. The strategies for university education and research are built in interaction with society. Therefore, the Cuban model has been called "interactive" in its university – society interaction. The Cuban university assumes that society is much more than market. Knowledge and science can address commercial demands but, above all, social demands. The agendas for the education and research set out to promote the widest social appropriation of knowledge and its benefits, seeking equality and social justice. In this regard all kinds of knowledge are useful: those contributed by science and technology as well as art, social sciences and humanities.

We believe this "interactive model" facilitates the university's participation in the innovation system. Furthermore, this model contributes to the social objective of advancing towards a knowledge-based social development model. The "New University" —a model promoting citizen's universal access to higher education and promoting learning spaces in all localities of the country— is an important resource to drive development forward.

The education of professionals puts study and work together and incorporates education into research. The process for the establishment of university programs, modification of curricula, conducting on-the-job training, students research, creation of training spaces in enterprises and other organizations, and even the founding of universities is directly associated with the solution of social, economic, cultural and environmental demands. Thus, the knowledge involved in the education and training of professional is closely related to the development of the country.
All full-time students have a job guaranteed at the end of their studies. This job is appropriate to the studies completed, which favors the insertion of students into the innovation system.

Continuing and postgraduate education are guided by the principle of pertinence. The process of approval, evaluation and accreditation of the programs take social pertinence very much into account and are part of the abovementioned interactive study.

The agendas leading scientific and technological research are also oriented to produce favorable social impacts, including economic impacts. The cases considered show the relationship between these innovations and scientific research of a good academic level, postgraduate education and international cooperation.

This paper has dealt with the negative consequences for the university as a result of the prolonged economic crisis the country has been going through since the last decade. The will of the university actors and the Cuban state to promote university knowledge and connect it with the country's social development, has been greater than the resources that could be mobilized to this end.

The relationship between university research and the productive sector is influenced by other factors. Throughout four decades, the economic efficiency of productive sectors has been on the spot. The different modalities of economic and scientific and technological policies that have been implemented have tried to improve the productive development and the innovation capacity of organizations, including a better use of scientific and technological capabilities. The results in various sectors are still modest. This is one visible limitation of the Cuban innovation system and it affects the interaction of the universities with the productive sector. In a context of serious economic shortages, financial limitations have also affected adversely.

However, there are a number of favorable examples. The Cuban biotech industry has become a strongly knowledge-driven sector. A major contribution by universities can be seen in it, especially through the process of education and training. Vegetal biotechnology is well represented in the universities. The software industry seems to follow a similar path. It is an industry where universities play a major role.

Universities have played a role in the consolidation of the tourist industry, which became the power house of the economy. This industry has required learning processes where the education provided by universities, together with a formidable training strategy of the sector itself, has been of importance.

The universities also support other emerging sectors of the economy and participate in the energy-saving programs and the exploration of new energy sources.

In the universities examples can be found of research groups and centers that have passed from research into production and commercialization of products and technologies with a high added-value. Even in cases where there is a genuine economic interest, the relation of groups and institutions with their Cuban peers usually lack a commercial nature or is very limited.

Then we showed the contribution to the national scientific development made by 17 institutions of higher education under MES, which receive a sizable part of annual research awards, have a large bearing in the publications and they are an important part of the training and education of doctors. Their research projects are involved in the main priorities of the country organized through the national, branch, sectorial and territorial scientific and technological programs.

In our experience, development-relevant research must take its application very much into account. It does not reduce the scientific value of the development. The context, the fabric of relations into which the scientific practice is inserted, can generate research agendas and technological and scientific trajectories enabling new explorations in the scientific and technological frontier, producing relevant research in scientific terms whose applicability can go beyond the borders which generated it. The Cuban Hib vaccine proves it clearly. It reveals the convenience of university research overcoming the basic-applied, science-technology, academic evaluation-context-based dichotomies, among others.

Social pertinence can be placed at the core of our values without hurting academic quality.

A preliminary conclusion to be drawn is that the Cuban universities have made important contributions to the advancement towards a knowledge-based social development model —bearing in mind the material and organizational shortages limiting its participation in the innovation system, still in a building process. Advances are made, the challenges are greater.

