ARTÍCULO ORIGINAL

Intersectoral relationships, scientific output and national policies for research development: a case study on Cuba 2003-2007

Relaciones intersectoriales, producción científica y políticas nacionales para el desarrollo de la investigación: un estudio de caso sobre Cuba 2003-2007

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ABSTRACT

The scientific output of research sectors involved in Cuban R&D activities during the period 2003-2007, using Scopus as data source, was analyzed. Quantitative and qualitative dimension of the scientific production was described through a set of bibliometric indicators. The most productive and visible sectors were identified. The evolution of the total scientific output by sector, and the behavior of the three most important sectors were studied. Inter-sector relationships were visualized with the aim to analyze the national scientific macro-structure. The growth of Higher Education and Health Sector determined the nation's growth during this period. Despite a positive evolution of the Cuban scientific output, a weak linkage between universities and institutions of science and technological innovation, and also scarce relationships between scientific research centers and health institutions, were observed. Low indices of international collaboration in Health Sector, and deficient links between R&D units of enterprises and institutions belonging to Higher Education and Science and Technology, were also identified.

Key words: scientific production, research sectors, bibliometric indicators, Cuba.

RESUMEN

Se analizó la producción científica de los sectores involucrados en las actividades de I+D desarrolladas en Cuba durante el período 2003-2007, con el uso de Scopus

como fuente de datos. Las dimensiones cuantitativa y cualitativa de la producción científica fueron caracterizadas a partir de una batería de indicadores bibliométricos. Fueron identificados los sectores más productivos y visibles. Se estudió la evolución de la producción total por sectores y el comportamiento de los tres sectores más importantes. Las relaciones intersectoriales fueron visualizadas con el fin de analizar la macroestructura de la ciencia nacional. El desarrollo de la Educación Superior y el sector Salud determinaron la evolución de la nación durante el período. A pesar de la positiva evolución de la producción científica cubana, fueron observados enlaces débiles entre las universidades y las entidades de ciencia e innovación tecnológica, e igualmente escasas relaciones entre centros de investigación científica e instituciones de salud. Fueron identificados, además, bajos índices de colaboración internacional en el sector Salud, y deficientes enlaces entre las unidades de I+D de las empresas y las instituciones pertenecientes a los sectores Educación Superior y Ciencia y Tecnología.

Palabras clave: producción científica, sectores de investigación, indicadores bibliométricos, Cuba.

INTRODUCTION

The scientific output and relationships of the different research sectors involved in Science and Technology policies is always an interesting topic for scientometricians. However, the analysis of this aspect using bibliometric methods is always a complex task.

Despite a growing set of papers analyze bibliometrically the science-technology interfaces, only a minority are focused in the particular study of research sectors involved in national scientific output. National or regional dynamics of the university-industry-government relationships, based on "The Triple Helix model" proposed by Etzkowitz and Leydesdorff,[1,2] is among the most studied topics.[3,4] Interdisciplinary links and inter-regional research collaboration are also related topics raised.[5-7] But this kind of research usually deals with a very laborious normalization process.[8,9]

Countries and regions have their own particular characteristics, and this must be taken into account during the normalization of affiliation data. The inclusion of any kind of institution in a specific sector requires the previous study of national science systems. Final decision of scientometricians depends on the objectives and functions of each institution in the national or regional environment. On the other hand, the analysis of the behavior of inter-sector relationships is also strongly related with principles and norms of national science policies.

Research sectors involved in Cuban scientific activity are not yet fully studied, especially from a bibliometric perspective. A previous paper of the authors explores the challenges in the study of Cuban scientific output at macro level, through the use of a battery of national socio-economic indicators and bibliometric measures based on Scopus data.[10] This short communication analyzes the scientific activity and impact of the different Cuban research sectors during the period 2003-2007.

