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The Relationship between Industry and Universities

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ABSTRACT
In this paper, the current relationship between industry and academia is presented by reviewing the historical development of research and development labs in order to classify the linkages and strengths that emerged between universities and industry.

Keywords: University, Networks, Cooperation

La relación entre industria y universidades

RESUMEN
En este trabajo, se estudia la relación actual entre la industria y la academia mediante la revisión de la evolución histórica de los laboratorios de investigación y desarrollo con el fin de clasificar los vínculos y las fortalezas surgidos entre las universidades y la industria.

Palabras clave: Universidad, Redes, Cooperación

1. INTRODUCTION

At the end of the nineteenth century and the beginning of the twentieth, some of the greatest technological advances came in the history of mankind. These developments were made possible, among other things, the eventual birth of companies which developed their own research and development laboratories. In this paper, we are interested in exploring the way in which this development unfolded, in order to classify the linkages and strengths that emerged between universities and industry. In other words; the object of this paper is to review the birth of connections between applied science and the reproductive apparatus that uses the technologies derived from it.

Consequently, we will present the current relationship between industry and academia by reviewing the historical development of research and development labs. We will present the formal links between both areas as they were made manifest through cooperation programs between the United Sates and Canada.

The current paper invites us to consider and to study in depth about the consequences derived by it, as far as the results obtained by universities and industries by carrying out the U-ICP (University-Industry Cooperative Programs.) At the same time, this work could be taken as a reference model for emerging countries, which have been carrying out efforts to have a greater bond among universities-industries; such is the case of Latin American Countries such as Argentina, Brazil, Chile, and Mexico. Each country has its own style to carry out its scientific and technological development, however, given the characteristics in Mexico, the proximity with US and Canada, the NAFTA agreement and their close commercial relation with both countries, it may seem very recommendable to adopt a learning model as of how the U-ICP have been developed in order to create their own model.

Since the XVIII century, the principal support for universities was directed towards agriculture, which later constituted a strategic tool, especially in key periods such as the Civil War, WWI, the 1929 recession, and WWII. During the XIX century and until mid XX century, agriculture was a key sector in American economy. The creation of research and development labs in the industrial sector was a consequence of the growing productivity of the agricultural field in combination with the up-scaled urbanization process of the late nineteenth century, both of which implied an accelerated and gradual reconstruction of the food production system. Even after 1950s, agriculture continued to occupy a privileged position in the American political scheme. As a result, agriculture became a specialized sector, supported partly by the activity of universities. (Mowery and Rosenberg 1989). We will argue that this was one of the important factors that explain the reason for which there were few cooperation programs arising between universities and industry during the first half of the twentieth century. These programs emerged as the result of a development process carried out during the two World Wars with the mechanization of agriculture and the development of the agro-industrial sector (Colman 1962).

In the first section of this paper we will present the evidence that moved us to support the above hypothesis. In the second section we present a brief history of the birth and development of the relationship in which industries began to generate their R&D relationship with academia.

In the third section we will describe the nature of both institutional frameworks - industry and universities -, with a view to exhibiting their limitations and the challenges that they have faced in their attempt to develop cooperation programs[1].

[1] This paper is limited to cooperation programs which imply technological research and development, since they are the most frequent cooperative efforts among these two institutions; I will therefore analyze only industries and no other type of company.

2. HISTORICAL BACKGROUND

The beginning of the industrial revolution in England and Germany provided important sources of influence for American industrial development, especially regarding the British textile sector, which “introduced the factory system into the United States early in the nineteenth century” (Sanford 1958). This situation marked the beginning of a critical stage in the industrial development of the United States. However, it took the US almost another 50 years to introduce applied science into advanced industrial technologies, which were considered relatively new during the early decades of the nineteenth century (Mansfield 1968). In effect, since the eighteenth century the principal forms of support for productive activities that emerged from universities was directed towards agriculture, which later constituted a strategic tool, especially in key periods such as the Civil War, the First World War, the Depression era, and World War II. Even after the 1950s, agriculture continued to occupy a privileged position in the American political landscape (Mowery and Rosenberg 1989)[2].

