Contributions of Universities and Public Research Centers to Innovation Processes in the industry: the Costa Rican case

Jeffrey Orozco and Keynor Ruiz[1]

Abstract: *This paper presents an analysis on the links among universities and public research institutes with the industry in Costa Rica. The study analyses information from three different sources. The first one is a data base from the national survey of science, technology and innovation in Costa Rica. The other one is a survey to researches in universities and public research centres. A third source is a deep interview to researchers within universities and public research centres. The objective of the study is to have a better understanding of the creation, transfer and materialisation of knowledge in the innovation processes of the industry. The main results give us an idea of the weakness of the Costa Rican innovation system. There are clear difficulties for the universities and the public research centers to develop satisfactory links with firms. It is a high concentration of the investment in science and technology in the academic sector. It would be natural that firms have access to the efforts by research centers. However, it is obvious that the percentage of firms that has an effective linkage with the universities and public research centers is very low. Some institutional barriers and mistrust between these actors, avoid better linkages. But there are also some positive efforts. The study focuses on the elements that promote or hinder the linkage among universities and firms, and attend the challenges of developing economies to improve these kinds of relationships. A chain of limitations hinder useful interactions of universities and public research centres with the industry, hindering innovation processes by firms. Most of the barriers are internal problems to the research centres, including very bureaucratic processes that hinder the possibility to joint projects with firms. It seems natural to strengthen trust among universities, public research centres and firms, but also the introduction of institutional changes that facilitate networking.*

Keywords: *Innovation, knowledge, University-firm links, research institutes, trust, R&D,*

[1] Researchers from the Centro Internacional de Política Económica para el Desarrollo Sostenible, Universidad Nacional (CINPE).

1. Introduction

The contribution of universities and public research centres (PRI) to development has stimulated a wide discussion. The focus of the discussion is on the support of this kind of entities to the innovation processes in the firm sector. In this paper we explore the Costa Rican case.

The study analyses information from three different sources. The first one is a data base from the national survey of science, technology and innovation in Costa Rica. The other one is a survey to researches in universities and public research centres. A third source is a deep interview to researchers within universities and public research centres.

The main results give us an idea of the weakness of the Costa Rican innovation system. There are clear difficulties for the universities and the public research centers to develop satisfactory links with firms. It is a high concentration of the investment in science and technology in the academic sector. It would be natural that firms have access to the efforts by research centers. However, it is obvious that the percentage of firms that has an effective linkage with the universities and public research centers is very low. Some institutional barriers and mistrust between these actors, avoid better linkages. But there are also some positive efforts. There have been some relevant efforts to improve the linkage and facilitate the creation and transfer of knowledge. The data by the surveys shows that, even when there are a few firms executing projects with academic sector and the public research centres, the results have been satisfactory.

At the end of the paper we discuss some policy implications. The idea is to develop some incentives and instruments to strengthen interactions between universities and public research with the industry, as a way to facilitate innovation processes in the firms.

1. Methodological Framework

This section describes the research method and the techniques used for the recollection of the data. We used two complementary methodological components. The first one is a survey to researchers in universities and public research centres. The other is a survey to firms.

2.1 Survey to researchers in universities and public research centres

An important motivation that impulse this research has been to create a data base about the links among universities and public research centers with the industry from the perspective by the researchers. The creation of a database with representative statistical information was crucial. We used a Simple Random Sample (SRS) from the list of researchers in universities and public research centres.

The first challenge was the definition and verification of an appropriate sample frame. The first task was to create a data base with researchers and research centres, and then verify it. This list was the base for a representative sample. Using information from the main universities and public research centers we got a sample frame with 178

researchers. We decide to use the formula of the SRS for proportions, due to the characteristics of the subject of study, where a considerable amount of the variables in the research are qualitative, and, in some way because they refer to the proposal percentages of observations that can be found inside the investigated categories. The result was a sample of 128 researchers. We finally were able to capture information from 98 researchers[2], getting of 76.6% of responses from the sample.

2.2 Survey to the industry sector

As part of researchers at CINPE, we had the opportunity to coordinate the National Survey of Science, Technology and Innovation of Firms (2006-2007), developed by the Ministry of Science and Technology of Costa Rica (MICIT, 2008). The data in this paper is taken by the section on research centers link with the industry in this official survey.

The survey considered the following manufacture, energy and telecommunication sectors, including the sector of technologies for information and communication (ICT[3]). According to the official data by the National Institute of Statistics and Census (INEC), these sectors have 2.285 firms all together.

INEC provided the sample using a simple random sample method for proportions. The result was a sample of 396 firms, spread thru all the considered sectors. From this sample, it was possible to reach responses by 376 firms. So 95% of answers where reach in the national level.

