GLOBAL PERSPECTIVES ON HIGHER EDUCATION

University and Development in Latin America

Successful Experiences of Research Centers

Simon Schwartzman (Ed.)

SensePublishers

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GLOBAL PERSPECTIVES ON HIGHER EDUCATION

Volume 2

Higher education worldwide is in a period of transition, affected by globalization, the advent of mass access, changing relationships between the university and the state, and the new technologies, among others. *Global Perspectives on Higher Education* provides cogent analysis and comparative perspectives on these and other central issues affecting postsecondary education worldwide.

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University and Development in Latin America

Successful Experiences of Research Centers

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TABLE OF CONTENTS

FOREWORD[1]

For scientists, science, technology, innovation and science education constitute the most essential set of components to enter the knowledge era without the negative elements today associated to it: the lack of proper employment and poverty in Latin America, hunger in Sub-Saharan Africa, unfair distribution of wealth around the world, global warming, the population's lack of hope, even in developed countries, terrorism and a lack of biodiversity are also characteristics of our age.

The InterAmerican Network of Academies of Sciences, IANAS[2], over which I have the honor to preside, states that:

> "In the XXI century it is inconceivable to think about creating decent employment, combating poverty and strengthening democratic governance without the extensive use of science, applying locally-appropriate technology, introducing the concept of innovation at all levels of society and improving the quality of science education. Without these considerations, society will be continuously torn between underdevelopment with poor jobs or modernization accompanied by poverty and unemployment".

However, the fundamental role of science is not to intervene directly in social changes, including economic development. On the contrary, this role is a function of the State, for which the incorporation of science, technology and innovation into the planning of public policies is indispensable. For science/technology/innovation to be included in public policies, some preconditions have to be satisfied, including:

- The rationality of scientific explanations must be incorporated by the State;
- The concept of national sovereignty must also be established from science created on sovereign territory;
- Science and scientists contribute to the consolidation of the National State;
- Science is international and, therefore, depends on collaboration between scientists of sovereign States.

Science and technology are not only forces for consolidating sovereignty, but can, also, contribute to the formation of regional blocks. The most eloquent example is that of the European Union.

IANAS strives to take the important message of science, technology, innovation and science education to the heart of this continent's political concerns. Partly as a result of this work, with the decisive support of the Organization of American States (OAS), and other civil society organizations with interest in these topics, the declaration of the Presidents attending the last summit at Mar del Plata included:[3]

45. We commit to support the improvement of the quality of the teaching of science and we will strive to incorporate science, technology, engineering, and innovation as principal factors in national strategies and plans for social and economic development, for the fundamental purpose of reducing poverty and generating decent work. In this vein, we support the Declaration and Plan of Action adopted at the Ministerial Meeting of Science and Technology held in Lima.

46. We recognize that scientific and technological research, and scientific development and progress play a fundamental role in the integral development of our societies, by building knowledge-based economies and contributing to economic growth and increased productivity. In this regard, we reiterate our support for the institutions established earlier in the Summits Process, such as the Inter-American Committee on Science and Technology, to create a scientific culture in the Hemisphere. We will continue to support public and private research associations and promote their interaction.

47. We will continue to increase investment in science and technology, with the participation of the private sector and the support of multilateral institutions. We will also intensify our efforts to encourage our universities and higher institutions of science and technology to increase their linkages and deepen basic and applied research and promote greater incorporation of workers in the agenda of innovation. We will facilitate the greatest interaction possible between scientific and technological research communities by fostering the establishment and consolidation of advanced research networks and synergies among educational institutions, research centers, the public and private sectors and civil society.

Also in the Action Plan from this meeting, the States are committed to:

> 41. To promote increased funding and investment in science and technology, engineering and innovation. To request the appropriate multilateral organizations to strengthen technical and financial cooperation activities aimed at pursuing this goal and at the development of national innovation systems.

The conversion of these declarations and action plans into instruments with concrete results requires a lot of work, political decisions, clarity of objectives and resources. It is also clear that it is no longer possible to not recognize the disparity of conditions and investments in science, technology and innovation (S&T&I) among the countries of Latin America and the Caribbean. It is also not adequate to state that cooperation and integration in S&T&I on the continent is impossible, as the reality shows that in some ways this has been occurring for decades. Programs such as ProSul (Program for the support of science and technology in South America) in Brazil, to cite just one example, integrated with others in other countries, would allow immediate connection. The existence of International and/or multilateral organizations such as the Organization of American States, IANAS, International Council for Science (ICSU) and the Academy of Sciences for the Developing World (TWAS), constitutes another potential source for resources and coordination.

The collaboration between scientists in Latin America and the Caribbean, through an infinite number of programs, dates back more than forty years. However, there is a lack of structures to transform the joint efforts into integrated strategies on the continent; joint post-graduation in areas of recognized competence and of mutual interest is just one example. There is a lack of negotiations that allow the installation of academic and/or laboratory centers on the continent to study common problems and experiments that require large investments.

The "Leading Latin American Universities and their contribution to sustainable development" project is within this spirit.

One of the structural characteristics that differentiates our continent from developed centers is that basic research, a high percentage of technological research and some innovation are exclusively developed in public universities, as is shown in various sources of information. Some countries on our continent are undergoing a transition in which it is beginning to be seen that this situation can evolve and, in some decades, start to catch up with the developed countries, where the only scientific sector that develops largely in the universities corresponds to basic research.

It is well known that the high-level science produced in a country or translated by its scientific community tends to be disconnected for its use in the continent. However, there are excellent examples on how scientific excellence can be associated to social or economic relevance. Although limited, these examples demonstrate that the possibility of associating science to society is a reality also on this continent. It is true that the examples are fee, and it is not for this introduction to analyze any determinants of this association. However, it is necessary to mention that large parts of the Brazilian economy, the only country I know relatively well, depend on this association. Without the attempting to provide a complete list, I can mention deep-water oil exploration, the aeronautics industry, Soya production in the Brazilian savanna (*cerrado*) and the alcohol-sugar cane production system. Most of the men and women who carried on this work of knowledge transfer, allowing the economy to reach high levels of international competitiveness in some sectors, studied in public universities. The question is whether the way the universities are organized and function has helped or hindered this effort

In a letter dated November 11, 1892, T.H. Huxley, famous English biologist and patriarch of a notable dynasty of British intellectuals, describes the dilemma the universities on that continent they find themselves in.

> "The medieval university looked backwards: it professed to be a storehouse of old knowledge... The modern university looks forward, and is a factory of new knowledge". This phrase cannot be used, in its literal sense, to describe the public universities on this continent in 2007. The gap between the reality in England at the end of the nineteenth century and the current situation exists, but is it that wide? The universities should, obligatorily, permanently analyze the relationships between the forms of knowledge production and their structures. One of the themes to be studied can be taken from a recent article in the magazine Nature (vol. 446, page 949, of April 26, 2007) which talks about the university of the future, where the structural units are not the departments, but the interdisciplinary centers which deal with subjects that are scientifically or socially relevant.

The tensions between the organization of the Latin American universities where this research was carried out, the projects from the agencies that support research, the needs of a part of society that demands access to higher education and another

part of society that is awakening to the need for knowledge to compete with innovation, can generate creative or destructive forces. This challenge of this book was to contribute to the analysis of some of these tensions from the perspective of successful examples of science/society associations, rather than from general trends, which is the usual approach. Examples like these can contribute to new perspectives on the universities' missions and, consequently, on their structures, governance and financing systems.

A final reflection on the current situation. A century ago or so, the pace of social change, government decisions and the changes in the state institutions were relatively slow. Changes in the understanding of nature and technological innovations, often not associated to the science as such, followed this pace. The feeling of urgency that prevails today is strictly related to the growing pace of our understanding of nature, but above all, to the growing relationship between science and technology. The time is now, and analyses that help to shape proposals to narrow the relationship between producers, players and the institutions that allow healthy relationships between science and society are becoming more urgent and necessary every day.

Hernan Chaimovich

NOTES

1 Translated from the original in Spanish
2 www.ianas.org
3 http://www.summit-americas.org/Documents%20for%20Argentina%20Summit%202005/IV%20Summit/Declaracion/Declaracion_POR%20IV%20Cumbre-rev.1.pdf

JORGE BALÁN

UNIVERSITY, RESEARCH AND DEVELOPMENT: THE NEW CONTEXT[1]

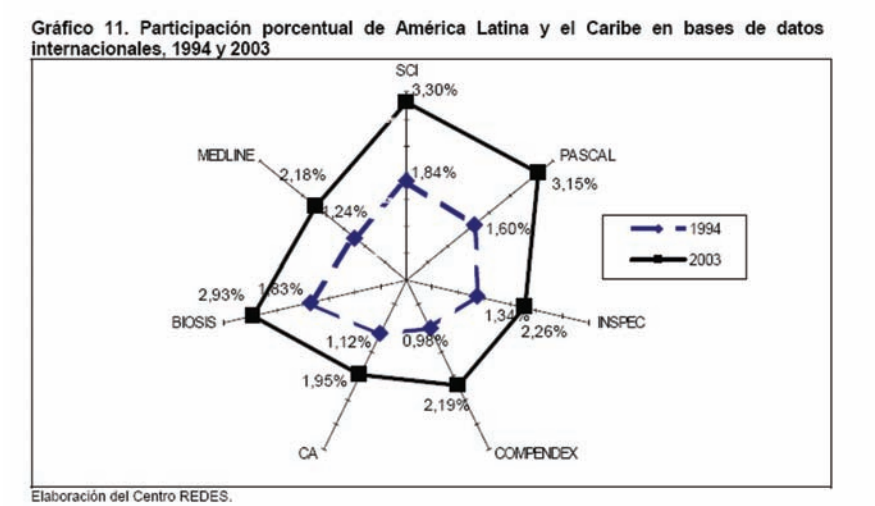
There is a widespread sense that Latin America developed more slowly in the last decades, both in relation to the main countries that it emulated, or at least took as a comparative standard, and in relation to other developing regions, especially East Asia. In education, these impressions are proven by the results of international mathematic and language tests, the drop-out and graduation statistics from the various education levels and by the low proportion of advanced students in science and engineering courses, when compared to other regions of the world. The university systems expanded quantitatively, but are criticized by their inefficiency, and their growing distrust about the general quality of their results. Few of the international rankings of universities, which have recently become popular, present encouraging results for Latin America.

Without discounting the validity of many of these unfavorable comparisons, the regional outlook – especially regarding universities and scientific research – is more varied and encouraging than it appears. It is not possible to ignore the positive changes that occurred during the last two or three decades of democratic governments and institutional stability, despite what is called the "lost decade" of the 80s and the fiscal adjustment policies, as well as the state reforms of the 90s and the start of this millennium. Some advances occurred in graduate education and in university research, in response, maybe belatedly, to the demands generated by the expansion of the higher education system itself, with stimulation and reforms driven by governments, as well as from the productive sector and the job market.