METHODS

DATA SOURCE

Scopus, the main Elsevier's database for bibliometric purposes, was chosen as data source.[11] A search strategy based on the identification of the word «Cuba» in *Author Address* and *Affiliation Country* fields was used. The retrieved items were downloaded to an *ad hoc* database, with the aim to eliminate false items (articles without Cuban authors) and normalize affiliation data. Cuban research sectors were the most important aspect identified in each register from the database.

Data was collected in January 2010. The Scopus retrospective coverage process does not significantly affect the comparison between data obtained in the current work and those obtained from the earlier paper based on the same period. The difference between data collected in June 2009[10] and data collected in January 2010 was of only 251 documents.

NORMALIZATION PROCESS

The scientific production was distributed in six sectors: Higher Education, Health, Science & Technology, Government Administration, Enterprises and Others.

Higher Education involves all universities and higher education institutions subordinated to any of Cuban ministries, including medical universities. Research centers belonging to universities were included in this sector. However, taking into account the specific characteristics of the Cuban health system, the scientific production of hospitals belonging to medical universities was also assigned to the Health Sector.

The Health Sector includes all public institutions and research centers directly related to the Cuban health system and subordinated to the Ministry of Public Health, except medical universities. The scientific production of national administrative units belonging to the Ministry of Public Health, medical societies and institutions belonging to the network of clinic laboratories were also included.

All the research centers of the country, except those belonging to the Cuban health system, were assigned to the Science & Technology sector, which includes the administrative units and agencies belonging to the Ministry of Science, Technology and Environment.

Government Administration sector involves all Organisms of the Central Administration of the State (OACE) at national, regional and municipal level in charge of the direction, execution and control of the state policy, with the exception of legislative, executive and administrative dependencies belonging to the Ministry of Public Health and the Ministry of Science, Technology and Environment. All the subsystems of the national system of education, with the exception of universities and educational institutions belonging to the health system, were included.

The absence of a private sector in the economic structure of the country, allowed the inclusion of all public, mixed, municipal and national enterprises in the sector Enterprises, with the exception of those related to the creation of biological and pharmaceutical products, which are part of the OACE.

Finally, the scientific production of all non-government institutions, societies (except medical societies), foundations, non-lucrative associations, as well as papers with only personal addresses in the *Author Address* field, was included in the sector Others.

INDICATORS

Total publication output (A), annual percentages, annual growth rate, and total numbers of institutions were the indicators selected to show the quantitative dimension of the scientific production.

The qualitative dimension was studied through a set of impact indicators: Total of cited articles (AC), percentage of cited articles (% AC), average of citations per article (C/A), H index (H-i) and R index (R-i).[12] Each of these impact indicators were calculated by sector. Social Network Analysis (SNA) techniques were employed to visualize the inter-sector collaboration.

RESULTS AND DISCUSSION

The Cuban scientific output is mainly distributed in three of the six sectors analyzed (Fig. 1). Higher Education is the most productive sector. The Cuban universities produce 55.4 % of the total national output in Scopus (table).

The leading role of universities during the country's scientific development has been observed in previous studies.[13,14] In this case, the output grows over the years studied (Fig. 2), and it is just over 58 % of the national scientific production in 2007. The universities of Havana (UH), Villa Clara (UCLV), Santiago de Cuba (UO) and Matanzas (UMCC), together with the Higher Institute of Medical Sciences of Havana (ISCMH), make a significant contribution to this output.

In terms of visibility, Higher Education is the sector with the highest H-index, although their proportion of cited articles and the average of citations per article are below the national mean. The cause of this behavior is the big amount of papers published in less cited national journals, an aspect that involves the output of higher institutes of Medical Sciences belonging to the Higher Education sector, and hospitals belonging to the Health Sector.

Only 43 % of articles published by universities, and 31 % of articles published by hospitals (led by the Institute of Tropical Medicine «Pedro Kourí» and the Hospital «Hermanos Ameijeiras») was cited on at least one occasion during the period, in contrast to the citation activity of Science and Technology (54 % of cited articles) and Government Administration (53 %). These two sectors showed the best performance during the period analyzed.