3. Theoretical framework: contribution by universities and public research centers to innovation in the industry

Innovations are normally developed in very complex processes with participation of different actors. Rarely, economic agents may innovate in isolation. Different kinds of knowledge and conditions are needed to stimulate the creation of new products, new processes or in general, a new way of doing things. For example, Edquist argues that *"the process through which technological innovation emerge are extremely complex; they have to do with the emergence and diffusion of knowledge elements as well as the 'translation' of these into new products and production processes... Innovation processes occur over time and are influenced by many factors. Because of this complexity, firms almost never innovate in isolation. They interact with other organisations to gain, develop, and exchange various kinds of knowledge, information and other resources"*. (Edquist, 1997: 1)

It is recognised that innovations are generated in interactive processes of learning, where the different pieces of knowledge are combined in new forms, in order to generate new knowledge materialised lastly in a new or upgraded product, process or

[2] The software "Statistical Package for Social Sciences" (SPSS) was used in the process of capture the information. Also MS Excel and SPSS where used in the quality assurance of the information, the analysis and tabulation of the data.

[3] The TIC´s services subsectors are excluded.

other changes at the organisational level (Orozco, 2004). Only in very rare cases individuals can innovate everything for themselves, without no interaction with other agents, or less possible, without the use of knowledge already existent (Edquist and Johnson, 1997). In fact, *"the processes of exploration, development, selection and diffusion of new technologies, new 'forms of making the things', organizational structures and institutions, and market interactions, may well often be beyond the control or even the imagination of individual actors"* (Dosi and Orsenigo, 1988).

The interactive character of innovation conducts to the conception of innovation systems. Studying innovation system goes beyond input-output system that only focus on the flow of goods and services thru economic sectors given a period of time. In the analysis are included other actors besides industries, organizations and firms, especially technology and science, as well the role of the technology policies and other kind of policies that affect innovation processes. Analysis is carried out at national level, studying at the aggregate level the R&D activities and the role played by universities, research institutes, government agencies, and government policies, and the linkages between them (Freeman, 1988; Lundvall, 1988 and 1992; Nelson 1988 and 1993; subsequently many others).However, there has been also emphasis on innovations in sectors (Breschi y Malerba, 1995, also Malerba y Orsenigo 1990, 1993 y 1995). In these cases, as in the analysis of Porter, the definition of System is based on 'industry' or 'sector'. The sectoral system of innovation is based on the idea of different sectors or industries that operate under different technological regimes, characterised by particular combinations of opportunities and conditions, levels of technical knowledge, and relevant characteristics from the base of knowledge (Orozco, 2004).

In addition a more geographic emphasis remarks the cultural and competence differences that explain the differences among regions, such that manifest in the hierarchy of concentration, experimentation, collaboration and collective learning, which at the same time affect the capacity to adjust to changing circumstances in technology and markets[4].

A fundamental characteristic of innovation systems is its base on institutions perspectives. The main point is that markets do not exist nor operate without certain rules, norms and habits that regulate the interrelations among the actors. The study of the system of innovation may be approached from different kinds of institutions who characterise it. In general terms, there are complicated linkages in both ways between institutions and organizations, affecting the innovation processes and having implications on systems of innovations and its performance (Edquist and Johnson, 1997). Institutions[5] shape the behaviour of firms and other organisations (Edquist, et al, 1998). "In that sense, changes in institutions can also generate constraints or incentives to innovation. In general, changes in the institutional set-up can be considered as innovations when are aimed to reach explicit targets. It is possible to have institutional innovation in the institutions that are created by design (patent law, and other institutions designed by public agencies as policy instruments, also formal organisations

[4] See a wide summary of different systemic approaches to study innovation in Carlsson *et al*, 1999.

[5] We use the definition by Edquist and Johnson (1992), considering institutions as the set of common habits, routines, established practices, rules, or laws that regulate the relations and interactions among individuals and groups. In that sense, there is a distinction among institutions and organizations. Organizations are understood as formal structures, consciously created and with an explicit purpose. There is a deeper discussion on the role of innovations on chapter 4.

as state agencies or non public organisations). It is also possible to find innovations in other institutions that evolve spontaneously over extended periods of time, such as various kinds of social rules or habits" (Orozco, 2004: 49).

It is a growing consensus in the literature that innovations are multi-causally explained. As it is argued by Nelson: "it is obvious that a very wide range of factors influence the innovative performance of nation's industries" (Nelson, 1992: 352). In addition, the different determinants cannot be expected to be independent of each other; they probably support and reinforce each other (Edquist, 2001). They could also hinder each other. Until now, there is not a theoretical model including specifications of the relative importance of different determinants. Actually, it seems that a "theory of innovation" is not a concern of many scholars, due to the considerable amount of determinants and the wide diversity of relationships among them regarding with different kinds or categories of innovations. A distinction among central and less important determinants is possible by only with empirical studies. But even in empirical studies it is clear that innovation determinants may vary along the time due to the evolutionary nature of economies and sectors (Orozco; 2004).

From system of innovation literature it is possible to draw a list of factors that usually promote or hinder innovation processes. Remarkable facts as institutions, knowledge and learning, infrastructure, organisation of work, demand patterns, productive structures, government policies, feedback mechanisms, science, universities and other organizations, size and level of affluence to markets, the natural resources base, the industry performance where the firm is part of, the education and entertainment systems, capabilities and promotion within the firms, financial facilities, macroeconomic tendencies, technological bottle-neck, the R&D system, the distribution of benefits from innovation processes and asymmetries among firms and other organizations[6]. Orozco (2004) concluded that main factors determining innovation at firm and sector levels are: institutions, learning and knowledge processes and the quality of the interactions, which at the same time affects each other. Quality of interactions is a central factor for the performance of the system of innovation.