Little attention has been paid, for example, to the notable increase in scientific and technological production during the past decade. As can be seen in the following chart, the various international sources that measure the world scientific production in the various fields of knowledge agree that the modest place the region still occupies as a whole improved considerably. Public investment in research and development is growing with the acceleration of the region's economy and more consistent public policies than those in the past, with the expectation that these efforts would at last lead to concrete results, as the long awaited private investments become a reality. Equally important, between 1990 and 2004, the number of people gaining doctorates increased five-fold in the region. Brazil weights heavily in the regional aggregate figures, total, both for the number of publications and the number of doctorates, but an analysis by country shows equally rapid rates of growth in Argentina and Mexico, and even faster growth in Chile from a much smaller base.

S. Schwartzman (ed.), University and Development in Latin America: Successful Experiences of Research Centers, 1–4.

Chart 11. Percentage of participation by Latin America and the Caribbean in international databases, 1994 and 2003



Prepared by the REDES Center.

Compared to Asian countries, especially China, India and Korea, during the last decades Latin America did not send proportionally significant numbers of its students to finish their undergraduate and graduate education abroad, tending to favor local education, perhaps in response to the debt crisis. Partly due to the increase in domestic capacity, a greater percentage of Latin American graduates tend to return home after gaining doctorates in the United States compared with graduates from Korea, India or China, countries which now seek to affectively reincorporate scientists and academics abroad. Since the 80s, Latin American governments tended to generate relatively strong incentives for developing graduate[2] programs within the prevailing fiscal restrictions. A graduate degree is now an obligatory requirement for commencing an academic career, especially in public institutions, and the universities respond to various incentives, both from the government and the market, to increase and improve the supply of their research programs and advanced education, although, in each country, this capacity is concentrated in a few universities. The -graduate programs were the first to be submitted to the systems of evaluation by peer review, in line with the usual practice of the scientific financing bodies, thereby strengthening the academic communities in many disciplines.

Up to the 70s, when government agencies for science and research support where established in the region, they followed two models, the first more academic, promoting pure research along an entirely autonomous science agenda, and the second that of the “developers”, who considered science and technology as the basis for a much broader social and political revolution. Divided into some

times irreconcilable camps, the scientific communities were a minority sector that was only influential occasionally within the public universities they wished to transform. At the start of this century, this segmentation became obsolete, and the public universities, which escaped the modernizing agenda of the 70s, were able to build niches that were relatively more protected and favorable to scientific research than in the past. Governing bodies in public universities serve a complex variety of internal and external interests, and it is unusual for scientists to occupy leading positions in these institutions. However, their capacity for negotiating with current administrations was reinforced by State financing and regulatory schemes established in the last decades. The case studies presented in this book show that the universities have to do more than just to adjust their administration to a new context. They have to respond to a much broader change in their environment, in public policies as well as in academic culture.

The academic and research groups were strengthened, among other factors, by the pressure for greater internationalization of Latin American universities, which appear to be weak in this respect, despite the globalization rhetoric. Compared to other countries, Latin American universities have low proportions of foreign professors and students, rarely take into account international standards for the evaluation of procedures and results, are deficient in training and the use of foreign languages (particularly English) and pay little attention to the impact that reforms of other systems (such as the so called “Bologna process”) may signify for them. In this context, the groups of academic excellence, such as the research universities considered in this book, are leaders in the internationalization process, serving as a bridge with the outside world for university administrations that are aware and concerned about their shortcomings. The growing concern of many Latin American governments about the need to strengthen the national innovation systems, including greater coordination between their distinct components and greater active participation by the business sector providing support and carrying out research and development activities, should also strengthen the researchers position inside and outside of the universities, as shown by the research groups and units studied in this book.

The current economic situation, with relatively high rates of economic growth in a good part of Latin America, expanded external investments and international business, improved public finances and relative monetary stability, has favored greater public investment in science and education in the countries considered in this book. The expectation is that the financial reforms of science and higher education started in the previous period, including the internationalization processes, will be consolidated in a context of relatively greater economic affluence. The hope is that the unavoidable ups and downs in economic expansion, which in large part depends on factors outside of the control of Latin American governments, will not be a set back for this sector.

NOTES

[1] Translated from the original in Spanish.

[2] Strictly speaking, there is no “undergraduate” education in Latin America, since the first degrees lead as a rule to a professional certification, and are therefore graduation degrees. Master and doctoral programs are, thus, post-graduate degrees, corresponding to the ISCED 6 level in the 1997 UNESCO classification. However, in this book, the expressions “undergraduate” and “graduate” are used according to the Anglo-Saxon practice, as referring to first and advanced higher education degrees respectively.

SIMON SCHWARTZMAN

THE LEADING LATIN AMERICAN UNIVERSITIES AND THEIR CONTRIBUTION TO SUSTAINABLE DEVELOPMENT IN THE REGION

INTRODUCTION

This book is based on the experiences of sixteen university research groups in four Latin American countries – Argentina, Brazil, Chile, Mexico - from different fields of knowledge, working in very different national contexts, but sharing the experience of producing high quality scientific knowledge in their fields, and, at the same time, being very active in transferring their knowledge to society. They are not typical of the usual academic centers in the their own countries, which work in accordance with research agendas established by their individual members, with subsidies from the education or science and technology authorities, and, even when working in applied fields, have difficulties or give low priority to making their competencies available to business, governments and public agencies that could put them to practical use. We believe, however, that they point to the future.

Science-based knowledge is essential for creating wealth, caring for the environment, improving health, and dealing with the social problems of poverty, urban overcrowding and social violence. It is not possible to expect scientific research in the region to mature first, and then start bearing fruit to society. As in the economy, the social benefits of accumulation cannot be postponed forever, and Latin American societies are not likely to put more resources in to their scientific establishments if they do not see the concrete benefits of their work. However, there are reasons to believe that this dilemma is false: knowledge creation and applications do not necessarily take place in sequence, and the best scientific institutions are those that can do both. In so doing, they attract additional resources, the best talent and, in time, overtake the institutions and groups that remain in isolation.

In developed economies, most technological research and development takes place in private companies as well as in government owned civilian and military research institutes. However, research universities are unique in their ability to attract and educate talented researchers and work at the edge of scientific research, and there is a growing trend, from private corporations, to develop strategic partnerships with universities. Japan and South Korea are examples of countries that developed strong technological capabilities in their large private corporations before developing their research universities, but, more recently, they began feeling the need to upgrade their best universities to the standards of their American and European counterparts, with India and China working to catch up (Altbach and

S. Schwartzman (ed.), University and Development in Latin America: Successful Experiences of Research Centers, 5–19.

Balán 2007; Indiresan 2007; Kim and Nam 2007; Liu 2007; Yonezawa 2003). In Latin America, however, most research is academic, takes place in selected departments and institutes within universities that are mostly geared to undergraduate and professional education, and with weak links to the broader economy and society.

To create these links, several countries are introducing legislation and making institutional innovations of different kinds, while, at the same time, many research teams and institutes are finding their own ways to link out and develop their innovation capability. These are, according to Judith Sutz (Sutz 2000), the ¨top-down¨ and the ¨bottom-up¨ approaches, and, in her work, she finds that "the results of the top-down mechanisms have been well below expectations of policy makers", while "bottom-up experiences usually exhibit successful results at micro level, but face great difficulties for broadening the impact of the technical solutions found". An appropriate institutional environment is necessary to spur and consolidate university science-based innovation (Hollingsworth 2000), but a precondition is the existence of a strong culture of innovation and academic entrepreneurship as a basis, and that is exactly what this study seeks to show.

In selecting the cases, we sought to cover a variety of academic fields, including mathematics, technology, biological sciences, agricultural research and the social sciences, both in public and private institutions[1]. We did not include non-academic research centers, but included some non-university institutions that are also involved in graduate education. Our unit of analysis is not the university, or even the department or institute, but a research center or group[2], which may or may not correspond to a formal administrative unit within their institutions. With these criteria, and after consultations with experts in each country, we completed our list. Several other research teams could have been selected instead of the ones we choose, but we expect that the ones we have are a good sample of this new type of research work.

This project was carried out with support from the Ford Foundation, and the cooperation of the InterAmerican Network of Academies of Sciences (IANAS). We are grateful to Jorge Balán, formerly at the Ford Foundation, and Hernán Chaimovitch, IANAS, for their continuing support and intellectual cooperation.

THE IMPORTANCE OF SCIENCE-BASED KNOWLEDGE FOR SUSTAINABLE DEVELOPMENT

Contemporary societies are often described as "knowledge societies". Economic, social, cultural, and all other human activities become dependent on a huge volume of knowledge and information. The knowledge economy is based on the development of sophisticated and knowledge intensive products for the world markets, and increasing competition among countries and multinational corporations, based on their scientific and technological prowess. The importance of science-based knowledge, however, is not limited to its impact on the business sector. Issues like environment protection, climate change, security, preventive health care, poverty, job creation, social equity, general education, urban decay and violence, depend on advanced knowledge to be properly understood and translated into effective policy making practices. These needs are urgent, and countries should not have the excuse of not making use of the best possible knowledge to deal with their economic and social

questions, aiming at what is commonly understood by "sustainable development" (Serageldin 1998). Even if the economy is not very well developed, and the education institutions are of poor quality, as many of them are in Latin America, there is almost always some space for scientific competence to develop, not necessarily at a very high cost.

	Cases in the study			
	Biology and Environmental Sciences	**Technology**	**Agricutural Science and Aquaculture**	**Social sciences**
Argentina	Instituto de Investigaciones en Ingeniería Genética y Biología Molecular (INGEBI)- Universidad de Buenos Aires	Área de Investigación y Desarrollo del Instituto Tecnológico de Buenos Aires	Instituto de Investigaciones fisiológicas y ecológicas vinculadas a la agricultura (IFEVA) -UBA	Departamento de Economía- Universidad Nacional de La Plata
Brazil	Departamento de Informática Univ Católica Rio de Janeiro	Instituto de Química, Universidade de Campinas	Escola Superior de Agronomia Luiz de Queiroz USP	Escola de Pós Graduação em Economia da Fundação Getúlio Vargas, Rio de Janeiro
Chile	Centro Universitario Internacional Europa América Latina (EULA). Universidad de Concepción	Centro de Modelamiento Matemático, Universidad de Chile	Centro Costero de Acuicultura y de Investigaciones Marinas. Universidad Católica del Norte	Centro de Investigación Jurídica, Universidad Diego Portales
Mexico	Instituto de Biotecnología de la Universidad Nacional Autónoma de México, Cuernavaca	Física Aplicada y Tecnología Avanzada (CFATA) de la Universidad Nacional Autónoma de México (UNAM)	Centro de Investigación y de Estudios Avanzados del IPN, CINVESTAV Unidad Irapuato	Centro de Estudios Económicos, El Colegio de México A. C.