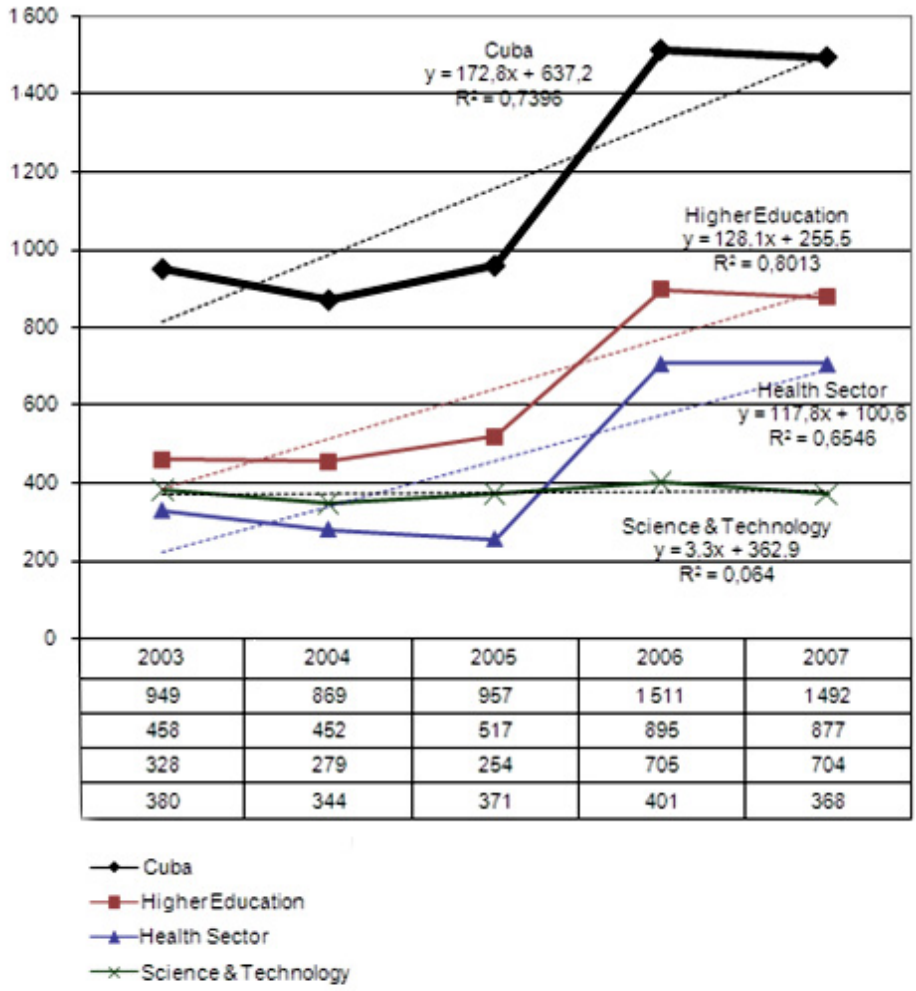