Universities and Public Research Centers

The role of universities and public research centres inside the innovation system is relevant because of their focus on the generation and transfer of knowledge and learning capabilities building. These are fundamental factors affecting innovation processes (Ruiz, 2007). The links between universities and society have been an issue in the agenda for technological and innovation policies, especially for developing countries. The linkage involves three fundamental actors: the State, Universities and Firms. It is important to have a holistic approach, considering the context and economic situation affecting the scientific development and the opportunities for technological innovation. The knowledge created by universities and its use in the industrial processes is a cause of controversy and discussion. Strong links among universities and public research centres may be a strategic element for capability building, knowledge transfer and innovation in the industry, especially in developing countries where most of the R&D investments are done by this kind of research centres.

[6] A detail analysis over the factors that affect the innovations processes is developed in chapter 4 of (Orozco; 2004).

When studying the interaction firms-universities (through research centres), we must keep in mind that this kind of links are in constant evolution and may change from one country to another (Albornoz, 1990). The dynamic relation between researchers in universities and public institutes with the industry sector has been a key for the development of the national system of innovation. It is important to consider both, the research capabilities in universities and public research centres and the absorption capacities by firms. These factors define in different ways the possible interactions and the processes of evolution across the time.

4. The role of universities and public research centres in the innovation processes by firms

The kind of links between universities, public research institutes and firms in Costa Rica are very similar to the situation in other Latin American countries. The situation is quite different to the one in more developed countries. The evidence indicates that most of the interactions oriented in promoting innovation processes have been very poor or inexistent. Some firms seem to have very indirect and casual interactions. However, this kind of interaction is mainly to use the labs of universities and public. Research institutes, universities and firms are generating additional some efforts to strengthen the systems of innovation. In some countries some policies are used to promote stronger links. But in Costa Rica there is a lot of work to do, especially in generating thrust among the different agents in terms of financial sources and other kind of institution to facilitate interactions.

National Scientifics have more linkages with foreign colleagues, than among them. Most of the funding for projects comes from foreign sources. The capacity of attracting foreign funds should be stimulated, but this is not enough. The country must generate a bigger capacity to capture national funds for research and development (MIDEPLAN, 2006).

The diagnosis by "Estrategia Siglo XXI" and the data from the national science, technology and innovation (2008) survey, shows that investment in science and technology, and particularly in research and development (R&D) activities, is extremely low for development aspirations of the country. A weak integration between science and the productive processes is evident. Besides, an insufficient effort is been done in the formation of scientific and technical professionals.

4.1 Costa Rica Science and Technology Activities

The investment in science and technology activities in Costa Rica is low in relation to the GDP. Most of the efforts concentrate in teaching and training activities, but less in R&D and scientific services. It is interesting the reduction in the investment on R&D activities in 2007 compared with 2006, especially in the industry sector. Table 1 shows how investment in R&D is relative low as a percentage of the GNP.

Chart 1

Costa Rica: Investment on Scientific and Technology Activities (STA)
2006 – 2007

Scientific and Technology Activities	Expenditure (millions of US$)		% regard to GDP	
	2006	**2007**	**2006**	**2007**
Total	284,72	326,87	1,26	1,24
Research and Development (R&D)	87,82	84,27	0,39	0,31
Formation and Education	142,10	170,00	0,63	0,65
Scientific and Technological Services	54,80	72,53	0,24	0,28

Chart 2
Costa Rica: Investment in R&D, by sector
2006 – 2007

Sector	Investment in millions of dollars		Percentages	
	2006	**2007**	**2006**	**2007**
Total	87,82	84,27	100,0	100,0
Public Sector	11,33	13,45	13,0	16,0
Academic Sector	28,64	38,18	33,0	45,0
Non Profit organizations	4,13	4,88	5,0	6,0
International Organisms	0,03	0,03	0,0	0,0
Firms Sector (R+D)	43,68	27,73	50,0	33,0

Source: National survey of science, technology and innovation to Firms. Costa Rica. 2008. MICIT-CINPE/UNA.