This belief has been clearly expressed by leading Latin American scientists who participated in the virtual forum on "Civil Society on Science, Technology and Innovation" held by the Organization of American States in 2005. This document states, among other points that:

> Cutting edge science can be produced under economically disadvantaged circumstances; scientific development, job creation and the fight against poverty are interrelated. The introduction of science, technology, engineering and innovation in our local and specific conditions, as has happened elsewhere, can determine equitable development. Information on successful cases where Science, Technology, Innovation and Science Education (STISE) have impacted on the fight against poverty, helped to create jobs and strengthened democratic governance is essential. Information and understanding of the international frameworks related to intellectual property rights and patents in all levels of society is essential, both to protect local ethnic culture, history, biodiversity and to make local inventions economically and socially useful to local society *(Organization of American States 2005).*

The challenge to improve the quality of academic research in Latin America and to make it more relevant for society is daunting. Academic and scientific institutions are complex, heavy and multi-purpose, and cannot be easily steered. In this study, we look at four among the most developed countries in Latin America – Argentina, Brazil, Chile and Mexico -, which, in different ways, have created significant higher education and scientific institutions. For many years, these countries have worked to develop their scientific and technological capabilities, in universities and specially designed Research and Development (R&D) institutions, under the assumption that modern Science and Technology (S&T) is an essential ingredient for the development of their societies from all points of view. There have been many instances of significant achievements, but also many failures, and the general view is that these efforts were not as successful as they should have been. Given the dramatic increase in investments in science and technology in the developed world, there is a strong sense that the gap is increasing. Furthermore, the recent success of some Asian countries – particularly Korea, Taiwan, China and Singapore – in closing this gap, has led to a renewed concern about the need to look again at what is happening in Latin America that is precluding similar achievements.

HIGHER EDUCATION AND SCIENTIFIC RESEARCH IN LATIN AMERICA

Higher education institutions have always played important roles in cultivating knowledge and putting it to the benefit of society. In different times and societies, these knowledge-producing activities have ranged from traditional education in the learned professions to the development of advanced research in the basic sciences and its applications. Traditionally, higher education and scientific institutions have existed separately, and the integration of science and higher education, which is often taken for granted, is in fact a very recent phenomenon, more typical of the Anglo-Saxon countries than of elsewhere, and justified by a mythical model of academic research attributed originally to the Humboldt University in Germany. In fact, the unification of knowledge and education proposed by Humboldt was closer to the philosophical concept of *Bildung* than to the modern notion of scientific research. As scientific research developed in Germany in the second half of the 19th century, it moved away from the universities, and was organized later in a different institutional setting, the Kaiser-Wilhelm-Gesellschaft, now the Max Planck Institutes (Nybom 2007). In most countries, as in Germany, science, technology and universities developed and organized separately. The extreme example in the 20th century was, perhaps, the Soviet Union, with the sharp separation between the Academy of Sciences and the higher education institutions, a model copied by China and other countries of the Soviet block. This separation has also been notorious in France, with the *Centre Nationale de la Recherche Scientifique*, CNRS, bringing together the research community apart from the prestigious *grandes écoles* and the universities (Clark 1995).

The most important exception was the American graduate schools, which provided for the systematic and large-scale education of research scientists and opened space in the universities for their laboratories, an innovation justified by the Humboldtian ideal, in what Thorsten Nybom described as “one of the most

successful and productive misunderstandings in modern intellectual history" (Ben-David 1977; Flexner 1968; Geiger 1986; Nybom 2007). The success of the American research universities, which attracted students from all over the world after the Second World War, and the sheer presence of the United States as the world's leading economy, led to the gradual spreading of elements of this institutional model to most of the world, adapted to local circumstances. This dissemination was sometimes quicker in developing countries, which depended on US agencies and its philanthropic foundations for technical assistance and support, than in European countries, with their own strong traditions and institutions. Already in the 1920, the Rockefeller Foundation was actively supporting medical research in Argentina, Chile, Brazil, Mexico and Colombia, among others (Abel 1995; Coleman and Court 1993; Cueto 1990; Cueto 1994; Díaz, Texera and Vessuri 1983; Schwartzman 1991; Solorzano 1996); the Ford Foundation was very influential in establishing economics, political science and other subjects as academic disciplines in several countries (Bell 1971). The United States Agency for International Development, USAID, helped to organize agricultural research in many places (Sanders et al. 1989), and also in the reorganization of Brazilian higher education in the 1960s, with the introduction of graduate education and research departments and institutes in the universities (Botelho 1999; Sucupira 1972).

Some of these initiatives were successful, but never to the point of changing the Latin American universities at their core. Higher education developed in the region, since the 19th century, inspired by the French model, first as training and certification institutions for the learned professions (Law, Medicine, Engineering) under strict state supervision, and later, already in the 20th century, as a mobility channel for the upper segments of a growing urban middle class. Some countries, like Argentina and Mexico, created very large, semi-autonomous, public national universities, with hundreds of thousands of students, heavily immersed in national politics, in which research, when it existed, took place in small, protected niches in medical and engineering schools, and, more recently, in American-style, semi-autonomous research institutes and departments. In other countries, such as Brazil and Chile, higher education spread among a large number of smaller, public and private institutions, in which, again, education for the professions, not organized research, was the driving force (Brunner 1987; Levy 1980; Levy 1986; Schwartzman 1996).

THE EXPANSION OF HIGHER EDUCATION

At the end of the 20th century, Latin America had to cope with the combination of an expanded, massive higher education sector, and a new vision of the way scientific and technological research should be organized to face the new challenges of the knowledge society. In 2003, the Gross Enrolment ratio in tertiary education was already 60% in Argentina, 22.7 in Brazil, 46.2% in Chile, and 23.9% in Mexico. In the whole Latin American and Caribbean region, it was 27%, compared with 69% in Western Europe and North America, and 51% in Central and Eastern Europe. At first glance, one could think that this massive expansion of enrolment was an appropriate response to the growing needs and requirements of the knowledge

society. However, this expansion was associated to several important problems which amounted, according to a comparative study carried on in the 1990s, to a serious crisis, characterized by a lack of coordination between sectors and institutions, institutional paralysis, low quality, and severe financial problems, associated both to lack of resources and their improper and inefficient use (Brunner et al. 1994). Different policies were attempted by countries to deal with this crisis, including profound changes in the financing mechanisms of higher education and the establishment of quality assessment systems. An important component of these policies have been the creation or strengthening of assessment and reward systems based on academic excellence. International organizations also contributed with their proposals for reform (Castro and Levy 2000; De Ferranti et al. 2002; Inter-American Development Bank 1997; UNESCO 1995; World Bank 2002).

THE NEW PRODUCTION OF KNOWLEDGE

In 1994, the publication of *The New Production of Knowledge*, by Michael Gibbons and others (Gibbons et al. 1994), opened up a wide debate, still continuing, on the adequacy of the way scientific and technological knowledge production should be organized in universities and other research institutions. The book compared two modes of knowledge production, labeled "mode 1" and "mode 2", the first academic, investigator-initiated and discipline-based, and the second context-driven, problem-focused and interdisciplinary. In mode 1, research institutions are autonomous, academic rewards are associated with publications in open literature, and knowledge production follows a linear pattern, from basic to applied science, and then to development and production. In mode 2, research institutions are closely associated or linked with users – companies, government agencies, service providers, compounding what was later called "the triple helix" (Etzkowitz and Leydesdorff 1997); rewards are based on actual or expected practical products; research outcomes are proprietary; and the linear production sequence is broken, with knowledge being developed in the context of applications. In a famous paper, Donald Stokes used the term "Pasteur's quadrant" to refer to the combination of fundamental and applied research which characterized both Pasteur's 19th century science and the new models of scientific innovation, in contrast to "Bohr's quadrant" of basic science, an early 20th century development. (Stokes 1997). In a classic paper, Joseph Ben-David and S. Katz showed how agricultural research in Israel, which started with strong links with the efforts to develop agriculture in the new country, later drifted towards an academic mode, choosing their topics and reference groups in the international scientific community, and losing its applied links (Ben-David and Katz 1975). Thus, as many commentators have noted, academic research was never fully organized in accordance with "mode I", while applied, context-based and multidisciplinary research is not a recent invention (Fuller 2000; Shinn 2002). But the book helped to make explicit a tension that existed within academic research in the advanced economies, and lent legitimacy to a different approach to science policy and academic management and organization.

This tension has always been present in Latin America, even if not as explicitly as it is today. Since the 1940s and 1950s, inspired mostly by the achievements and

promises of nuclear physics, many scientists in the region had hoped that their universities could be transformed to place science and technology at their core, as part of a much broader social and economic revolution in their societies. (Herrera 1970; Klimovsky 1975; Lopes 1969; Nye 1975; Varsavsky 1971). They tended to share the political philosophy of the British and French scientific socialists, J. D. Bernal and Jean Perrin, and differed from those, more in line with the ideas of Michael Polanyi and Robert K. Merton, that had argued for a more detached, community-based, "pure" model of scientific organization, such as the mathematician Amoroso Costa in Brazil (Amoroso Costa 1971; Bernal 1967; Merton 1973; Perrin 1948; Polanyi 1947; Polanyi 1997; Ranc 1945).They were very influential and supportive of the creation of national science and technology councils and agencies.[3] All these institutions have, in their mission, the goal to support science and technology in very broad terms and put it to the service of society, and, to different degrees, created administrative and financial mechanisms to support and facilitate the bridges between science and society.

In the 1980s and 1990s, the belief that science and technology should be integrated in a comprehensive planning system for the management of society, shared both by the socialist scientists and the nationalist military, was replaced by the notion that science, technology, government and industry should be linked by complex, multi-institutional innovation systems that existed as a matter of course in the developed economies, but were mostly absent in Latin America (Branscomb and Keller 1998; Cassiolato, Lastres and Maciel 2003; De la Mothe and Foray 2001; Jones-Evans et al. 1999; Krauskopf, Krauskopf and Méndez 2007; Melo 2001). The concept of "innovation", as applied to the field of science and technology, comes mostly from economists, concerned with the ways to make companies and countries more efficient and productive in a competitive environment, and led the creation of a large array of new institutional and financial mechanisms to stimulate businesses to reach out to universities for support. In several universities, it led to the creation of offices for technical assistance and the management of intellectual property, as well as new institutional arrangements such as incubators and science parks. It also led to broader policy recommendations for changes in the national science and technology policies that, however, were seldom implemented (Schwartzman et al. 1995a; Schwartzman et al. 1995b; Schwartzman et al. 1995c)

EXPECTATIONS AND OBSTACLES FOR THE STRENGTHENING OF THE LINKS BETWEEN UNIVERSITIES, INDUSTRIES, GOVERNMENT AND SOCIETY

So far, and with the caveat that many of these initiatives are still emerging and ongoing, these policies and institutional innovations have been less successful than what one would expect. To reach outside their walls and link with society, academic research centers and institutes need to compete with the demands of mass higher education, and also with the "mode 1" culture they have developed to support their research activities. They have to deal also with the limited demand for locally generated knowledge-based information and technology in their societies, both from industries and governments. Combined, these two factors have limited their ability to place their capabilities at the service of their societies.