As of 1850 the agricultural sector suffered an important transformation, due to the application of new technologies which gave way to agro-industry. Instead of adding more manpower, farmers turned to using mass-produced farm machinery, new types of fertilizer, and new strains of crops and cattle. This allowed them to widely increase the production levels of their fields (Chandler 1977; Rostow 1960).

In addition to observing a fundamental transformation in American manufacturing (Mowery 1983b), the late nineteenth and early twentieth centuries saw a number of major manufacturing firms emerge through the efforts of individual inventor-entrepreneurs such as Hall, Eastman, Bell, and Westinghouse (Schmookler 1957). Hence, according to Financial World, “this period came to be referred to as the century of the American Genesis, given that investors, industrial scientists, engineers and systems designers were said to have become the makers of modern America” (Financial World 1991). This process exerted a strong pressure over universities to update and improve their laboratories and to increase their efforts towards R&D. However, to date the relation between industry and academia has experienced limitations related to the hiring of technicians and scientists to cover the internal needs. “Neither the Universities which have played important roles in the education of scientist and technologists” (Steacie 1957) to the industries nor “industrial firms, have reached satisfactory levels of communication for obtaining the best results in hiring highly educated and skilled human resources” (NSF 1994).

Some authors claim that since the early 1900s there has been a U-ICP (University-Industry Cooperative Programs), however there is very little research to sustain this assertion due to the lack of attention of researchers towards U-ICP in those years. As of the 1920s some universities were gradually branching into industrial research (e.g.

[2] For instance “in 1999, [agriculture] was the second major area of application of the biological sciences after medicine” (Appel 2000).

Kansas, Carnegie-Mellon and Ohio, for which see Mowery 1983a, Robbins 2006; Graner 1972)[3].

Throughout the final years of the nineteenth century, the most frequent link between universities and industry took place whenever universities took on the roll of suppliers of scientists and technicians, but there were no cooperation agreements for R&D (Fusfeld 1994). Eventually, plant-level laboratories established within many factories at the beginning were supplemented by laboratories devoted to longer-term research endeavors (Mowery 1990; Rosenberg 1985). Research activities were gradually directed towards the application of science to advanced industrial technology. As a result of this process there were significant changes in employment, such as the massive hiring of research scientists, engineers and technicians (Mowery 1983b; Rosenberg 1985). Some relevant examples were the laboratories established by Edison (1876), Kodak (1883), Goodrich (1895), General Electric (1900), and DuPont (1902) (Mansfield 1968; Hounshell and Smith 1988).

World War I demonstrated that U.S. technology was far behind Europe in many fields, which gave place to the rapid development of chemical and textile industries (Graner 1972). This process took place at such an accelerated rate that universities started resenting the important reduction of professors in key areas of investigation. The Dye Industry Research (DIR) members, which were senior technical directors of large corporations with research laboratories, discussed the matter and agreed to stop this practice (Fusfeld 1994).

From 1910 to the 1930's the increasing use of electrical power kept growing steadily, aside massive construction projects, even though industrial processes advanced faster in the areas such as chemistry and textiles, food products, boots and shoes, iron and steel, agricultural implements, electrical machinery and supplies, and paper and printing. In turn, the aviation industry grew through the foundation of mainstream commercial airlines, with companies such as Boeing and Douglas (Jennings 1926; Graner 1972)[4].

Industrial development was able to change the situation for USA and Canada, propelling them from being incipient industries to major technological innovators (Galambos and Pratt 1988). The pursuit of research was recognized as an important professional activity (Mowery 1990), which eased investments in R&D for the big corporations "as a mean for keeping them innovative over the long term" (Galambos and Pratt 1988).

The structure of the American research system as well as the engagement of many universities in R&D emerged with a greater strength during and after World War II.

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[3] "In Canada, links between universities and industries go back to the 19th century, but never have they been taken as seriously by both universities an industries as they were since the 1970s" (SCC 1988).

[4] "Although universities never received federal financial support, the first engineering experiment stations were established early in the twentieth century, at the University of Illinois in State College in 1904. By 1910, there were five engineering experiment stations, in 1925 twenty-six and by 1938 thirty-eight" (Mowery and Rosenberg 1989).