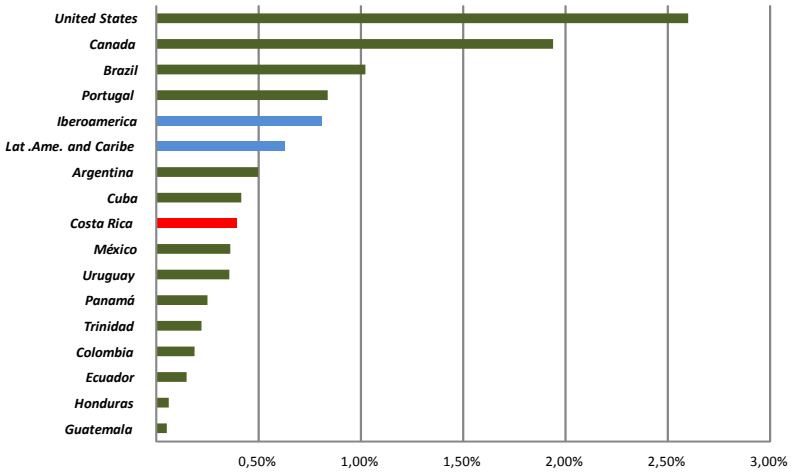
The role of academic sector is important, not only in absolute term, but because of a sustain tendency into these kind of activities within the sector, even with a considerable rise from 2006 to 2007. This data evidence that even with the efforts made in R&D in the private sector, the academic sector continues as the one that concentrates a major contribution and continuity in these kinds of scientific efforts. Universities may become a solid base supporting the industry sector. The industry sector reveals considerable changes from one year to the other. The composition of R&D investment varies considerably. The industry sector moved from providing 50% of R&D investment in 2006 to 33% in 2007. There was an absolute diminution from US$43.68 millions to US$27.73 millions for that sector.

Another finding is that 62% of the enterprises said they have carry out R&D activities, but only 29.2% make them regularly or in a continuous way, centralised in an exclusive

R&D department. 12.5% of the firms have regular but decentralised way R&D activities. This means that they do not have a specialised R&D department. 52.8% of the firms carry out R&D activities but occasionally and in decentralised way (MICIT, 2008).

As appreciated in Graph 1, no matter was has been done until now by the academic sector and the private sector, the investment in R&D as a percentage of GDP is still below the Latin-American average. Actually, the Costa Rican situation is very low with respect to the regional leader, Brazil, and more developed countries as United States or Canada.

Graph 1. Investment in I+D with regard to GDP, year 2006



Source: Own elaboration with data from RICYT and MICIT, 2008

4.2 Contribution of Universities and PRC to Innovation Processes

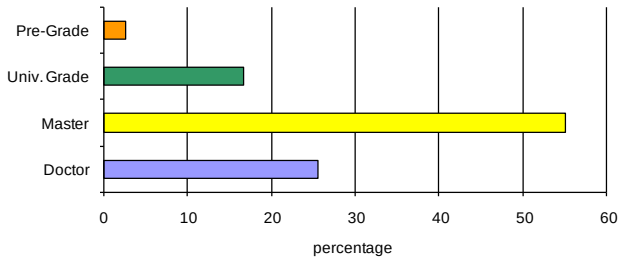
Costa Rican academic sector plays a fundamental role due to its contribution in scientific and technological activities in general, but also for its investment in research and development activities. However, the interactions with the industry sector are still weak and keep facing some barriers.

Education and Capabilities Levels of the Researchers within the Academic Sector

The universities and public research centers have invested in building research capabilities. A growing amount of researches are getting masters (55%) and doctors (26%) degrees. Those results show a relevant local base that may be very useful for R&D projects and for joint projects with the industry sector.

Graph 2

Costa Rica: Academic Level of Researches



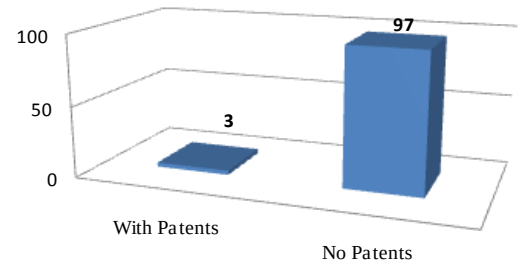
Source: Own elaboration based on Universities and PRC survey, 2008

Low Patent Culture

The amount of request and granted patents by research centres is an indicator of the scientific efforts. In Costa Rican case, very few research centres patent. Only 3% of the interviewed centres had obtained patents properly registered in Costa Rica Patent Office. These reflect that patenting is not part of the development strategy of public research centres. Most of those centres (94%) do not apply for a national nor international patent. The few centres that have decided patenting seem to stronger interactions with multinational firms located in the country (see graphs 3 and 4).

Graph 3

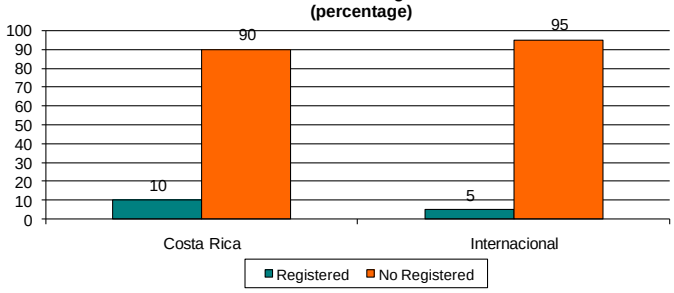
Costa Rica: Public Research Centres and Universities with Patents



Source: Own elaboration based on Universities and PRC survey, 2008

Graph 4

Costa Rica: Firms with Registered Software (percentage)