In the mass higher education systems in Latin America, academic researchers are a smaller segment of a much larger academic profession, which also includes traditional professors, part-time lecturers, and a growing number of teaching, unionized and demanding university employees (Altbach 1996; Balbachevsky and Quinteiro 2002; Schwartzman and Balbachevsky 1994). The career patterns, teaching loads, resource allocation and priorities in higher education institutions are not geared to the values and expectations of the researchers, but to these broader constituencies, which also include very vocal, active and politically connected student associations

Education authorities spend their limited resources supporting the on-going activities of higher education institutions, while research agencies tend to work, typically, with grants that are provided project by project. This creates a competitive environment that is accessible to scientists with strong scientific qualifications, but not to other members of the academic profession. To make sure that the resources for science and technology are not lost in the support of routine teaching and practical activities of low scientific and technological content, scientists stress the need for peer review, international quality standards and the use of publication indicators and track records as the main criteria for selecting projects and distributing resources. They view with mistrust the use of non-scientific criteria, such as social or economic relevance, as the basis for project evaluation, as well as the participation of non-scientists in the evaluation committees and boards.

This drive in support of high-quality research has led to the establishment of quality assurance institutions that have provided support and visibility to a significant number of high quality, research oriented university departments and institutes in the different countries. The best known example is CAPES (Comissão de Avaliação de Pessoal de Nível Superior), the Brazilian agency for assessing higher education in Brazil, which, for several decades, has maintained a successful mechanism for peer-review assessment of Brazil's graduate education programs, the largest in the region (Castro and Soares 1986). CONEAU, the Comisión Nacional de Evaluación y Acreditación Universitaria, in Argentina, and the Padrón Nacional de Posgrado (PNP) in México, play similar roles.

There is also a downside, however. The resources allocated to these agencies tend to be small, and just a fraction of what the countries spend on research and technology, and innovation (Schwartzman 2002); the money tends to be scattered over a large number of small projects, since these peer-review agencies have difficulty in establishing priorities and concentrating resources; and the assumption that good quality research will eventually be transformed into applied, useful technology is seldom fulfilled.

There are also problems in the demand for technology and innovation. In the post-war period, and up to the 1980s, the prevailing view in Latin America was that it was necessary for governments to protect the region's infant industries and support the development of local technology to allow them to grow. This policy, known as "import substitution", was preached by economists from the United Nations Economic Commission for Latin America (ECLAC/CEPAL), and inspired the work of the Argentinean economist Raul Prebisch (Prebisch 1981). To some extent, Brazil, more than other countries in the region, tried to follow these recom-

mendations. The most ambitious project in this area was the market protection policy for microcomputers, but it also included the establishment of research centers associated to state-controlled companies, partnerships between public companies and universities (as between Telebrás, the communications holding company, and Campinas University), and large projects in the areas of atomic energy and space. In the eighties, high inflation, fiscal imbalances and external shocks forced the countries to open their economies and privatize the state-owned companies. The market protection policy for microcomputers was interrupted, and privatized companies cancelled their cooperation agreements with universities and shut or scaled down their research departments (Adler 1987; Baer and Samuelson 1977; Botelho and Smith 1985; Schmitz and Cassiolato 1992; Sutz 1997; Sutz 2000; Vessuri 1990)

There is an on-going argument about whether the import substitution policies could have succeeded in the long run, or were doomed to failure from the beginning, and whether the Asian model, of strong public support for a market oriented, internationally competitive economy would not have been more successful (Amsden 2004; Castro and Souza 1985; Dahlman and Sercovich 1984; Dedrick et al. 2001; Michell 1988; Tigre and Botelho 2001) Even at its best, the links between government, industries and the research institutions in Latin America was limited to a few sectors and a small number of large companies. With the opening of the economy, local companies were forced to compete in the international market, creating a new challenge and a new opportunity for the scientific institutions to increase their links with the production sector. However, privatization and internationalization also meant that many local companies were absorbed by multinational corporations which had their research and development work done elsewhere, while financial restrictions reduced the governments' ability to support long-term innovation projects. For the scientists and their institutions, the alternative was to keep being subsidized with dwindling resources, or move more aggressively to get their resources in the market (Vessuri 1995).

THE LESSONS FROM POSITIVE EXPERIENCES

In spite of these difficulties, our research shows that, in all countries being studied, several research teams were able to reach out and make important contributions to society, while keeping the academic quality of their work. In doing so, they obtained resources and created a rich and stimulating environment for their researchers and graduate students. These research teams are not representative of the average university research sectors in their countries, but showcases that demonstrate that it is possible to overcome the usual constraints of internal "mode I" culture.

All research groups had to deal, in one way or another, with three central issues – the nature and availability of resources for research support; the tensions between academic careers and scientific and technological entrepreneurship; and the tension between the production of knowledge for the open scientific community and the appropriation of knowledge as patents or other forms of intellectual property. These three dimensions are explored in detail in this volume by Antônio Botelho

and Pimenta Bueno, Elizabeth Balbachevsky and Carlos Correa. They are part of the constraints that are external to the research groups, which have to react and adapt to them differently in each country.

Regardless of the large differences among countries and fields of knowledge, it is possible to state that all the groups studied share some common characteristics. First, by virtue or necessity, they had to move away from the conventional pattern of academic research, and reach out to society and the business sector for support. In Brazil, private institutions, such as the Catholic University and the Getúlio Vargas Foundation in Rio, have no independent means to support advanced research with their own resources; in Argentina and Chile, even the best public institutions do not get full support for their work, and have to develop a strong entrepreneurial culture to function. Public research institutions in Brazil and Mexico are much more likely to obtain strong support and high salaries for their researchers, but, even so, several research groups, such as the Chemistry group in Campinas, or the Unidad Iraupuato of CINVESTAV, in Mexico, developed strong cultures of making their work relevant to industry and society, and bringing additional resources to that which they could obtain from regular sources of support.

A second common feature is that they all had to deal with the norms and regulations of the larger institution to which they belong, usually the central administration at the universities. For the institution, these active research centers are an important asset, bringing prestige, recognition and support to their alma mater, and additional resources. At the same time, they tend to be different from other departments and research centers, do not adapt easily to across-the-board rules and regulations, and, in many cases, their researchers enjoy better working conditions and higher income than others formally in the same situation. To deal with research groups like this, the universities have to be flexible and more concerned with the performance of their units than with their formal procedures and bureaucratic norms. This is not very frequent in Latin America, however, not just because of the tradition of formalism and bureaucratic administration, but also because these formalities often hide ingrained conflicts of values and jealousy among different sectors and groups.

A third common characteristic is that most of the groups had a leading figure that embodied a sense of mission and was able not only to establish high standards for research, but could also establish effective links with the outside world, with government agencies, the business sector, and international agencies and scientific and technical communities. This combination of academic excellence and entrepreneurial prowess is not an anomaly, but, in fact, a common element in most successful research teams and institutions anywhere, as well described in a classic text by Bruno Latour (Latour 1987). The positive role these leaders can perform do not require further elaboration; there is, however, the downside, which is when the leader needs to be replaced, and has not groomed a successor nor created the institutional conditions for sustained work, a transition that many research groups and institutions are unable to handle.

Finally, a fourth common element is the presence of multiple outside clients. In some cases, however, such as the Computer Science Department of the Catholic

University in Rio de Janeiro, there is just one major client, Petrobras, which creates two risks. First, the research group may become too dependent on a partner over which it has no control, and may have difficulty surviving if the partnership ends for some reason; and second that the partner, particularly if it is a public company or institution, can become, in practice, a supplier of funds, rather than active user of the knowledge produced by the research group. The best arrangement, not always easy to obtain, is to work with multiple clients, responding to actual demands for knowledge, instead of relying on a single source. This can be achieved, in some cases, with the support of a major external client at first, and a clear pattern of differentiation later on.

The main question is whether, in the future, these localized experiences can become the norm rather than the exception, and help to shape and make broad, "top down" policies that are closer to the actual behavior and experiences of the leading research groups, and could make science more relevant for Latin American societies. There are reasons for hope, since the need is clear, and many research groups and institutions are already finding their ways and being better rewarded for their achievements, both in terns of resources and recognition. We hope that the evidence, the experiences and the analyses reported in this study can help to accelerate this trend.

NOTES

[1] For Brazil, we did not deal with the distinction between federal and state public universities, and our two public institution cases are from the University of São Paulo, the country´s largest research university.

[2] The notion of the "research unit", not the individual researcher or the institution, as the basic social component of scientific work was adopted by the UNESCO International Comparative Study of Research Units (ICSOPRU) surveys in the 1980s (Andrews 1979; Schwartzman 1985a; Schwartzman 1985b; Stolte-Heiskanen 1979). What a "research unit" actually is, however, varies among disciplines, institutions and points in time.

[3] Such as the Conselho Nacional de Pesquisas, CNPq, in Brazil, 1951, changed to Conselho Nacional de Desenvolvimento Científico e Tecnológico in 1978; the Consejo Nacional de Investigaciones Científicas y Técnicas, CONICET, in Argentina, 1958; the Comisión Nacional de Investigación Científica y Tecnológica, CONICYT, in Chile, 1967; and the Consejo Nacional de Ciencia y Tecnología, CONACYT, in Mexico, 1970.

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PART I – COMMON THEMES

ELIZABETH BALBACHEVSKY

INCENTIVES AND OBSTACLES TO ACADEMIC ENTREPRENEURSHIP[1]

The objective of this chapter is to analyze the reward systems in the environment of Latin American academic science institutions. International literature defines these systems as a set of benefits, incentives and privileges associated to different career positions open to an institution's academic body. As Moore (Moore 1992) pointed out, these incentives can be both external, a characteristic of the culture of each discipline or institution, and subjective, and translate into material or symbolic rewards, or a combination of both. In one way or another, an institution's reward system shows, to its body of professionals, the activities and performance standards recognized as the most meritorious and, therefore, conform to the performance expectations of the others.