BIBLIOGRAPHY

1. Anuario Estadístico de Cuba 2004 (AEC). (2005): Versión electrónica. ONE. C. La Habana.
2. Arocena, R y Sutz,J (2005): Para un nuevo desarrollo, CECIB, Madrid.
3. Carr, K (1999): “Cuban biotechnology treads and lonely path”, Nature, vol. 398, abril, (supp): A 22-3.
4. Castro Díaz-Balart, F(2004): “El papel de las nuevas tecnologías en el desarrollo económico nacional: la experiencia cubana” en Ciencia, Tecnología y Sociedad, Editorial Científico-Técnica, pp119-142.La Habana.
5. Castro, F. (2006): Discurso pronunciado el 1ro de mayo en el acto por el día Internacional de los Trabajadores. Granma, Suplemento Especial. La Habana, p. 3-4.
6. CEDISAC (1999) Multimedia Todo de Cuba, La Habana.
7. Centro de Estudios de la Economía Cubana (CEEC) (2005): Cuba. Crecer desde el conocimiento. Editorial Ciencias Sociales, La Habana, p. 1-33.
8. CEPAL (2003). Cuba: evolución económica durante 2002 y perspectiva para 2003. 24 de julio, 44p.
9. CIEM/PNUD (2004): Investigación sobre Ciencia, Tecnología y Desarrollo Humano en Cuba. ENPSES, La Habana.
10. CITMA (1995). La ciencia y la innovación tecnológica. Bases para su proyección estratégica. La Habana, mayo, 58 p.
11. CITMA (1998). Dirección de Política Científica y Tecnológica: El Sistema de Ciencia e Innovación Tecnológica. Documento Básico. La Habana, diciembre, p.3-61.
12. CITMA (2002): Propuesta de temas priorizados de investigación científica y desarrollo tecnológico en los próximos años, CITMA, La Habana.
13. CITMA (2003): Informe de Balance, Ministerio de Ciencia, Tecnología y Medio Ambiente.
14. Codorniú, D. (1998): Ciencia e innovación tecnológica en Cuba, estado actual y proyecciones. En: IBERGECYT 98. Seminario Iberoamericano sobre Tendencias Modernas en Gerencia de la Ciencia y la Innovación Tecnológica. Matanzas, 26 y 22 de mayo, p.1-26.
15. Companioni, N. (2005): Escenario productivo de la Agricultura Urbana. Intervención realizada en el taller “La gestión universitaria del conocimiento, la ciencia y la tecnología y la innovación en el contexto de la Universalización de la educación superior”. Del 28 de junio al 1 de julio. C. Habana.
16. Consejo Superior de Universidades (1962): La Reforma de la Enseñanza Superior en Cuba, Colección Documentos.
17. Echeverría, J (2003): La Revolución Tecnocientífica. Madrid; Fondo de Cultura Económica.
18. Etzkowitz, H y Leydesdorff, L (1997): University and the Global Knowledge Economy. A Triple Helix of University- Industry- Government Relations. Pinter Publishers, London.

19. Fernández, C. (1994): Contenido tecnológico y competitividad: elementos para la reconversión de la industria cubana. Cuba: crisis y reformas. Boletín ICE Económico. No 2433, p. 3027-3034.
20. Fernández, F; Chassagnes, O (2003): "Políticas de innovación en Cuba: una revisión de las políticas aplicadas en el desarrollo de la industria biotecnológica asociada a la salud". Revista CTS+I, número 6, mayo-agosto, disponible en: http://www.campus-oei/revistactsi/numero6/articulo07.htm.
21. Figueras, M. (1994): Aspectos estructurales de la economía cubana. La Habana, Ed. Ciencias Sociales, p.46.
22. Freeman, Ch (1988)-. "Japan: a new system of innovation", en: Technical Change and Economic Theory (Dosi, G, ed.). Pinter Publishers, London, p. 330- 348.
23. García Capote, E (1996):" Surgimiento y evolución de la política de Ciencia y Tecnología en Cuba"(1959-1995). Seminario Taller Iberoamericano de Actualización en Gestión Tecnológica, García Capote y Faloh (eds), Gecyt, La Habana.
24. García-Guadilla, C (1997):"El valor de la pertinencia en las dinámicas de transformación de la educación superior en América latina", en La Educación Superior en el Siglo XXI. Visión de América Latina y el Caribe, Ediciones CRESALC/UNESCO, Caracas. Pp. 47-80.
25. Gibbons, M, Limoges C, H, Nowotny, S, Schartzman, and M, Trow (1994): The new production of knowledge. The dynamics of science and research contemporary societies. Sage. London.
26. Horruitiner Silva, Pedro (2006): La Universidad Cubana: el modelo de formación, Ed. Félix Varela, La Habana.
27. Jaramillo, J (2004): Globalización, Ciencia y Tecnología en Iberoamerica, Temas de Iberoamerica, OEI, disponible en: http://www.campus.oei.org/salactsi/jaramillo.pdf
28. Juma, C y Yee-Cheong, L. (coord).(2005): Innovation applying knowledge in development, Earthscan, UK and USA, 194 pp.
29. Kaiser, J (1998): "Cuba´s Billion-Dollar Biotech Gamble", Science, Nov; 282: 1626-8.
30. Lage, A (2000): "Las biotecnologías y la nueva economía: crear y valorizar los bienes intangibles", Biotecnología Aplicada 2000; 17: 55-61
31. Lage, A. (2001): "Propiedad y expropiación en la economía del conocimiento ¨, Ciencia, Innovación y Desarrollo, Vol. 6, No. 4, CITMA, La Habana.
32. Lundvall, B-A (2000): "Los Sistemas Nacionales de Innovación: relaciones y aprendizaje", en: Los Sistemas de Ciencia e Innovación Tecnológica. Editado por el Ministerio de la Industria Básica (Cuba). La Habana.
33. Martínez, O (2004). Intervención del Diputado Osvaldo Martínez, Presidente de la Comisión de Asuntos Económicos de la Asamblea Nacional, sobre los temas del Plan de la Economía Nacional y el Presupuesto del Estado. Periódico Granma: 27 de diciembre del 2004.
34. Martínez, O (2005): Intervención del Diputado Osvaldo Martínez, Presidente de la Comisión de Asuntos Económicos de la Asamblea Nacional, sobre los temas del Plan de la Economía Nacional y el