From 1940 to 1969, research laboratories expanded their status rapidly, but not at the rate the investors expected, partly because scientists were unwilling to undertake the tasks of development and commercialization. This phenomenon went on until the early 1990's (Galambos and Pratt 1988; Financial World 1991).

By 1950, the National Science Foundation (NSF), which since its creation has been the principal agency of the Federal Government, envisioned becoming the principal source of support for all basic scientific research in institutions of higher education (Fusfeld 1986; Geiger 2004). From 1940 to 1969, U-ICP began in a slow, isolated manner and without any long-term agreements. Industries were very cautious before undertaking any joint activities with universities, since they preferred to have their own research and development as well as their own researchers and technicians in accordance to their needs.

As of WWII and immediately afterward there is more evidence for the growth of U-ICP. A social transformation was caused within university faculties, adding higher value to their research output (Rosovsky and Ameer 1988). At the beginning of the 1970s better results were gradually obtained, with the support of previously created organisms in order to support the U-ICP in the US as well as in Canada (B-HEF 2001; Doutriaux and Barker 1995)[5]. However, there continued to be disagreements, problems and constraints, with universities defending basic research and industries attempting to carry out applied research in order to obtain innovations which would allow them to subsist in a long term throughout the income of utilities. These and other constraints provoked a halt to the emergence of better agreements and programs (Wright 1989).

During the decades of 1970s and 1980s the government and the universities backed the newly created organisms to support U-ICP in order to streamline their working procedures. National and international meetings were held on behalf of the government and even the United Nations, inviting high ranked members of universities, general managers and R&D experts from industry in order to achieve agreements on stronger bases that were created, studied and analyzed by these experts (cf. UN 1974).

By the late 1970s and the beginning of the 1980s, American industry was under tremendous pressure. Competition from overseas was undercutting many of the country's largest most important business. R&D expenditures were low and continuing to decline, pivotal years had entirely evaporated (Galambos 1987). During the 1990s and the beginning of the XXI century international competition had increased, the productivity and some R&D indexes in developed countries being superior to the ones in the USA.

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[5] Public support for science led to greatly expanded funding for science agencies in the U.S. federal government and began to provide significant funds for university research and continue investing in university research (Atkinson 2002; Appel 2000).

Little by little R&D had started to be shared among universities, industries and governments, outstanding in countries belonging to the European Union and at an industrial level by the number of strategic alliances and merger and acquisitions that had been carried out at a national and international level during the 1990's and the beginning of the first decade of the year 2000.

At present, globalised frameworks for agreement between academia and industry have begun to offer new forms of collaboration and broad-ranging results[6]; thus, for instance, "the role of local university laboratories and/or technology centers is important as they are more sensitive in identifying the needs and interests of local industrialist and farmers" (APO 2001). In sum, U-ICP frameworks have generally proven to be increasingly beneficial for both parties, and society as a whole.

3. RESEARCH & DEVELOPMENT IN UNIVERSITIES

In this section we will try to define the two existent forms of research, according to how R&D has turned towards companies and their evolution.

"Research is a systematic investigation of some phenomenon or series of phenomena by the experimental method to discover new facts or information or to coordinate these facts as laws" (Wehmeier 2000).

Within the context of this paper, research may be classified into two main spheres: academic or basic research, and applied or technical research. In the following section I will explore these two forms of research, within the purview of how R&D has transformed companies and their evolution. Research may be classified in two main dimensions: the basic research; and the applied research.

Basic research seeks essentially an extension of knowledge (Clover). Basic research may be defined as the human activity directed toward the advancement of knowledge, and thus may have no known immediate application, it normally requires underwriting by foundations or universities or government. Applied research is problem oriented where the results are predictable and relate only to solve a specific problem (Clover and Balsley 1974, Nelson 1959.)

Basic research for universities is the type of research directed towards increasing knowledge in science (Sanow 1959). Applied research is directed to the discovery of new scientific knowledge that has specific commercial objectives to solve production problems and invent new processes or products (Sanow 1959; Masfield 1968). Consequently, "basic research is fundamental; applied research is consequential" (Holland 1973).

[6] "Since the decade of the 1970s universities and industries in United States and Canada have worked together to advance the frontiers of knowledge and incorporate that knowledge into new products, processes, and services" (B-HEF 2001).