From the standpoint of the higher education institutions, a relevant question is up to what point their reward systems recognize and stimulate innovative attitudes in the academic body. As pointed out by Clark (Clark 1998) , academic entrepreneurship is associated to a culture that accepts change and the risks associated with it. As such, it can be instrumental in giving these institutions a pro-active position in their area, exploring new opportunities, increasing their social impact and relevance, and therefore, contributing to strengthening its legitimacy compared to other institutions. To use a concept in neo-institutionalist theory (Carlsson 2000; Rhodes 1996), an institution with these attributes can create for itself an active leadership role in the social networks to which it is connected, while strengthening its connections to the environment. As stressed by Clark (1998) simple autonomy is not a guarantee of pro-active self-determination:

> "Autonomous universities may be passive institutions. They may live for the past rather than look to the future. They may be satisfied with what they have become and do not wish for more". *(p. 5)*

Recent studies of various Latin American countries tend to show the absence of these attributes in the regions' large universities (see, for example, (Balbachevsky 2007; Fanelli 2003; Gil-Anton 2006) . In most of these institutions, careers open to academics are constructed from two central criteria, length of service and academic credentials, and so, the professors' entrepreneurship has no space to develop.

However, Latin American universities always had a relevant role in the development of science on the continent. In many countries, the universities, particularly the public ones, provide the most important institutional support for the

S. Schwartzman (ed.), University and Development in Latin America: Successful Experiences of Research Centers, 23–42.

national scientific communities. Even where isolated research institutes play a more central role, the university environment never remains detached. In most Latin American universities it is possible to identify sites - groups, laboratories and centers - active and relevant from a world science viewpoint. In many cases, these groups not only show important development from a strictly academic standpoint, but also are significant socially, creating stable channels of communication and producing a relevant impact on their societies.

This chapter looks at this contradiction, seeking to reveal the logic of the reward systems operating in these micro-environments that support academic entrepreneurship. Some time ago, a Brazilian author coined the expression "islands of competence" (Oliveira 1984) to describe the institutional environment that tends to predominate in science enclaves within Brazilian universities and is also present in universities of other countries in the region. However, this expression assumes an isolation that does not correspond to the majority of these experiences, as we will see below. Therefore, the text starts with a brief overview of the common features of an academic career in Latin American universities, followed by highlighting the most striking specific aspects of the experience of each of the countries analyzed in this book.

This text also discusses another two subjects. Firstly, what is the way these researchers evaluate and how they value the connections they establish with society as a whole and, specially, with the productive sector? Are they just an utilitarian device – needed, but potentially harmful, as they could contaminate with their demands the "pure" research agenda of the researcher? Or are they recognized as strategies to generate new questions and new directions, creating positive feedback for the creating original knowledge?

Secondly, we seek to gather evidence on the standards of accommodation and conflict that emerge from the coexistence of reward structures in these entrepreneurial micro-environments and those recognized by the institution as a whole. Seeking answers to this question is crucial to understanding the possible modernization routes of Latin American universities. As well highlighted by Clark (1998):

> "University transformation, for the most part, is not accidental or incidental. It does not happen because several innovative programs are established here and there within a university: the new approaches can be readily sealed off as minor enclaves…". *(p. 4)*

Everywhere, the structural bases of universities are heavy and generate strong institutional inertia. Modernizing these institutions includes adhesion to an entrepreneurial culture, which accepts and values change and risk. In the last decades, as higher education expanded, its costs increased and its economic relevance became more visible to society, the pressures to impose external control and evaluation mechanisms became stronger (Schwartzman 2007). To preserve their autonomy, these institutions need to take the initiative in the establishment of a new pact with their societies.

AN ACADEMIC CAREER IN A LATIN AMERICAN UNIVERSITY: NEW AND OLD DILEMMAS[2]:

A common thread in almost all Latin American universities is the organization of a professor's career on three main levels: Assistant Professor, Associate Professor and Full Professor. Often, these three large levels are subdivided into sublevels: for example Associate Professor I, II, III and IV in Brazilian federal universities, or Associate Professor A, B and C in the large Mexican public universities. It is also possible to see a strong convergence around this model within the private sector. In many countries, such as Argentina, these positions are preceded by an entry level of assistant professor.

A preliminary question is about the proportion of academics who, in each institution, are included in the career plan and, therefore, have access to a stable position, with the right to have a role in governing the institution. Fannelli (Fanelli 2003) calls attention to this question in the Argentine experience. In that country, the policies that led to mass access to the public universities created a situation in which a large proportion of the academics in the public sector are not regular professors. In Argentina, as in other countries on the continent, access to university career positions should by a public entry examination. However, the lack of resources and the pressures to rapidly expand admissions created a situation in which entry examinations are not held frequently, and a large proportion of professors in the Argentine public universities remain on temporary contracts, a marginal situation in relation to their institutions.

This question is less relevant in the experience of other countries. In Brazil, all professors employed in public institutions are public servants, and as such have job security. Until recently, public universities in the state of São Paulo required a probationary period of, in general, three to five years, before a professor could effectively become a stable civil servant. However, due to changes in labor legislation, this procedure has been abandoned, and today, once the person is admitted through the entrance examination, he or she acquires stability at the same time In the same manner, in Mexico, job security or *definidad* is accessible to all public sector professors, after a short probationary period (Gil-Anton 2003). Also in the case of Chile, access to stable contracts is the norm in public universities, and the private universities, especially the more traditional ones, also acknowledge job security and access to a career plan, sometimes after probationary periods of various durations (Bernasconi 2003).

What changes from country to country and, within each country, from one institution to another, are the requirements associated to access to each of these levels. Formally, one of the criteria central to a career is the academic title of the applicant, usually a doctoral degree. However, in all these countries, this formal requirement had to conform to the fact that there are more university academic positions than persons with doctoral degrees in Chile (Bernasconi 2003; Bernasconi and Rojas Aravena 2004), Mexico (Gil-Anton 2006; Gil-Anton, et al. 1994), Argentina (Fanelli 2003) and Brazil (Balbachevsky 2007). Therefore, in almost all Latin American universities, the formal requirements for academic titles are bypassed by the creation of "alternative routes", that allow professors to further

their careers without a doctorate[3]. So, traditionally, an academic career in Latin American universities tended to be based on not very transparent criteria, which opened a wide margin for negotiations with unions and even political parties.

Throughout the 90s, the situation described above was subject to strong pressures and underwent important changes in all countries included in this study. Firstly, in all of these countries, the growth in graduate education increased the supply of those with doctorates. Secondly, from this period it is possible to observe a stronger regulatory effort by the government authorities responsible for higher education. Generally, this effort translated into a set of converging guidelines that tended to strengthen the academic hierarchies within higher education, particularly in the public sector, stimulating institutions to provide holders of doctoral degrees with full-time contracts and to rank and provide support to institutions according to their professors' publications and their ability to raise resources raised to support their research activities.

In all of these countries it is possible to identify policies of this kind. However, they have not succeeded the same way. In Chile, the adoption of such policies took place in the 80s and was accompanied by the introduction of market mechanisms that had a strong impact on the flexibility of traditional institutional hierarchies. The competitive environment created by these reforms created space for the emergence of new or reformed institutions, which successfully competed for higher positions in the Chilean higher education institutional hierarchy. This environment favored an unusual amount of institutional experimentation, affecting the career paths open to professors in different institutions. In many institutions, payments could above as much as 100% of the base salaries according r the productivity of professors. Even in the more traditional institutions, where time of service continues to be a relevant criterion for promotion, the need to attract young holders of doctorates let to the adoption of parallel career systems, which allowed paying higher salaries to the most productive professors.

In Mexico, the adoption of programs to stimulate professors and researchers, such as the National Researchers' System (*Sistema Nacional de Investigadores* - SNI), the Programs to Stimulate Academic Performance (*Programas de Estímulos al Desempeño Académico)* and the Program to Improve Teaching (*Programa de Mejoramiento del Professorado*) introduced clearer and quantifiable parameters for evaluating individual academic performance, and created a more transparent basis for measuring the relative quality of institutions. For the institutions, these programs let to the adoption of more objective standards for promotion within academic careers and, in many cases, in the adoption of productivity incentives (Heras-G. 2005). The impact of these changes, however, is limited by the fact that most of the resources involved in these programs remains concentrated in the metropolitan area of the capital and tends to predominantly serve the teaching staff employed in the public sector.

In Brazil, policies of this nature gained relevance in the second half of the 90s. During the two presidential terms of Fernando Henrique Cardoso (1994-2002), various measures adopted by the Ministry of Education introduced some degree of competition within higher education and created more objective parameters to evaluate the quality of the education offered by each institution. The Federal

Government also introduced incentives for professors in federal universities according to their dedication to teaching at the undergraduate level. Additionally, a reform of of the evaluation system for graduate education programs, introduced in the 70s, tended to quantify more strictly the parameters used to measure the quality of these courses. An important difference in this experience, in relation to that in Mexico and Chile, is that, in Brazil, all of these measures were orientated towards establishing the collective quality of the academics' performance and not the individual production of each professor. Several of these policies were discontinued after 2002, with the presidency of Luís Inácio Lula da Silva, but the assessment of individual academic performance as a criteria for granting support for research projects was maintained. Since the 90s, it is possible to observe a trend for the growing formalization of the assessment parameters.

In Argentina, a degree of flexibility in the institutional hierarchies and competition had been introduced by two important policies: the graduate courses accreditation program and an increase in the academic performance requirements for the concession of public support for research projects. These stimuli were sufficient for some smaller public institutions, such as the General Sarmiento and Quilmes Universities, and other prestigious private institutions, such as the Buenos Aires Technological Institute (*Instituto Tecnológico de Buenos Aires*), sought to change the careers of professors, introducing a periodic evaluation of individual academic performance to decide whether or not the professor remains on the staff of the institution. The impact of these initiatives on the large public universities , however, is much smaller, especially because of the chronic shortage of resources in these institutions and their connections to political parties, which allows them to keep free of outside pressures from the government bureaucracy.

In short, in all of the countries studied the current situation signals a change in the academic environment and the streamlining of the career of these professionals, especially those holding a doctorate. However, a weak point in this new scenario must be noted. Given the preeminence of the government's regulatory levels, the institutional differentiation process responds to the signals emanating from one source and, therefore, tends to validate only one set of indicators to evaluate the excellence of academic work: productivity, as measured by the number of publications, the quality of which, if considered, is measured exclusively by the formal use of scientometric indicators. The consequence is the convergence around a single ideal profile for a professor, an academic gold standard (Bernasconi and Rojas, 2004), which consists of a professor with a doctorate and a full-time contract, whose research activity is financed with external resources (and necessarily public resources, in some cases) and with a production published in indexed journals (preferably by the ISI - Thomson Information Science Institute - system, for some countries). In this profile, there is no consideration for the interface between academic life and national society, the institution's contribution to regional development or the interaction of academic researchers with the productive sector. This situation stimulates stereotyped behavior by the academic body, which tends to adhere to routines considered more efficient to gain points in the performance indicators recognized by their institution and by the regulatory agencies.