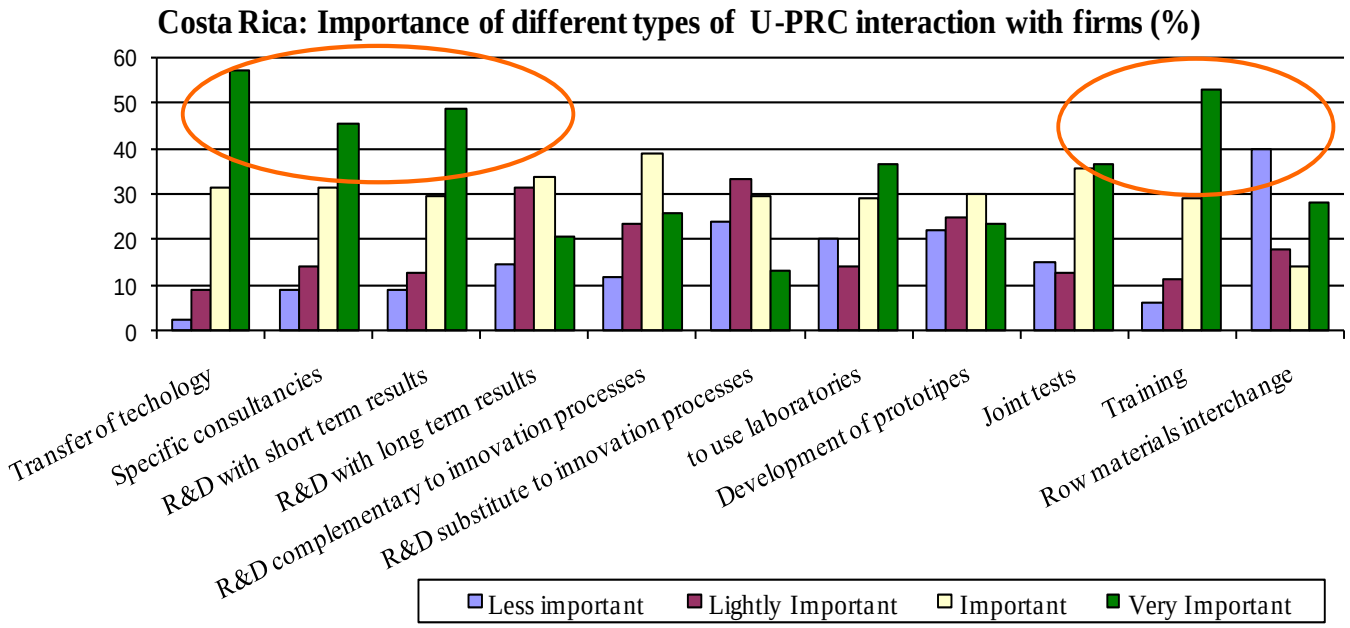
Source: Own elaboration based on Universities and PRC survey, 2008

Another indicator of local capabilities to promote innovation and technological change is the use and development of their own software. In Costa Rica the study shows that even when the PRC do not patent their own software, a 30% of them used any kind of own made software, with a rise tendency in last few years. Then local capabilities have been creates for a greater development in this aspect.

Different types of Universities and PRC – Firms Links

A central aspect of the dynamic linkage between universities and firms is the participation of research centres in the knowledge transfer, solving technical and technological problems and training to the productive sector. It is necessary an important change by universities and PRC in how they create interactions with firms, taking into account research activities that complement productive processes. Researchers should become able to participate in teams with firm´s workers in order to solve real problems. A result would be the creation of capabilities inside the firms. Most important kind of linkages are the projects that imply technological transfer, consultancies about concrete technological problems of the firms, R&D projects and training and capability building by the research centres (see graph 5).

Graph 5



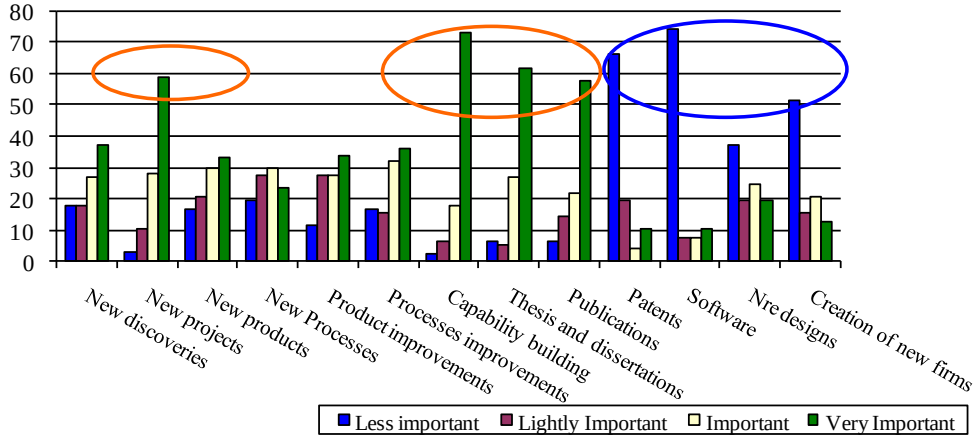
Source: Own elaboration based on Universities and

Main results from the Linkages between Universities and firms

From the researcher's point of view, professional capability building (for 73% of researchers), dissertations and publications and thesis, are the most important results in the interaction with firms. Otherwise, the acquisition of new patents or any kind of own software (see graph 6) are less important. Notice that the research centres are not focus in creating new firms[7] neither the development of new software for firms or patents.