Since their beginnings, universities have been dedicated to developing basic research, "and will continue to do so because it is one of the pillars of knowledge their existence is based upon" (Holland 1973). However, industries have developed applied research for commercial reasons and in order to "move faster to face competitor's innovation" (Cohen and Levinthal 1989), by trying to find new products and processes or improve existing ones (Wehmeier 2000). Hence, if there were no long-term basic research, applied research would be very limited and product development would suffer (Zieminski and Warda 1999).

With respect to the costs of such an operation, it is important to note that R&D expenditures by industry and government in the United States and Canada have played a larger role in determining the pace and configuration of productivity growth. Thus, in the early 1920s, R&D in the USA constituted far less than 1 percent of GNP; in the 1960s it represented around 2 percent, (Gray and Peterson 1974), and for the year 2000 it constituted roughly 3 percent of GNP (OECD 2006). By contrast, in Canada, from 2000 to 2005, R&D has had a mean annual rate of 9.4 percent (2.0 per cent of Canadian GDP), which places it in second place among OECD countries, just below that of Sweden.

In most industrialized countries there is a wide spectrum of R&D activities, which spans the field from basic research to development of problem-solving processes. The research end is characterized by long-term exploration of scientific possibilities with high risk in the market place, while the development end tends to be driven by low risk, short-term satisfaction of urgent needs. In between those two extremes, there are other R&D priorities that ensure the continuity required for an effective industrial R&D system in a highly competitive market.

Due to historical, political and/or organizational reasons, middle-level research is performed by various actors in different countries. Where universities work under liberal regulations, as in the United States, academic research can be extended to cover middle-level research on an industry-sponsored basis. Some national governments were provident and created early middle-level research institutes to serve their industries, as in Canada and Mexico. In the latter country the research institutes are concentrated in the National University of Mexico (UNAM), which concentrates the largest proportion of research in Mexico, and is largely supported by the National Council of Science and Technology.

4. UNIVERSITY-INDUSTRY COOPERATIVE PROGRAMS

As has been mentioned throughout this paper, one of the most effective forms of university-industry collaboration, in terms of its beneficial impact on local communities, have been the so-called University-Industry Cooperative Programs, U-ICP. U-ICP are not an end in themselves; rather, they are means by which different institutions and communities can try to achieve applied advances in science which favor the objectives of both academia and industry in a way that obtains a higher standard of living for broad sectors of society (IRI 1995)[7].

In 1974, the UN pointed out that the U-ICP were necessary for improving the needs of the domestic economy and the skills produced in universities (UN 1974). However, as the above sections reveal, throughout the twentieth century there have been various barriers and constraints in the development of partnerships between academic and private industry. On the whole, many of the obstacles that emerged through the years were due to the way in which the cultures and missions of both universities and industries differed. “Industries underlying goals are to make a profit and build value for shareholders by serving customers” (NAS 1999), with short-term horizons in mind (Abelson 1982). In turn, universities look to develop, create, and transmit knowledge and culture, to prepare talented young people to assume productive roles in their societies in order to foster the creation of “human capital” for the purposes of conducting long-term research at the frontiers of science (Abelson 1982; Blau 1973; Bowen et al. 2005; Florida 1999; Fowler 1984; Lynton1984; NAS 1999).

The university’s greatest concern is the need to protect its right to publish versus industry’s to protect proprietary information. Likewise, industries own in-house research capabilities, which they tend to use unless the university can demonstrate a clear-cut cost advantage or a unique capability for the particular research. Another factor which is regarded by both groups is the mismatch between universities’ orientation toward basic research and industry’s near term needs for new or improved products. Another factor closely related to the latter, is the industry’s perception that the university often does not understand what industry needs in the way of product-oriented research nor the need by industry to maximize profits as a primary objective” (Fowler 1984).

One of the needs universities feel they must consider is their more aggressive policies toward technology transfer and particularly regarding the ownership of intellectual property, preserving their more valuable principles, that is, to generate knowledge and produce top talent” (Florida 1999; Geiger 2004), and preserving their academic freedom even when collaborating with industry (SCC 1988; Lynton 1984).