NEW MODES OF KNOWLEDGE PRODUCTION AND THE REDEFINING OF SCIENCE'S SOCIAL ROLE: A TYPOLOGY OF THE INTERACTION PATTERNS OF SCIENTISTS WITH THE EXTERNAL ENVIRONMENT

Before we move on to the available empiric material for this analysis, we will make a recap of the changes to the nature of the forms of scientific knowledge production that have occurred since the end of the 70s. This exercise seeks a better understanding of under what circumstances the interaction of the academic community with the external environment, assumes transforming characteristics.

Various authors have sought to capture this transformation using different conceptual tools. Gibbons and his collaborators (Gibbons, et al. 1994; Nowotny, et al. 2003) characterize a new scientific knowledge production method (mode 2) which, in contrast to the traditional academic method (mode 1), is produced within the context applications and marked by being transdisciplinary and heterogeneous. In this new mode of knowledge production , the the instruments for quality evaluation are reflexive and based on social control.

Another contribution, already a classic, to this debate comes from Donald Stokes (Stokes 1997), who proposes a matrix model, combining the useful and fundamental dimensions of scientific knowledge (see Figure 1, below). According to this model, the search for useful knowledge is no longer opposite to the concern with the advance in basic understanding of nature, a trait usually cited as a characteristic of basic science. On the contrary, useful and fundamental knowledge appear as independent dimensions, which come together to form a space where we can allocate different knowledge production strategies[4].

Search for fundamental understanding?		Consideration of possible applications?	
		no	yes
	yes	Quadrant 1 Basic research (discipline) mode 1. "Bohr quadrant"	Quadrant 2 Basic research aimed at application, mode 2. "Pasteur quadrant "
	no	Quadrant 3 (didactic research)	Quadrant 4 Traditional applied research. "Edison quadrant"

Source: adapted from Stokes, D. 1997, p. 73.

Figure 1. Stokes model for scientific research quadrants

In this way, we can position knowledge production Mode 1, as described by Gibbons et al (1994) in Quadrant 1. Here the problems are established and resolved within a specific scientific community, which uses internal criteria to set the research agenda and the evaluation of its quality and relevance. Stokes proposes that this quadrant is called the Bohr quadrant, an allusion to the work style of one of the most eminent physics researchers in the twentieth century.

For Stokes, Quadrant 2 describes a research style that is strategic for contemporary science and technology policies, as with it the researcher develops research

aimed at problems posed by the external environment, but with a "basic style" (Beesley 2003). The author calls this quadrant the "Pasteur quadrant", with reference to the later works of this scientist who, at the same time, responded to an applied question, the improvement of industrial fermentation techniques, and launched the basis of modern microbiology.

The fourth quadrant refers to applied research as it was understood by Vannevar Bush (Bush 1945) , which is exclusively aimed at the solution of concrete problems, which are often very complex. For Stokes, this is the Edison quadrant, the brilliant inventor and director of the first industrial laboratory in the United States, Menlo Park, who always refused to consider any scientific implication from the results of his research on the commercial application of electricity.

It is not difficult to associate Quadrant 2 with the characteristics of mode 2 for knowledge production, described by Gibbons and his collaborators. It is also not difficult to understand the importance of the research developed according to this model. In the world today, marked by the globalization of knowledge production, the ability to do research according to this quadrant is inestimable social resource for any country. As pointed out by George Ferné (Ferné 1996), a description of the contemporary scenario must take into consideration the growing internationalization of national economies; the speed, intensity and global reach of the lock-in processes of new technological families; and the development of global networks for creating new technological knowledge. This scenario creates new challenges for science in all countries, and particularly in emerging countries.

This discussion allows us to see the set of new social aptitudes that need to be developed so that a researcher moves successfully in the networks created by the new knowledge production modes. Attaining this refined interaction between researchers and the broader social context is not only relevant for the society. The ability to establish and sustain this type of interaction appears to be vital for creating a support network within a society that recognizes, legitimizes and sustains the demands of the scientific community. The importance of this network has been recognized by various authors, including, many years ago, by Joseph Ben-David (Ben-David 1971) .

From the point of view of research groups, it is possible to adapt the model presented by Stokes, producing a typology of possible attitudes or responses to the external demands on the researchers and their institutions (Figure 2)

Permeability of the research agenda to the external demands and problems	Incorporation of support from external sources to research activities	
	yes	no
yes	strategic	blocked
no	tactical	isolated

Figure 2. Typology of attitudes in response to external demand

The proposed typology has two distinct dimensions: on one hand it considers the researcher's **predisposition** for incorporating demands from the external sector

into the research agenda. On the other hand, it appraises the effective **success researchers have in mobilizing support** from this sector, to bolster their professional activities. International literature indicates that the latter is not a trivial competence (Diederen, et al. 2000; Edquist 1997; Lundvall 1992): it requires an apprenticeship which is far from easy for the researcher, used to relatively isolated research environments. All cases analyzed in this study take into account how arduous this apprenticeship is, which begins with an often fortuitous interaction, but must be consolidated over time, in many and repeated interactions, which, little by little, consolidate communication channels and generate an environment of mutual confidence.

The typology allows the identification of four different attitudes of the researcher in relation to the interaction with sources external to the academic environment. First, we we have the researchers for whom this participation is **strategic**. That is to say, it is not just important from the viewpoint of support they can receive, but also for the questions generated by this interaction. Researchers in this quadrant posses the necessary qualities to qualify as practitioners of knowledge production Mode 2, developing their production as participants of diversified social networks.

For another group of researchers, however, the interaction with the external environment represents a set of motivations that are merely **tactical**. For them the support obtained from other sectors of society only fills a logistical gap: the lack of resources for supporting their research. However, the problems and questions produced in this interaction are not recognized as legitimate for incorporating into the research agenda. Therefore, the interaction acquires a negative quality, and results in the disassociation between the services rendered, in exchange for support, and the research activity itself, with an agenda that remains submitted to only the dictates of science.

At the other extreme we have the classic scientists, **isolated** from all influences and contacts, uninterested in the problems of the outside world and motivated only by the agenda produced by their discipline. These are the researchers who occupy the Bohr quadrant in the Stokes model. The researchers for whom considerations about the use or possible application of knowledge has no importance.

Finally, when a potential opening for external demands combines with an effective isolation situation, in which this interaction is not reached, we have an effective **blockage** situation. In this event, the researcher has the intention or the predisposition to incorporate an agenda negotiated with other players, but in fact doesn't reach this objective. Very likely, this situation is produced when the researcher, familiar with Mode 1, does not come to terms with the effective access channels to the other sectors.

The consideration of these different ways of relationship between the academic sector and external sources is very important for the understanding of the different reward systems that are present in the experiences analyzed in this project. The assumption of this chapter is that a strategic approach is essential to achieve a substantial change in the group culture of scientific teams and institutions and to create the basis for a science which is both robust and endowed with strong legitimacy and support from society (Gibbons 2004).

MATERIAL INCENTIVES TO THE INTERACTION WITH THE EXTERNAL ENVIRONMENT

The analysis of the cases showed that two factors encourage the scientist to emerge from the isolation expected by traditional academic culture: the scarcity of material resources and the perception of the social responsibility science has to society. Within the first question, the interaction with the external environment is perceived as an alternative to bypass the chronic shortage and uncertainty of resources from public agencies which finance research.

> "However, in the last years, precisely in the last six years, it seems to have disappeared... there has been no help for buying equipment. During the entire six years they have only made a donation of relatively little money, around a million pesos for the six years, which is nothing... nothing close to what we need. Now, for example, I have two approved projects. In one, we have already delivered the receipts to CONACYT and up to now they haven't paid... and the other is approved in academic terms but the agreement is not signed, nothing. The situation of research continuity is terrible" *(Mexico, IBT, UNAM).*

> Or,

> "...it is a source of money to act as a buffer when the Agency, UBA or Conicet are no longer there" *(Argentina, IFEVA)*

The reports of experiences from the Rio de Janeiro Catholic University Department of Informatics (*Departamento de Informática da Pontifícia Universidade Católica do Rio de Janeiro)*, the Getúlio Vargas Foundation Graduate School of Economics and Brazilian Institute of Economics (*Escola de Pós Graduação em Economia e o Instituto Brasileiro de Economia da Fundação Getúlio Vargas*), by the research group lead by Professor Fernando Galembeck of the Campinas State University Institute of Chemistry (*Instituto de Química da Universidade Estadual de Campinas*) and the Center for Research and Advanced Studies, Irapuato unit (*Centro de Investigación y de Estudios Avanzados*, *Unidade Irapuato*) (CINVESTAV), Mexico, confirm this scenario. In all these experiences, the financial crisis that hit the Latin American countries in the 80s and the start of the 90s is presented as justification for the importance that the contacts with the productive sector had for financing research. As public resources dwindled and, at the same time, became more uncertain, these research groups were forced to search for diversification of their financing sources.

This alternative is even more urgent for more structured groups, where research activities take place in a collective environment, requiring the participation of a variety of players, students, trainees, technicians and specialists, from various areas. Here, the diversification of resources appears to be essential:

> " I have to play the role of managing the search for the project's financing resources that allow us to maintain the laboratory and the people that work there: Grants for students to continue their studies, repayments to students

> who stop having grants, payment of laboratory technicians and specialist maintenance personnel for particular situations, assistance for field work, conferences, etc." *(Mexico, IBT, UNAM).*

This pressure is also felt in interdisciplinary groups, as is the case at the Center for Mathematical Modeling of the Department of Mathematical Engineering *(Centro de Modelamiento Matemático da Departamento de Ingeniería Matemática* - DIM*)* of the Faculty of Physical and Mathematical Sciences of the University of Chile *(Facultad de Ciencias Físicas y Matemáticas de la Universidad de Chile* - UCH*)*. In the report of this group's experience, the knowledge is constructed from an interaction between engineers and mathematicians, and the resources coming from the external environment are essential for sustaining the presence of a large number of professionals, who cannot be incorporated into the academic body by hiring them as professors.