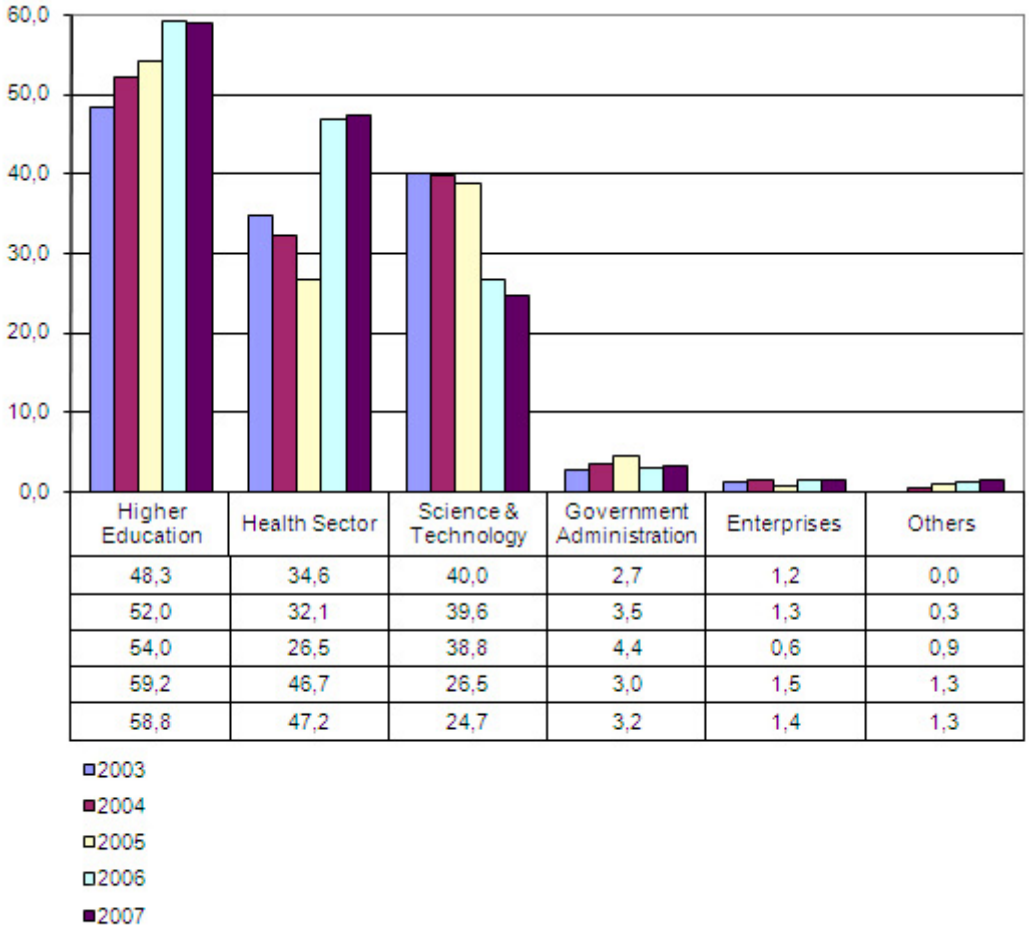