As Bok (1982) has pointed out, “technology transfer is disturbing not only because it could alter the practice of science in the university but also because it threatens the central values and ideals of academic research”. Besides, “Ties between science and industry create all sorts of risks for compromising the objectivity and independence of academic research” (Bok 2003). Some authors have stated that the

[7] The United Nations uses the term industry-university linkage (UN 1974), but many of the authors that analyze these linkages name them: University-Industry Cooperative Programs U-ICP, which is the name it has received in this paper, and it refers to interaction between all parts to a higher educational system and the industrializing economy.

difference between these two entities resides in their different approaches, whereby they sometimes appeared to be incompatible and to an extent inadequate for each other (Geisler and Rubenstein 1989)[8].

From a pragmatic and entrepreneurial point of view, "the reason why universities and industries have to look at each other is economic, due to the mathematical equality; research and investment" (Scowcroft 1988). Robert M. Solow (1997), Nobel Prize award, maintains that technology has been chiefly responsible for expanding the economy over the long term, increasing capital and labor, and it is in this regard that universities have played an important role. The annex 1 shows the benefits which would be obtained by the industry by carrying out a U-ICP, with science and technology standing out, the supply of qualified manpower from students and professors and the access to research and data collection of the University. Annex 2 shows the benefits for the Universities, one of the most relevant benefits is the learning of students over practical experience, as well as professors and researchers who are exposed to real industrial problems and needs. Finally in the annex 3 we mention the benefits the society would receive when U-ICP are carried out, proving that there would be a more effective educational contribution to economic development and as consequence a better utilization of human and physical resources.

The table 1 shows a summary of the most relevant events that have characterized the history of U-ICP initiatives, as indicated in this table, the U-ICP had acceptance and recognition on behalf of both universities and industries.

As the table shows, at the beginning of the 1970s there was an evolutionary process in which the most common type of programs consisted of special research agreements and grants, cooperative research centers, seminars, and publications, consulting relationships, technology extension services, faculty consultation, equipment, library and computer services, small-company counseling and support, and joint ventures (B-HEF 2001; Carboni 1992). That marked what could be considered as the beginning of a more formal and systematized stage in the U-ICP, even though for some years there were still barriers and constraints.

From 1980 to 2004, the U-ICP in United States and Canada have multiplied, with national and international industries (Ijiri 2004), during this period "universities occupied the central position in the performance of basic research within the economy" (Mowery and Rosenberg 1989), and major companies such as DuPont, RCA, General Electric, and Bell Telephone have reduced their commitment to basic research (Ijiri 2004).

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[8] In the past, there have been various initiatives to try to overcome these differences and obstacles. For example, in 1988 the American Council of Education set itself the task of trying to obtain better results in their attempt at defeating the most common constraints and/ or barriers that showed up when carrying out U-ICP agreements (B-HEF 1988).

Table 1 Events that have characterized the history of U-ICP initiatives

University Industry Cooperative Programs (U-ICP)	1970s	1980s	End of 80s	1980-2004
U-ICP are created for strengthening the science and technology base and improving economic competitiveness (B-HEF 1988)				
More systematized form of U-ICPs was introduced searching mainly that they could produce the proposed benefits	**			
U-ICPs flourished and started to produce their intended benefits (B-HEF 1988).		**		
Some barriers arise and constraints as a consequence of the difference in mission, objectives and culture of universities and industries (NAS 1999)			**	
The American Council of Education celebrated the Business Higher Economic Forum where it proposed a series of recommendations for both parties in order to obtain better results in research and technology exchange programs (B-HEF 1988).			**	
Despite the existence of a wide range of information over national and international conferences about U-ICP, there was not sufficient information to evaluate the results of the programs (B-HEF 1988)				**
U.S.A. and Canada programs and agreements multiplied between(among) universities and industries				**

5. UNIVERSITIES IN CANADA

During the 1960s, a series of factors arose that favoured the growth of universities in Canada, in quality as well as quantity: a) the government offered tax incentives to the industry in order for it to invest in R&D projects with the universities (Zinn 1987); b) as a result of post-war baby boomers, there was a major demand to register in the universities: c) pressures towards universities for expansion into many new fields and: d) an important financial increase to the universities on behalf of the government (Naimark 1989). Consequently there has been a broad range of U-ICP in research and technology exchange (SCC 1988).