Furthermore, in most of the cases studied, external resources generate extra income, which reinforces the gains received by the researcher. The amount of this income is variable, according to the institute's tolerance limits. In some experiences, as in the case of the Center for Legal investigation of the Diego Portales University (*Centro de Investigación Jurídica da Universidad Diego Portales* - CIJ-UPD), in Chile, and the Center for Environmental Sciences (*Centro de Ciências Ambientales* - EULA) of the Concepción University (*Universidad de Concepción*) - Chile, this addition to the salary is part of the institute's deliberate policy. In these two examples, both relying on flexibility which is typical from the private sector, the researcher's contract with the institution only covers a part of his time.[5]. In other cases, this addition to the salary is seen as an alternative, which compensates for the low level of academic salaries. As most of those interviewed recognize, the addition is often a necessity, in order to ensure the recruitment of professionals with a profile of excellence, especially in areas where competition with the non-academic markets is stronger:

> "… the College does not pay very much, and if you have children to keep at school… It is a delicate balance, if this income didn't exist, many people would just leave the discipline". Centre of Economic Studies, College of Mexico *(Centro de Estudios Económicos, Colegio del México).*

In some ways, therefore, in all of the cases investigated, the interaction with the external environment receives a positive incentive, which translates into resources for acquiring, maintaining and modernizing the infrastructure necessary for research. Also, in all of these cases, the institution's support for research is limited: in some cases it is limited to the physical space, in others the basic infrastructure costs are covered – water, electricity, telephone, optical cables, etc.; in some others the costs for administration and the administrative support personnel are paid. But the infrastructure itself for carrying out research – acquiring the necessary equipment and, in many cases, its maintenance, and supporting the research team itself – always depends on the initiative of the researchers who are dedicated to the project in that location. In some cases, for example EULA-Chile, Buenos Aires Technology Institute (Instituto Tecnológico de Buenos Aires - ITBA) in Argentina,

CINVESTAV/Irapuato in Mexico and DI-PUC-RJ in Brazil, this expectation is the result of a deliberate institutional policy and jointly agreed with the research groups. In these situations it is common to also put in place a cost and equipment sharing strategy. In other cases it is a non-intentional result of the particular conditions of each institution: the lack of budgetary resources or the limits of an egalitarian policy that limits the incentives that can be given to the best qualified researchers.

INTERACTION WITH THE EXTERNAL SECTOR AS AN INSTITUTIONAL MANDATE

Incentives for interaction with the external environment also arise from a moral imperative, according to which it is the duty of scientists to serve society and their country. In some cases, this imperative is an institutional mandate: for the CINVESTAV/Irapuato researchers for example, the institution has a mandate to contribute to the solution of regional development problems. Interaction with local agricultural problems and the usefulness of the knowledge produced is a dimension understood as necessary by the research groups, even when they are in a blocked situation. Consequently, published works make frequent references to the possibility of applying the knowledge produced, likewise the selection of study objectives tends to incorporate these kinds of concerns.

This dimension is also present in almost all of the cases studied and is particularly prevalent in research groups linked to agrarian sciences, such as the Institute for Physiological and Ecological Research Linked to Agriculture of the University of Buenos Aires, (*Instituto de Investigaciones Fisiológicas y Ecológicas Vinculadas a la Agricultura* - IFEVA *da Universidad de Buenos Aires* - CONICET) the ESALQ – FORESTS program for sequencing the Eucalyptus genome. It is also central for the researchers linked to the Coastal Center of Aquiculture and Marine Research (*Centro Costero de Acuicultura e Iinvestigaciones Marinas* - CCAIM) in Chile:

In other cases, the imperative is for applying knowledge is intrinsic to the disciplinary field to which the research group is affiliated. In the technology and engineering areas, this is almost self evident, as expressed in a clearly understood institutional mandate:

> The Center's essential mission is to "create new mathematics, to model and resolve complex problems of industry and other scientific disciplines" *(CMM/DIM, Chile).*

There is also a subjective, personal dimension, expressed in personal satisfaction, the feeling of a mission accomplished, shown by researchers linked to different environments and disciplinary areas, on confirming the results achieved by partnerships with the productive sector:

> "This attraction for doing things and for resolving concrete problems using relatively simple knowledge, that does not involve 'important science' …made me aware that it helped many companies a lot" *(IBT, Mexico),*

> "Therefore, if you put energy into this, it is because it is very, very stimulating and very enthusing to see what happens, after all there are 300 producers..." *(IFEVA/UBA, Argentina).*

These examples spell out the issue of the social responsibility of science in the Latin American countries, its relevance for regional development and the moral imperative that the scientists should respond to the needs of their society and their country. They reflect also, to some extent, the nationalist ideologies that were so important in Latin America up to the 1980s. The ways in which this imperative appears, in each case, will be discussed in the next section.

TWO PERCEPTIONS OF THE INTERACTION WITH THE EXTERNAL ENVIRONMENT: A TACTICAL AND STRATEGIC APPROACH

We saw above that, in all of the cases studied, interaction with the external environment is valued for the relative affluence of the generated resources. Successful groups in this area are better equipped and are guaranteed continuity of their work team. Even if the opportunities for accessing the resources from agencies that encourage research and international philanthropic foundations are systematically exploited in the majority of cases, access to resources from the private sector makes a difference for these groups, both in relation to their volume and in respect their flow. However, the role of these activities in the knowledge production process varies from case to case.

In some experiences, this interaction with the external environment is merely tactical. It is a "toll" that researchers "pay" to guarantee the material requirements to do their work. In this perspective, there is a clear line dividing what is appropriate as "consultancy" and that which represents its real intellectual contribution:

> "Consultancy does not require much thought. It only requires a couple of moments of concentration. It is more technical, not stimulating at an intellectual level". *(CEE/Col. De Mexico, Mexico)*

In other experiences, however, these two objectives come together, generating mutual synergies. The resolved problems and questions in the application environment are restated, generating a unique rich and diversified research agenda, which is valued because it is original compared to the production from the international community:

> "It pays for the enrichment of a particular problem, and as it leads you to ask research questions, to which if you find the answers...you will not only produce a paper or just knowledge, you will be creating knowledge and solving a problem. Therefore as a researcher, instead of creating a problem, which generally is very artificial, or is an obsession or doesn't make any sense, or there are 15 laboratories in Japan, 35 in the United States and 40 in Europe dealing with the same problem, it is better that I chose another problem which is more meaningful for my country and to resolve concrete problems" *(IBT/UNAM, Mexico).*

In many cases, this is the result of the researcher's deliberate approach in his interaction with the external environment:

> "almost all technology development and transfer projects have associated theses and papers which we publish, which means we are creating science with this..." *(IFEVA, Argentina)*

Or:

> "I don't want to establish the difference between basic and applied, probably if a basic specialist sees our work, he will say that 100 or 90% is applied. Because we have an opinion that is a little different from theirs, but I believe that the discussion about basic and applied is not solved, it is a discussion from the 70s that many say is resolved and the way of closing this discussion is to say: yes, we create good science, I believe we create good science... But, I firmly believe that, additionally, we have to create science that undoubtedly has a social commitment... Any well thought out and argued line of research, but which takes into account the country into which it is inserted" *(IGENBI, Argentina)*

Various factors may contribute to producing this synergy between the contexts of application and production of original knowledge. The cases analyzed for this research point to the importance of signals produced in the disciplinary field. Therefore, the most important factor seems to be the identification, by the researchers, of opportunities for building their academic prestige from the results obtained in their work with external clients. As these results open new horizons and create alternatives for new academic products, valued within the disciplinary field, the gap that separates the rendering of services from the academic research tends to close.

Another common factor, found in most cases where strategic conception predominates, is the presence of very clear signals in the immediate institutional environment about which types of services and consultancy are legitimate in the eyes of the group. A comparison between cases shows that the more intense these signals are, the more strongly the activity is recognized and structured as an institutional objective. This is a common experience, for example in EULA-Chile, ITBA in Argentina, CFATA in Mexico, IGENBI in Argentina and in the Department of Informatics of PUC-RIO. In all these cases, the institutional discussion reinforces the academic character of the group and, at the same time, underlines the question of the quality of the services they offer, imposing requirements relative to the minimum complexity of the questions set for the research groups. In many of these institutions, it is also possible to observe a deliberate strategy of constructing interfaces between the questions dealt with in application contexts and the requirements of academic life. Finally, also in all of these experiences, the institution tends to place barriers to accessing these services, whether by charging different prices or by setting time requirements for the project to mature. This strategy avoids the researchers' working time being spent on consultancy activities to solve trivial problems.

On the other hand, where consultancy remains, in large part, exclusively dependent on the researcher's will, interest and entrepreneurship, the definition of these limits tends to be less problematic. This is the case, for example, of the experience of the Center for Economic Studies of the College of Mexico (*Centro de Estudios Económicos* (CEE), *do Colégio de México*) or of CIJ in Chile and, in some measure, can also be seen within IBT/UNAM in Mexico. In these cases, the limits for consultancy practice, if they exist, are external, based on the demands of science supporting agencies on the researcher's academic preformance.

The dichotomy between the academic work and consultancy is more evident among the research groups in the social sciences area. In three of the four cases studied in this large disciplinary area, it was possible to see tension, some times latent, some times explicit, between the products valued for their academic content and those that are in response to external demands. Thus, the recent process of redefining the institutional mission by CEE, in Mexico,let to a split between those that set, as a personal academic objective, to publish in highly prestigious international periodicals and those that valued participating in the debate on the direction of the national economy. In this experience, the controversies were also around the legitimacy of revealing consultancy results in academic magazines.

In the Getúlio Vargas Foundation, this dichotomy produced a division of labor, where some are fully dedicated to research and graduate education, working in topics valued by highly prestigious international journals with little connection to local issues, while others are absorbed in rendering services and consultancies organized by the institution; this last group occupies an attractive position from the standpoint of financial gain, but less prestigious in the institution's status scale[6].

An interesting trajectory is that observed at the Center for Legal Research (CIJ), in Chile. This institution built its academic prestige during the 90s, for its insertion in the public debate on subjects related to improving the legal structure in Chile, during the transition to a democratic regime. Therefore, the founding group built a research agenda with an emphasis on public policies and on discussing reform alternatives for the country's legal structure. This agenda lent the Center originality in the Chilean legal scenario. To a certain extent, the insertion of these intellectuals into the public debate, created an arena to scrutinize its production quality, an experience very similar to that related by Ben-David and Katz(Ben-David and Katz 1975) , in analyzing the interaction between the first generation of researchers in the Israeli agricultural area and the regions agriculturists. However, as happened in the experience related by these authors, within the new generation of researchers linked to the Center, after democratization, orientation towards "pure", theoretic academic research, tended to predominate, which overcame the standpoint defended by the veterans, which was to participate in the public debate. Very probably two factors contributed to this development: the end of the public debate on the topic of re-democratization and reform of the State, followed by a tightening of the financial sources for applied research in this area, and the lack of efficient institutional mechanisms for evaluation and recognition of the products from the interaction with the external environment.

Only in the experience of the Department of Economy of the La Plata National University (*Departamento de Economia da Universidade Nacional de La Plata*) in

Argentina, does this tension appear to be less, in large measure due to the predominance of two lines of applied research which are recognized as strongly contributing to the academic prestige of the discipline in the institution: the analyses of public finances and the study of the process of income concentration and distributiom, through the Center for Distributive, Labor and Social Studies (*Centro de Estudios Distributivos, Laborales y Sociales* - CEDLAS).