Fig. 1. Cuban scientific output and behaviour of the three most important national sectors during the period 2003-2007 in Scopus.

Government Administration comprised only 3.3 % of the national output, but showed the highest average of citations per article, mainly by the contribution of the Experimental Station of Sugar Cane "Villa Clara-Cienfuegos" (ETICA), with close cooperation with the UMCC and UCLV (Fig. 3). Meanwhile, the sector Enterprises only published 71 articles during the period, with no role for any particular institution, and poor visibility (table).

Institutions belonging to the scientific park from the west of Havana were the leaders of the sector Science and Technology, with a protagonist role of the Center of Genetic Engineering and Biotechnology (CIGB) and the National Center for Scientific Research (CNIC). This group of institutions is responsible not only for a large number of publications in mainstream journals, but also for a significant proportion of the total number of the national patents, as well as an increasing amount of cash income that has made Cuba's biotechnology industry the third motor of the country's economy at the end of the decade.

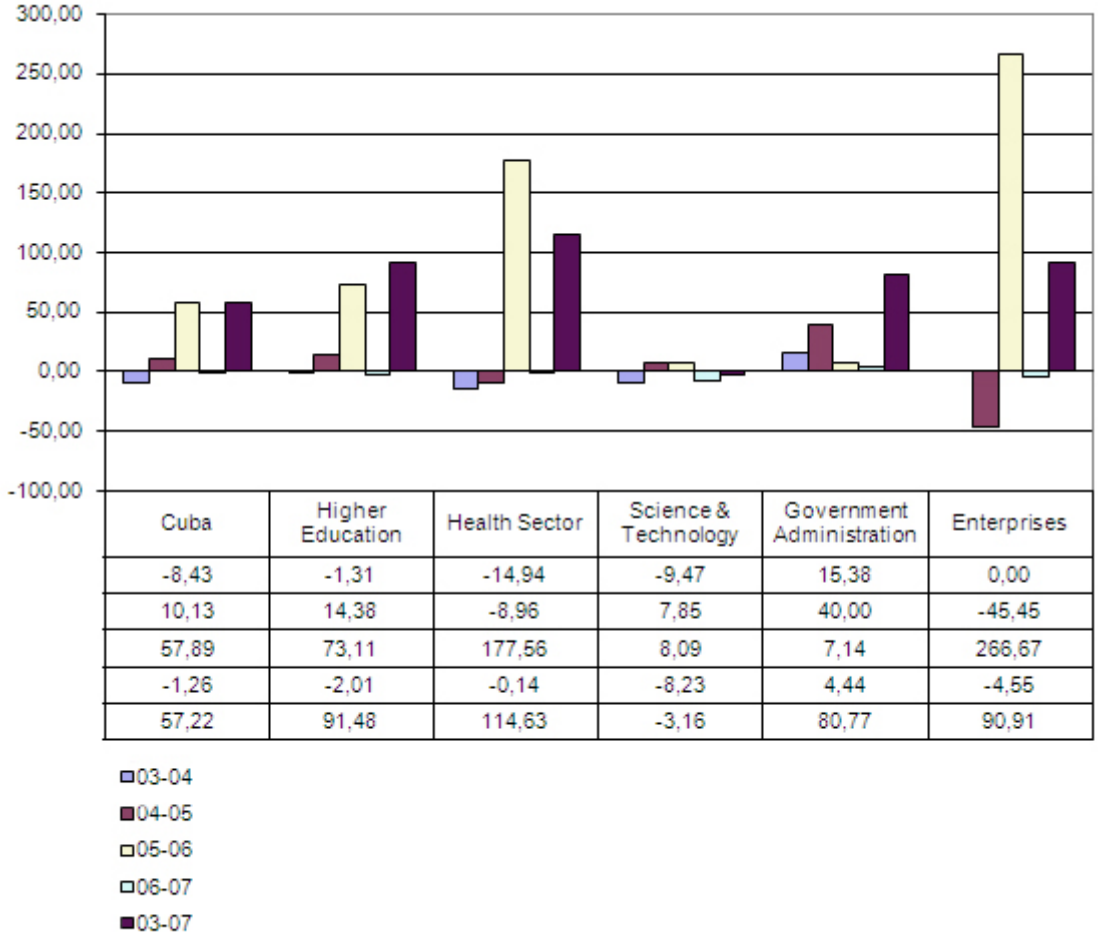


Higher Education	Health Sector	Science & Technology	Government Administration	Enterprises	Others
48,3	34,6	40,0	2,7	1,2	0,0
52,0	32,1	39,6	3,5	1,3	0,3
54,0	26,5	38,8	4,4	0,6	0,9
59,2	46,7	26,5	3,0	1,5	1,3
58,8	47,2	24,7	3,2	1,4	1,3

Fig. 2. Percentage evolution of the total scientific output by sector.

The growth of Higher Education and Health Sector determines practically the nation's growth in global terms. However, the greatest growth is in the health sector, which evolved from 34.6 % of the national output in 2003 to 47.2 % in 2007.

The production of health institutions declines during the first two years analyzed, but recent actions undertaken by the Cuban Ministry of Public Health and the National Information Center of Medical Sciences, aimed at promoting and strengthening the scientific publication visibility of biomedical journals in SciELO (the most important Latin American scientific database), contributed significantly to a high output during 2006 and 2007, coinciding with the inclusion in Scopus of these journals. The Health Sector also showed an important evolution in the annual growth rate (Fig. 3) and the number of institutions involved in the scientific output (Fig. 4).