During the 1970s, the boom became to an end and federal and provincial governments destined their funds to other social and economical programs consequently reducing education-related funding programs (Naimark 1989). Despite this situation, the support to Canadian universities did not stop; provincial governments continued developing programs to promote the university-industry relationship in science and technology (Doutriaux and Baker 1995).

"As their American counterparts had done in the 1970s, Canadian universities began in the 1980s to take more interest in patenting and licensing inventions, fostering "spin-off" companies, undertaking contractual research for industry, and exploring other ways of enhancing communication and collaboration with industrial researchers" (RSC 1991).

In the 1980s, the university-industry agreements were more important (SCC 1998), involving a few large firms in important projects (Anderson 1987). It is important to point out that during the 1990s federal and provincial agencies were introduced to meet the needs of high-technology for small and medium enterprises (Doutriaux and Barker 1995), marking a reference that the support would not only be for major industries. At the end of the 1980's tax incentives suffered a large number of amendments and interpretations, so given the lack of clarity for the industries, it was difficult to make plans for R&D financing (Zinn1987).

It is very likely that due to the amendments in tax incentives, during the 1980s the economic and political context for the development of university research changed, focusing their efforts in improving the efficiency, productivity and competitiveness on international markets of its resource-based industries. "At the same time industrial corporations expressed their concern about the relatively low level of research and development activity in Canada and about the effects of general under funding on the ability of universities to undertake the kinds of research and related training that are relevant to economic development" (Naimark 1989).

By the end of that decade, the federal government responded to numerous demands from industrial corporations, thereby creating The Prime Minister's National Advisory Board on Science and Technology (NABST), the Department of Industry, Science and Technology (DIST), and the National Conference on Technology and Innovation, and "announcing a new 1.3- billion fund for science and technology" (Naimark 1989).

Canada knew that it was confronting a highly competitive world economy, so it acknowledged that it was necessary that universities should help industry to develop R&D programs for improving economic performance (SCC 1988). "Consequently, universities were being called to play a greater role by improving their collaboration with industry through both R&D and education" (D'Cruz and Fleck 1986). Since then, they have continued "to encourage the commercial exploitation of discoveries made by them" (Abu-Laban 1988). In turn, provincial governments took care to support the large, medium and small industry.

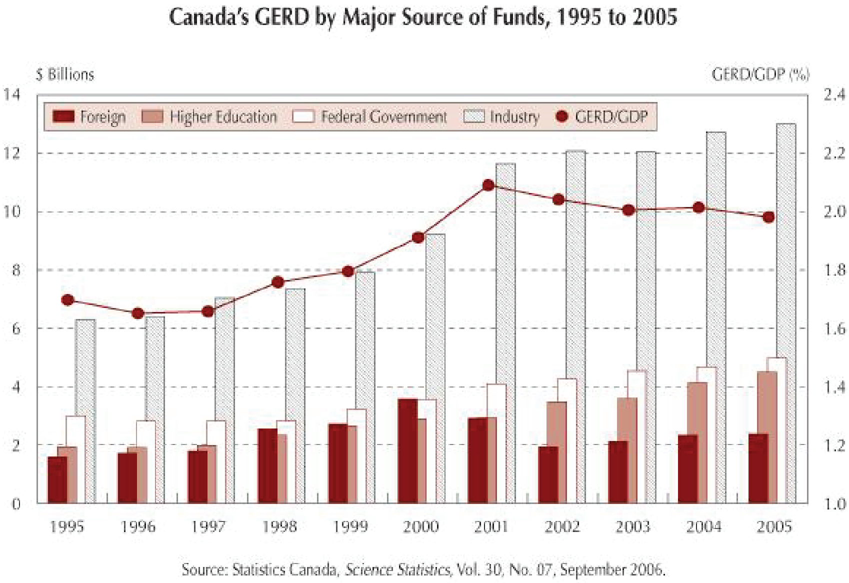
By 1989 the federal government, in an attempt to reinforce university-industry collaboration, created a national network of centers of excellence, which were supported by university, industry, and government researchers on a national scale (RSC 1991). However, important difficulties arose that would have long term effects: at the beginning of the 1990s it was detected that in the following years there would be a strong demand for PhD graduates and the universities might experience difficulty in the recruitment of new faculty, particularly in fields for which there is also a strong demand in industry. The impact of these pressures and shortages on the quality of research and both graduate and undergraduate instruction in Canadian universities is likely to be felt well into the twenty-first century" (RSC 1991).