Our observation, therefore, indicates that the predominance of more tactical or strategic orientation, in relation to utilizing the questions and demands posed by the external environment, appears to be a result of a complex set of factors, some associated to different disciplinary fields, and others related to the institutional environment in which these research groups work. This last dimension will be explored more deeply in the next section.

ACCOMMODATION STANDARDS AND THE CONFLICT BETWEEN THE RESEARCH CENTERS' MICRO-ENVIRONMENT AND THE INSTITUTION

The last question posed in this work must be approached from two distinct points of view: the perspective of the institution to which the research groups are affiliated and the perception of their researchers. From the institutional standpoint, there is no doubt that the productivity and the excellence of the scientific activity developed in these enclaves, is a source of prestige, valued by all of the institutions.

The smaller the institution the more important is this value. Thus, in the Chilean experience (CCAIM, CIJ and EULA) and in Argentina (ITBA and Department of Economy of the La Plata National University), the cases that describe a positive and reasonably satisfactory interaction between the institution and the research groups are exactly those in the smaller institutions. In these examples, the research groups could mobilize considerable support from the higher echelons of the central administration. For all of these institutions, the presence of these enclaves of excellence is a high prestige factor, and their renown benefits the entire institution. It is also not strange that, in almost all of these experiences, the research group occupies a high position in the institution's organization chart, generally attached to its central management.

In the reports of these experiences, a common theme is the difficulties and resistance that an institution faced, from its internal environment, for the accommodation of specific needs of a research group. Also in all of them there are reports of these conflicts resolving in favor of the research groups, by catering for, exceptionally, their institutionalization requirements. Therefore, to be part of the staff of these centers is, in itself, a privilege and a publicly recognized distinction. The researchers recognize that the internal environment favors a climate of mutual confidence and mitigates the effects of any tense situations. When these were reported, they were related to the difficulties in accommodating the internal dynamism of these groups to the bureaucratic assessment criteria adopted by the science support agencies.

On the other hand, the reports of the groups and centers affiliated to the large institutions, such as the Autonomous University of Mexico (*Universidade Autônoma*

do México) or the University of Buenos Aires, describe more divergent situations. These gigantic and intensely bureaucratic institutions, although recognizing the relevance of scientific activities in these centers, have little space to accommodate and serve specific requirements. The support they offer is very limited, principally in relation to the specific needs of interaction between the research group and the external environment:

> "Look, central bureaucracy is always a big problem. Signing agreements. UNAM, for example, has no structure to administer patents, so we have to do it here, well, the institute does have a technology transfer unit where we have good support, but there is no central support. If you want to hold a patent, or when it is granted to you…you have to pay large amounts, if you don't take this from your grants or the institute's budget, UNAM doesn't have a strategy for this. Even worse, when purchasing reagents and importing, many times you fall into situations straight out of Kafka: they are held for two or three months by the authorities and things are lost" *(IBT, Mexico).*

Some reports tell of tension between a career and the performance indicators set by the institution and by the public research support bodies – particularly the production of academic articles and student education – and the effort demanded for interacting with the productive sector, as well as recognizing the result of this interaction:

> "...undoubtedly, I feel that a large part of the energy I put into this is not valued by the classic science evaluation systems. For me, it would be better in this sense to be producing papers" *(IFEVA, Argentina).*

Others still reveal a watchful resistance by central bureaucracy, towards resources arising from the interaction with the business sector:

> "Typically, you buy equipment... Well, I have a lot of financing from companies, so if you buy equipment with money from CONACYT, UNAM pays the import costs. If you buy with money from a company, then you have to pay the import costs" *(IBT, Mexico).*

As a response to this situation, a characteristic common to all cases of groups affiliated to large universities, is the construction of barriers which isolate the group from the institution, which gives them a large margin of autonomy against the regulations and decisions emanating from the central authority. In the reports of these experiences, the university appears as an external entity, or at least unknown, frequently an obstacle and, sometimes, even a threat to group's survival and work.

In all these experiences the institute or center constitutes a basic institutional reference for those interviewed, the focus of their academic life and, at the same time, an institutional space accessible for collegiate participation. These qualities are intensely appreciated by the researchers, and create powerful incentives for the professional adhering to a common project to preserve these micro-environments.

In this sense, the processes and values that expand within these centers, often against those emanating from the main institution, are perceived as more central

and relevant for the daily life of these researchers. In some measure, they cushion the researchers and their teams from any disfunctionality present in the larger institution:

> "Yes, I have to speak very well of the institute... if you noticed, it was even difficult for me to find problems within UNAM. Apart from the structural inconveniences, it was difficult to define the problematic areas. Largely it is because I am at the Institute of Biotechnology" *(IBT, Mexico).*

The cases analyzed in Brazil are half way between the two realities described above. The same as the groups affiliated to UNAM and UBA, the Brazilian groups have a large amount of autonomy in relation to the decisions and initiatives taken by the main institution. However, their institutional context tends to be more receptive and flexible to their needs. Both the Getúlio Vargas Foundation and the University of São Paulo, the University of Campinas and the Catholic University of Rio de Janeiro are important institutions in the Brazilian scenario, for being relatively affluent and homogenous. In the specific case of the Department of Informatics of PUC-Rio, the institution is very receptive to the entrepreneurial activity of its members.

CONCLUSIONS

The object of this chapter was to analyze the reward systems in the institutional research environment within Latin American universities and institutes, seeking to identify the elements that favor the entrepreneurship of these research groups, and to better understand the interaction between these micro-environments and the institutions they belong to.

Our analysis show that academic entrepreneurship basically arises from the need imposed on all of these professionals to ensure financial conditions for their research activities. The manner in which research financing is organized in Latin American countries is basically by support for specific research projects, creating the seeds of an entrepreneurial culture within the academic world. These researchers have always been in a situation in which maintaining their team and equipment depends on their initiatives to find sources of financing, sponsorship and support. This pressure is the main structure for sustaining the pro-active stance of all the groups analyzed. The rewards coming from this posture is the guarantee of access to the necessary equipment and consumables for research and maintaining a cohesive and motivated team.

Whether this activity is exclusively directed at seeking public resources or not, basically depends on the amount and frequency of them. Paradoxically, the financial crisis that hit Latin America in the 80s had unexpectedly positive effects on the scientific communities of these countries, in forcing them to diversify their sources of financing. As public resources became scarcer and uncertain, many research groups also started to consider the alternatives to access to external resources, including international bodies and foundations, organizations in society and companies in general. The reports made on each case study in this research,

takes into account the slow and tortuous routes by which the research groups analyzed, constructed and consolidated the access channels to these alternative sources of research financing.

The search for knowledge that is socially relevant and that represents an effective contribution to the country's development, is part of the scientific discourse in Latin America, as well as other developing countries (Schwartzman 1994). The application imperative is not in conflict with the ideals of pure science; and the practical orientation is reinforced by very successful and highly satisfactory personal experiences.

However, as shown by the typology we developed above, access to channels of external financing and the motivation to incorporate a dimension of usefulness into the research agenda, alone, are not sufficient to create positive synergies in the interaction of the research group with the external environment. A situation is possible in which good intentions become sterile because of the lack of effective channels of access to the external environment, and situations are also likely – and even frequent – where researchers, while allowing for the practical need to render services to external clients, "reality of the time", preserve their research agenda from contamination by the outside world. In the first case, the researcher is in a blocked situation; in the second the interaction with the external environment is tactical, only seeking to preserve the material conditions required to produce academic science. The cases analyzed by the research show that the tensions arising from this last alternative are very common in the Latin American academic area. The solution is frequently found by this tactical disassociation. It is possible that the evaluation mechanisms adopted by the universities and the bodies that encourage scientific research, favor this solution.

One of our objectives was to understand under what circumstances application and knowledge production come together, generate synergies and produce an original research agenda. The results of our analysis indicate that for this result there must be pressures and opportunities in the disciplinary field and also in the institutional environment. The existence of a strong institutional mandate in this direction, that cuts through topics built from these synergies, supported by evaluation mechanisms that recognize and value interaction with the external environment, counts in favor of this solution. On the other hand, it is also decisive for a group to reach a clear definition of the attributes of the problems and questions to be explored, and what type of interaction is sought in the external environment.

Finally, there is one last question: what is the potential for the successful experiences listed in this study to forecast the start of the transformation of Latin American universities? Unfortunately our answer cannot be encouraging: internally, these groups are dynamic, horizontal and exposed to strong positive pressures that recognize and reward productivity and entrepreneurship. However, most of these experiences tend to remain isolated and, therefore, their internal dynamism does not spread very far to their institutions. Nevertheless, some cases go against the tide of this general conclusion: they are extremely productive groups and have strong projection in society, and, in general grow, within smaller institutions. There they occupy a unique position, and their spillover effect is much more visible.

NOTES

[1] Translated from the original in Portuguese

[2] The following discussion takes as its reference the elite institutions of the higher education systems in the countries studied – mostly universities – where research has a recognized, institutionalized and valued space. Higher education institutions in the region have always been highly differentiated and segmented. In all countries, , , alongside these prestigious institutions, it is possible to identify others, aimed almost exclusively at teaching graduation courses, where academic careers practically do not exist, and where tlecturers are hired exclusively as instructors. However, this aspect is outside the scope of the analysis in this section.

[3] In Brazil, public universities used to grant the degree of “”livre-docente”, a direct translation of the German *Privatdozent*, who was given though a public examination which was, in practice, an alternative route to entering the university career without a doctors degree. Today, most public universities have abolished this degree, and in the University of São Paulo, where it remains, it requires now a doctoral degree as a prerequisite.

[4] The discussion about the limits of the linear model and the proposed typologies which distinguish the concern about knowledge applicability and its contribution to fundamental understanding, is already a theme covered by other authors, in earlier works to the two in this article. In Brazil, a pioneering contribution to this debate can be found in Schwartzman 1991a.

[5] The EULA-CHILE experience is a complex institutional arrangement: although the university pays a full time salary to the researcher, each quarter the center repays half of these transfers with resources that the center’s researchers and professionals generate with their activities. In the case of the Center for Legal Investigations, the university limits itself to paying the equivalent of a part time salary. It is the professor’s responsibility to top up this salary by teaching classes (inside and outside the university) or rendering services of a distinct nature.

[6] The academic career in the Graduate School of Economics, EPGE, leading to tenure, requires that new professors have to publish at least three papers in international journals recognized for their academic merit. If this publication target is not complied with, the professor is generally transferred to the Brazilian Institute of Economy, IBRE, to do applied work.

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