Cuba	Higher Education	Health Sector	Science & Technology	Government Administration	Enterprises
-8,43	-1,31	-14,94	-9,47	15,38	0,00
10,13	14,38	-8,96	7,85	40,00	-45,45
57,89	73,11	177,56	8,09	7,14	266,67
-1,26	-2,01	-0,14	-8,23	4,44	-4,55
57,22	91,48	114,63	-3,16	80,77	90,91

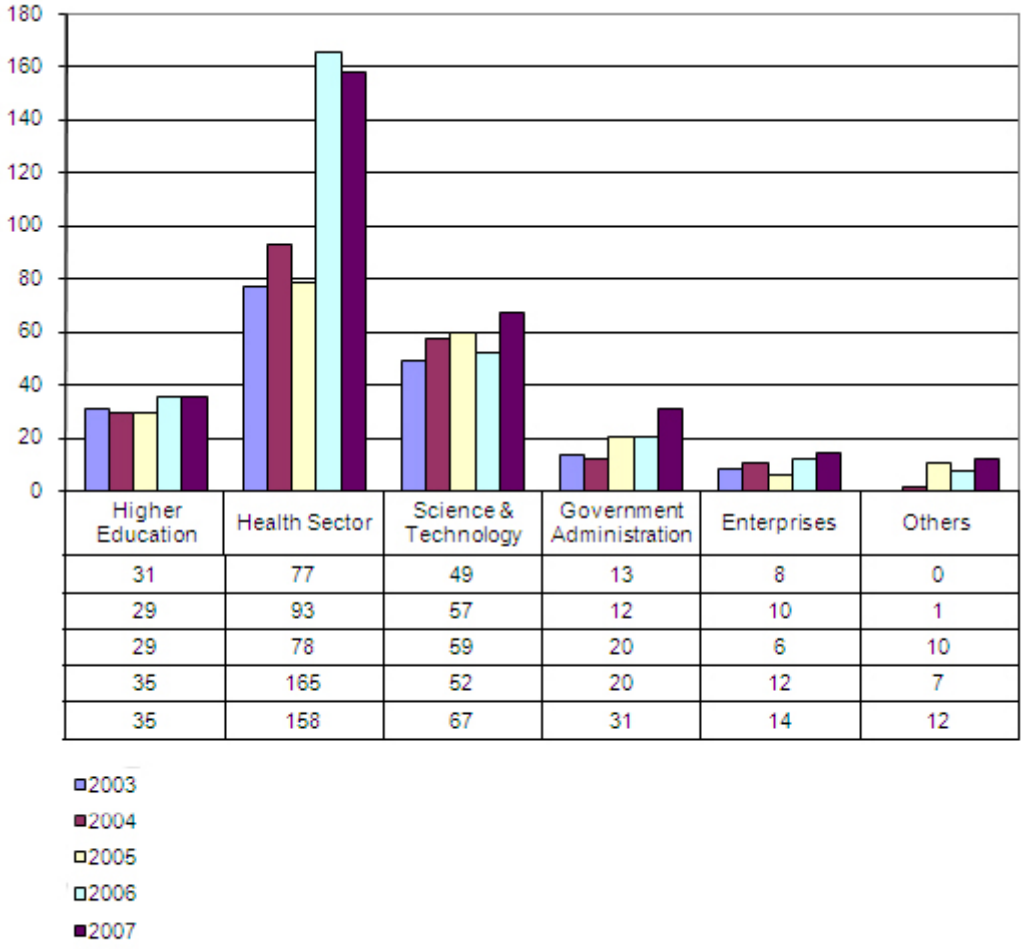
Fig. 3. Annual growth rate of the total scientific output by sector.