[7] The software sector has an important development in Costa Rica. The amount of firms in this sector is notorious. So, probably firms satisfies their software necessities in the private market and do not have this issue as a goal for interaction with universities and PRC. For major detail of the software sector development see CAMIC, 2003.

Graph 6
U-PRC interactions with firms in Costa Rica : main results (percentages)

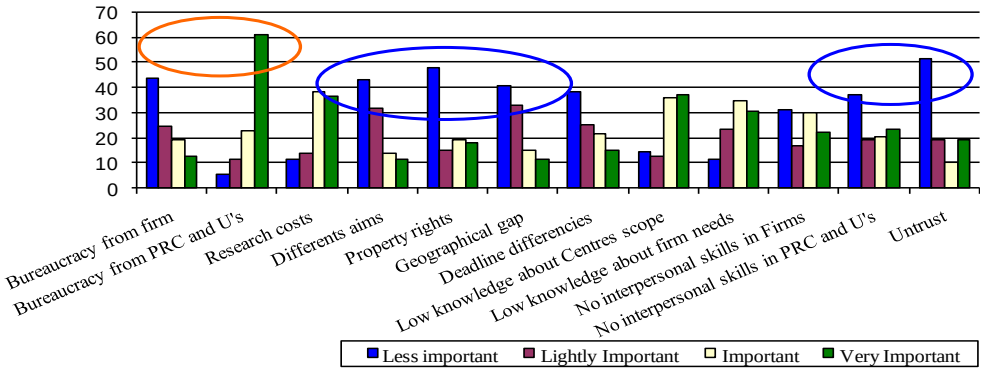


Source: Own elaboration based on the survey to Universities and PRC

Obstacles for linkages

The recognition of internal and external obstacles give us an idea of how important these are in universities-firms linkages, in a way that manifest an important phenomenon related not only with the universities dynamic but with the socioeconomic characteristics of the surroundings. Bureaucracy in universities and research centres is recognised as one of the main obstacles when executing and formulating projects. Lack of knowledge of activities realised by centres and the costs of investigation are other important obstacles (see graph 7). Even when some of these aspects have been discussed, not so much have been done to improve them. The role of public policies may be crucial as facilitator agent for better linkages, but an important responsibility falls on the universities and research centres, which must promote mechanisms that facilitate interactions with the industry.

Graph 7
Costa Rica: Main barriers in the relationship with firms (percentage)



Source: Own elaboration based on Universities and PRC

4.3 Interactions from the Firm's Perspectives.

The results on this section come from a national effort to generate indicators on science, technology and innovation, brought by the National Ministry of Science and Technology of Costa Rica (MICIT), with support of several organizations, among them CINPE / UNA. From a special module within the survey applied to firm sector, was possible to detect 33% of the firms in the country with linkages related to universities or public research centres (PRC). Such percentage, low in relative terms, evidences challenges both for universities and firms, where interactions based on trust and recognition of mutual benefits are the axis for collaboration schemes.

62% of the cases with any kind of interactions with research centres considered that specific problem solving is the main reason to have collaboration with PRC. The mechanism in practice has been based on professional consultancy. Around 50% of the firms contact universities or PRC for their availability of laboratories or other resources, including the possible support on quality control. Another motive of interaction for 51% of firms is the possibility of having early contact with the students and academic departments. This gives the opportunity to strengthen future professional recruitment. For the industry sector, key objectives as research and development are not important objectives to generate interactions with universities and research centers.

CHART 3
FIRMS´ OPINION ABOUT THE COLLABORATIONS WITH UNIVERSITIES AND/OR PUBLIC RESEARCH CENTRES, ACCORDING OBJECTIVES, LEVEL OF IMPORTANCE
-PERCENTAGES-

Objectives of the collaboration	Less Important	Very Important	TOTAL
In order to have an earlier contact with future professionals	*48,40%*	*51,60%*	*100,00%*
To support quality control process	*51,60%*	*48,40%*	*100,00%*
To contract important researches for normal innovation activities of the firm (complementary activities)	*52,40%*	*47,50%*	*100,00%*
To use labs and other resources available on U's and PRC.	*50,00%*	*50,00%*	*100,00%*
Technology transfer from U's and PRC	*55,60%*	*44,30%*	*100,00%*
In order to get technological support from researches to problem solving	*37,90%*	*62,10%*	*100,00%*
To increase the limited capability of the firm to knowledge absorption	*49,20%*	*50,80%*	*100,00%*
To get information about engineers or scientists on R&D fields	*54,00%*	*46,00%*	*100,00%*
To obtain information on R&D tendencies	*58,10%*	*42,00%*	*100,00%*
To contract research that the firm cannot develop (substitutive activities)	*68,60%*	*31,50%*	*100,00%*
In order to test products or processes	*61,30%*	*38,70%*	*100,00%*

Notes: Percentages are regarding 124 firms that have had any relationship with Public Research Centres or Universities.