Presupuesto del Estado. Periódico Juventud Rebelde. 23 de diciembre del 2005.
35. Montalvo, L. (1998): La política científica y tecnológica en Cuba: evolución y electos para su perfeccionamiento. Campinas, Sao Paulo, Brasil, 190 p.
36. Nueva Empresa, (2004): Revista Cubana de Gestión Empresarial. Vol. 3 No 1 y 2, 88p.
37. Núñez, J (1999): La ciencia y la tecnología como procesos sociales. Lo que la educación científica no debería olvidar. Editorial Félix Varela. La Habana.
38. Núñez, J y Alonso, N (1999): "Universidad e innovación tecnológica", en Revista Universidad de La Habana No. 250, primer semestre de 1999, La Habana, pp. 36-56.
39. Núñez, J y Castro, F (2005): Universidad, Innovación y Sociedad: Experiencias de la Universidad de la Habana, Revista de Ciencias da Administraçao V. 7 Número 13 Janeiro/Julio. P9-29.
40. Núñez, J.; Castro, F.; Pérez, I.; Montalvo, L. (2006): Ciencia, Tecnología y Sociedad en Cuba: construyendo una alternativa desde la propiedad social. Texto presentado a publicación. La Habana, 27 p.
41. OCCYT (2005): Elementos para una evaluación general del Sistema de Ciencia e Innovación Tecnológica. Resumen ejecutivo. La Habana, Diciembre, 10p.
42. ONE (2005): Censo de Población y Viviendas Cuba 2002. Informe Nacional. La Habana, Septiembre 400p.
43. ONE (2005): Panorama económico y social. Cuba 2005. Diciembre. 17p.
44. Pérez, A. (2006): Intervención de Armando Pérez Betancourt, Secretario Ejecutivo del Grupo Gubernamental de Perfeccionamiento Empresarial, en evento por VI Aniversario de Constitución de la Empresa GECYT. 28 de marzo de 2006.
45. Pérez, E. (2005): Concretan Cuba e Irán plataforma para una mayor colaboración. Elson C. Pérez. Granma. 21 de enero del 2005.
46. PNUD (2001): Poner el adelanto al servicio del desarrollo humano, Ediciones Mundi Prensa, México.
47. RICYT (2003): Principales Indicadores de Ciencia y Tecnología Iberoamericanos. Disponible en www.ricyt.ar
48. Rodríguez, C (1997): "Universidad de La Habana: Investigación científica y período especial", en: Revista Cubana de Educación Superior, Vol XVII, No 3. Editada por CEPES, La Habana (pp 13- 16).
49. Rodríguez, J. (2004): Informe sobre los resultados económicos del 2004 y el Plan Económico Social para el 2005, presentado a la Asamblea Nacional del Poder Popular por José Luis Rodríguez, Ministro de Economía y Planificación. Periódico Granma. 27 de diciembre del 2004.
50. Rodríguez, J. (2005): Informe sobre los resultados económicos del 2005 y el Plan Económico Social para el 2006, presentado a la Asamblea Nacional del Poder Popular por José Luis Rodríguez, Ministro de Economía y Planificación. Periódico Juventud Rebelde. Suplemento Especial. 23 de diciembre del 2005.
51. Sáenz, T; Capote, E (1989): Ciencia y tecnología en Cuba. La Habana, Ed. Ciencias Sociales, 235 p.

52. Salomón, J.J. (1975): Ciencia y Política. Ed. Siglo Veintiuno Editores. p. 47-57.
53. Starr, O (2004): The Cuban Biotech Revolution, disponible en: http://www.wired.com.
54. Sutz, J (1997): "La universidad latinoamericana y su pertinencia. Elementos para repensar el problema" ", en La Educación Superior en el Siglo XXI. Visión de América Latina y el Caribe, Ediciones CRESALC/UNESCO, Caracas, pp.257-278.
55. UN Millennium Project (2005): Innovation: Applying knowledge in development. Task Force on Science, Technology, and Innovation.