Table. Impact indicators of the Cuban scientific output by sector

	Total output							
	A	%	CA	% CA	C	C/A	H-i	R-i
Higher education	3 199	55,4	1 384	43,3	7 680	2,40	29	33,97
Health sector	2 270	39,3	708	31,2	4 237	1,87	24	36,00
Science and technology	1 864	32,3	1 012	54,3	5 521	2,96	25	32,74
Government Administration	190	3,3	105	55,3	777	4,09	17	19,85
Enterprises	71	1,2	19	26,8	62	0,87	4	5,48
Others	51	0,9	6	11,8	16	0,31	2	3,32
Cuba	5 778	100	2 582	44,7	14 727	2,55	34	45,96

As can be seen, except for Science and Technology, all sectors experienced a significant growth in the five years analyzed. The health sector in 2007 doubled the number of documents published in 2003. A key moment of the period was 2006, when universities and health institutions began an intensive production. Moreover, the number of institutions that contribute to the growth of scientific production in journals indexed by Scopus progressed substantially, from 178 in 2003 to 317 in 2007. The health sector showed the greatest contribution, doubling in 2007 the number of institutions achieved in 2003.

This aspect is a key point, because a high number of national institutions devoted their efforts to publishing their research results in communication channels with high visibility for the global scientific community. Such efforts made Cuba's main contributions in Science and Technology visible to scientists and scholars around the world. These contributions, in some cases and by multiple factors, had been destined to invisibility when the national scientists made available their research results in local sources, or just in unpublished reports.



Higher Education	Health Sector	Science & Technology	Government Administration	Enterprises	Others
31	77	49	13	8	0
29	93	57	12	10	1
29	78	59	20	6	10
35	165	52	20	12	7
35	158	67	31	14	12

Fig. 4. Evolution of the number of institutions by sector.

The scientific collaboration expressed in the different sectors analyzed can be approached from multiple perspectives. On the one hand, the collaboration among sectors offered an important view of the national scientific activity. On the other

one, the establishment of strong networks of international collaboration was a very important strategy with the aim to achieving a high visibility or impact.

On the figure 5, the size of the nodes identifies the volume of the sector´s output, the node ring represents the proportion of international collaboration, the lines imply the existence of collaboration among sectors, and the thickness of links expresses the intensity of those relations. Thus, the structural dimension of the national scientific output from the characterization of its strategic sectors was objectively represented.