Source: **National Survey of Science, Technology and Innovation. Costa Rica, 2008. MICIT-CINPE/UNA.**

One important aspect is that a 64% of the firms with linkage experiences consider this as successful in terms of reaching the goals they have proposed. In addition, 25% of the firms have actual interactions and think that the objectives are going to be reached on time and as planned.

CHART 4
SUCCESSFUL LEVEL OF COLLABORATION BETWEEN UNIVERSITIES AND PUBLIC RESEARCH CENTRES WITH THE INDUSTRY

(IN TERM OF ACHIEVEMENT OF OBJECTIVES)	
	Percentage
a) Yes, Collaboration have been successful to reach the objectives	*63,7%*
b) No, Collaboration have not been successful to reach the objectives	*8,9%*
c) Collaboration is ongoing, but objectives will be reached on time	*25,0%*
d) Collaboration is ongoing, but objectives will not be reached	*2,4%*
TOTAL:	*100,0%*
Notes: Percentages are regarding 124 firms that have had any relationship with Public Research Centres or Universities. Source: **National Survey of Science, Technology and Innovation. Costa Rica, 2008. MICIT-CINPE/UNA.**	

5. Biotech sector as an example of Innovation and Technological Transfer

Research and development on biotechnology is incipient in Costa Rica, but has played an important role articulating the research centres with the industry. One contribution is the improvement, quantitatively and qualitatively, of the researchers´ capabilities and competences. The research centres have also supported initiatives for development of certain sectors, as agriculture, horticulture, forestry, nutrition and food, animal and vegetable health care, pharmaceutical products, waste conservation and agricultural sub products.

5.1 Role of the Public Policies in the development of the Biotechnology sector

The Ministry of Agriculture and Livestock (MAG) is a leading organisation in the biotech area, focused on Bio-security. The Ministry of Science and Technology (MICIT) is another leading organisation, focused on Bio-Tech development support. Another organisation giving support in biotech projects is the National Committee of Bio-Technology, created by a government in 2006 to promote this kind of R&D and to coordinate actions among different national instances in the field. The official entity to manage juridical and political aspects related with rational ecological negotiation of the biotechnology is the Ministry of Agriculture and Livestock, through the biotechnology program "Biology and Environmental Security".

The National Centre of Biotechnological Innovations was created with the support of European Union, with the objective of supporting the Costa Rican scientific organisations in the biotechnology field. This centre also contributes to preindustrial testing in labs, which stimulate firm's links with research centres, through development and application of biotechnology (CENIBiot, 2006).

5.2 Research Centres and Technological Transfer

In Costa Rica, public research centres (PRC) developed programs in agricultural biotechnology since 20 years ago, supported by government sectors responsible of science and technology. The policies have benefitted the establishment of local private companies, dedicated to plants biotechnologies, especially dedicated to *in vitro* propagation system.

There are activities for development of genetic improvement programs assisted by

biotechnological techniques as the genetic engineering. These activities are organised by universities and public research centres (Universidad de Costa Rica, Centro Agronómico de Investigación y Enseñanza, Universidad Nacional and the Instituto Tecnológico de Costa Rica), and others private centres as INBIO.

The first project with trans-genetic technology began 1990. The challenge was to develop a trans-genetic rise resistant to the "white leaf virus of the rice"(RHBV). The project was developed by the biotechnology rice program of the Molecular and Cellular Biological Centre (CIBCM), Universidad de Costa Rica. This program has a multidisciplinary and integral point of view including: genetic flow evaluation of the trans-genetic rise to wild species, food and environmental bio-security, as copyright and technology transfer to farmers (UCR, 2004).

Research centres in universities (UCR, ITCR, UNA, CATIE) and InBIO are also working on modern technologies applied to genetic improvement in agriculture and forestall sector. They are developing the use of molecular scoreboards, micro-propagation techniques, techniques for conservancy of species in danger and bio-prospection techniques.

The main biotech research centre in Costa Rica is part of one of the public universities, the Costa Rican Technological Institute. Most important research areas of this institute are: Bio-products (human skins farming), environmental biotechnology (environmental education, applied ecology and bio-safety), micro-bacteriology (diagnosis and molecular characterisation) and vegetable biotechnology (ecology, macro and micro propagation, germ-plasma conservancy, cleaning and detection of viruses, characterization and molecular diagnosis, cells framing, research of plants with a bio-active compound and genetic improvement (CIB, 2008).

5.3 The Biotechnology Impact to Productive Sectors

Projects in the biotech area have had relevant impacts on the industry sector. There are R&D projects and technological transfer in areas as: medicinal plants, height fruit, dengue projects, human skins cells farming, forestry, vegetables, bio-fertilisers, and seeds diversification (rice, potatoes, chayote, and blackberry). All the projects developed by the research centres have a transfer complement of technology to the interested groups.

5.4 Barriers and Challenges of Biotechnology Linkages with Firms

There are some limitations and weakness for development of the biotech area in interaction with firms. For example: i) very few researches in certain areas which limits their application to important economic and industrial sectors, ii) low amount of patents or industrial applications, iii) weak participation of the industrial sector in research activities of the public and academic sectors, iv) bureaucracy in universities to develop joint projects with the industry, v) low investment from firms on R&D activities.