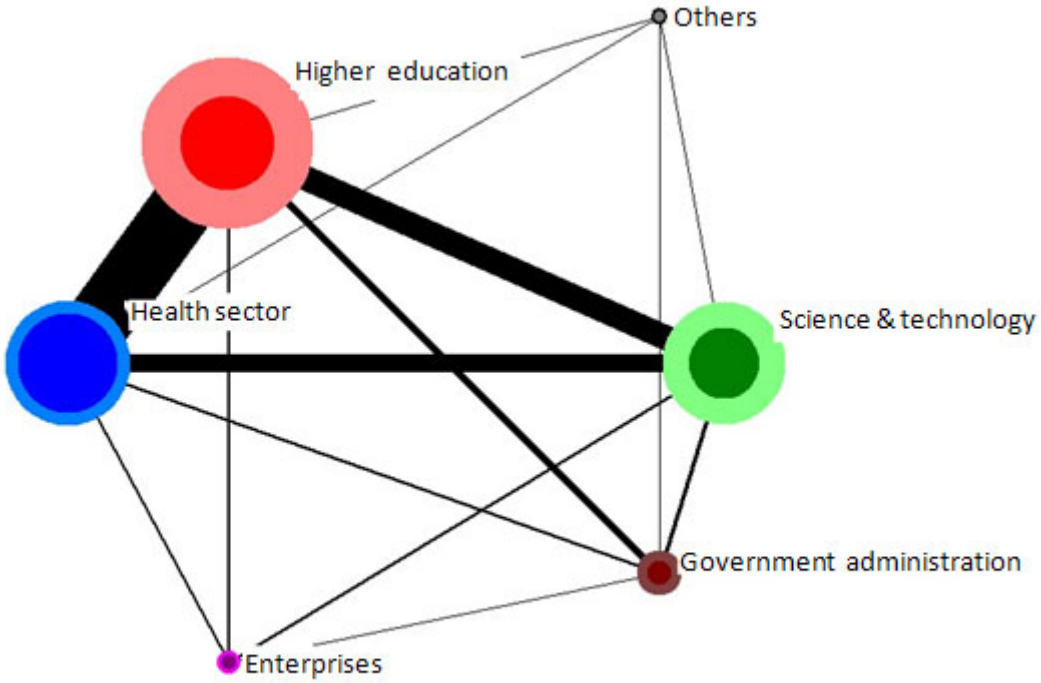


Fig. 5. Inter-sector collaboration (UCINET 6.123; NetDraw 2.38).

If we use a subjective approach with the aim to describe the inter-sector relationships suitable for the national scientific macro-structure (taking into account the state's leading role in financing and development of R&D activities; the absence of a private business sector with influences in the strategic decisions of the National Policy of Science and Technology (PNCT); and the PNCT´s strategies oriented to the internationalization, application and generalization of research results), and if we take into account also the most relevant schools of thought on science, technology and innovation in the last 20 years,[15-21] we might infer that a suitable structure must show strong links with similar proportions among the three strategic sectors (Higher Education, Science and Technology, Health). Similarly, the proportion of international collaboration should be homogeneous, perhaps more intense in those sectors most in need of external financing for development, and the Enterprises sector should have a greater role in the major component, with intense links to Higher Education and Science and Technology.

There are some problems that can be inferred from the presented map. First, there is a weak linkage between universities and institutions of science and technological innovation, and also reduced relationships between scientific research centers and health institutions in the country;

second, the international collaboration is not representative in the health sector, taking into account the many Cuban health experiences and missions throughout the world; and third, there is a divorce between R&D units of enterprises and the institutions belonging to Higher Education and Science and Technology, given by the still insufficient research activity generated by Cuban enterprises.

The causes of these problems have a multifactorial nature. Despite the advanced research policy of higher education in Cuba, it is evident that still are low the level of actions developed by scientific institutions with the aim to attract the interest of students and research teams from universities. In this sense, the necessary link between the academy and institutions of science and technological innovation must be more evident not only in articles published by mainstream journals, but also in patents.

On the other hand, taking into account the wide biomedical scope of Cuban scientific activity, there is no reason to avoid the collaboration between hospitals, health care centers and research institutions in research processes. An important number of Cuban products developed by scientific research centers are introduced in hospitals and distributed by the national network of pharmacies. Therefore, a more active role of physicians and professors from hospitals and health institutions, especially in research lines related to the use of these products by Cuban population, is necessary. And this can be reflected not only by national journals but also by mainstream journals.

Finally, it is clear that the absence of incentives is the main cause of a low international collaboration in the health sector, as well as the complete divorce between Cuban enterprises and institutions belonging to Higher Education and Science and Technology. However, the recent creation of a biotech company (BioCubaFarma) that involve the research centers of the west of Havana, is a decisive step of the country in order to change the current status.

FINAL CONSIDERATIONS AND FUTURE SCOPE

Cuban scientific output has experienced increasing growth during the first decade of the new millennium, which is clearly observed during the period studied in this work.

The country´s efforts and expenditures in Research and Development activities had positive implications for the Cuban science system evolution,[10] and the total output of the country is led by the research developed in institutions belonging to the most developed sectors involved in scientific activities: Higher Education, Health, and Science & Technology systems. However, inter-sector relationships reveal some weaknesses in the national scientific macro-structure.

What factors affect the interactions between the sectors involved in Cuban scientific activities? How these factors can be taken into account by the National Science and Technology System? It's evident that more research is needed to analyze the science and technology policies in each of the sectors studied.

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