Some challenges related with cooperation, investment, productivity and practical application are mentioned by the researchers as the most relevant elements to improve interactions among research centres with the industry. These actions would be

specifically relevant for developing the biotech sector as a relevant motor for the development of the country.

6. Some concluding remarks

We may conclude that universities and public research centres have been doing important efforts in science and technology fields in Costa Rica. Actually, most of the R&D efforts in the country are done in the universities and public research institutes. However, several limitations avoid stronger interactions with the industry, hindering innovation processes. Many of those limitations are originated inside the universities and public research centres. Most of the may be overcome with institutional changes to avoid the bureaucracy and excess of requirements that delay the links with firms.

It is crucial to strengthen the trust among different actors. A positive indicator, in spite of the small amount of firms having linkages with universities, is the high level of satisfaction with the results. There is some accumulated experience, as demonstrated in several projects, like in the biotech sector. Therefore, there is a clear space to improve the contribution by universities and public research centres to innovation processes in the industry. Strengthen of collaboration networks seem to be the clear mechanism to improve the contributing of universities and research centres to innovation in the industry.

References

Breschi, S. and Malerba, F. (1997). Sectoral innovation Systems: Technological Regimes, Schumpeterian dynamics and special boundaries. Edquist, C. (Ed), Systems of Innovation Technologies, Institutions and Organizations. London, Francis Pinter.

CAMTIC. 2003. **La Industria del Software en Costa Rica: Bases para la definición de un plan estratégico Nacional**. CINPE / UNA. Heredia, Costa Rica

Centro Nacional de Biotecnología (CENIBiot), 2006. **Plan operativo Global 2006-2010**. Ministerio de Ciencia y Tecnología. San José, Costa Rica

Centro de Investigación en Biotecnología (CIB), 2008. **Informe de Gestión del Centro de Investigación en Biotecnología**. Instituto Tecnológico de Costa Rica.

Edquist, Charles (ed) (1997). System of Innovation: Technologies, Institutions and Organizations. Pinter, London and Washington.

Edquist, C. and Johnson, B. (1997). 'Institutions and organisations in systems of innovation', in C. Edquist (ed.) Systems of Innovation: Technologies, Institutions and Organizations. London and Washington: Pinter/Cassell Academic.

Edquist, C (2001). The Systems of Innovation Approach and Innovation Policy: An account of the state of the art. Lead paper presented at the DRUID Conference, Aalborg, June 12-15, 2001, under theme F: 'National Systems of Innovation, Institutions and Public Policies'. Draft.

Freeman C. (1991). The nature of innovation and the evolution of productive system, OECD-TEP, Technology and productivity, the challenge for economic policy, TEP Program

Fundación CYD, 2003. **La Universidad y empresa española**. Fundación Conocimiento y Desarrollo. Madrid España

Lundvall, B.-Å. (1988): "Innovation as an Interactive Process: From User-Supplier Interaction to the National System of Innovation", in Dosi et al. (eds.), op. cit., pp. 349-369.

Lundvall, B.-Å. (ed.) (1992): National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning, London, Pinter Publishers.

Malerba, F. and Orsenigo, L. (1990): "Technological Regimes and Patterns of Innovation: A Theoretical and Empirical Investigation of the Italian Case," in A. Heertje and M. Perlman (eds.), Evolving Technology and Market Structure, Ann Arbor, Michigan University Press, pp. 283-305.

Malerba F., Orsenigo L. (1993a), 'Technological Regimes and Firm Behaviour', Industrial and Corporate Change, vol. 2, No 1,pp. 45-71

Malerba, F. and Orsenigo, L. (1995): "Schumpeterian Patterns of Innovation," Cambridge Journal of Economics, 19 (1), pp. 47-65.

MICIT. 2008. **Encuesta Nacional de Ciencia, Tecnología e Innovación.** San José, Costa Rica

Mideplan. 2006. **Plan Nacional de Desarrollo 2006-2010**. Gobierno de Costa Rica

Nelson, Richard R. (ed 1993). National Innovation Systems. A Competitive Analysis. New York: Oxford University Press.

Nelson R. and Rosenberg N. (1993). Technical innovation and national systems. In: Nelson R. (ed), National Innovation Systems a comparative analysis. New York, Oxford: Oxford University Press.

Nelson R. (1992). The role of knowledge in R&D efficiency. Quarterly Journal of Economics, Cambridge, Vol 97, n3, p.453-471, August.

Orozco. 2004. Innovation and Performance Improvements in the Cooperative sector: Costa Rica. Ph.D. Thesis. Department of Development and Planning. Aalborg University. Aalborg, Denmark.

Porter, M. (1990): The Competitive Advantage of Nations, The Free Press, New York.

Ruiz, Keynor. 2007. **Costa Rica as a Learning Economy: An Exploratory Study of Competence-Building and the Significance of Labour Relations and Labour Market Institutions.** Ph.D. Thesis. Department of Business, Aalborg University.

Universidad de Costa Rica, 2004. **Estado actual de la biotecnología en Costa Rica**. Revista Biología Tropical. 52 (3): 733-743, 2004. San José, Costa Rica