As regards their linkages with industry, Canadian universities began to promote important technological innovations, which translated as concrete benefits to society at large. By 1991, the University Research Committee of The Royal Society of Canada presented recommendations that would ensure universities could maintain a strong basic research capability, serving multidisciplinary research in all fields, and encouraging the collaboration of researchers in team groups at high level of excellence (RSC 1991).

By 1997, the total R&D investment in Canada reached 13.5 billion (Canadian dollars), the gross domestic expenditure on R&D has been growing at an average annual rate of 5 percent since 1963. The countries which devote the largest share of their output to R&D are Japan and the United States, with 2.8 and 2.62 (as a percentage of GDP). The most striking change is observed in the shares of industry and government: the academic sector has remained strong and relatively constant, the government has increased at a much slower rate than the industry and universities (Gu and Whewell 1999). On figure 1 you can observe the percentage on the GDP which is invested in R&D in Canada from 1995 to 2005, as well as the destination the funds are given, standing out that from 2002 to 2005 the increase for higher education is bigger than the rest, which shows the importance that has been given to the universities for R&D. In figures 2 and 3 you can observe the spending on research and development in millions of Canadian dollars. "In Canada, the private sector, universities and government laboratories are the three most important performers of R&D. As major research performers, universities have the potential to influence on the Canadian prosperity, which has provoked an increment on the industries interest and on policy makers" (Zieminski and Warda 1999) [9].

[9] In general terms Canadian universities are financed 66 percent by federal and provincial government transfers and 34 percent through their own resources. Industry funds a small portion of research, but its role in sponsoring university research is increasing. Foreign sources are increasingly being used to conduct R&D at Canadian universities" (Gu and Whewell 1999).

Figure 1.



6. UNIVERSITIES IN THE US

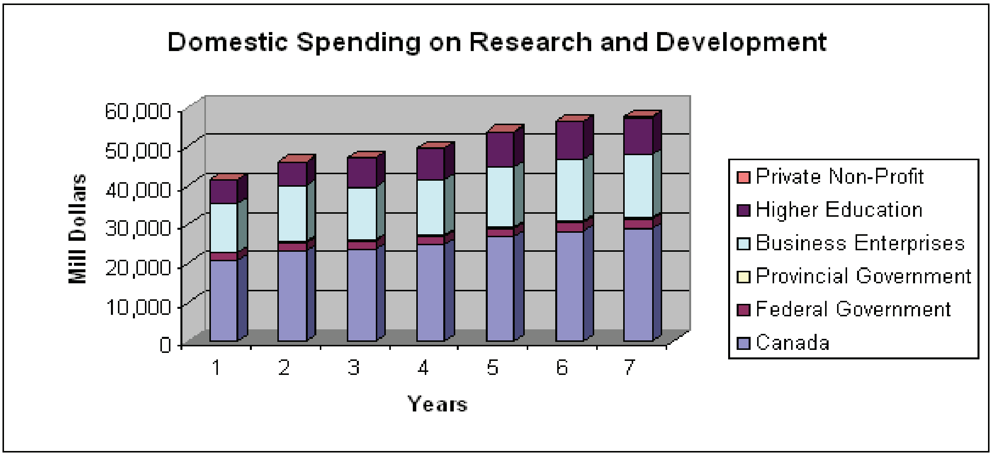
Prior to World War II, most of the best university research was performed in European universities, and much of the best fundamental research was performed in corporate research laboratories. The process which R&D went through in the American universities started to come forth as American industries demonstrated their growing needs. On the other hand Occidental Europe, especially Germany, showed an efficient development in this field, which placed much more pressure for American universities to exploit their potential.

Figure 2 Domestic spending on research and development (GERD), performing sector, by province. Canada. (Millions of Canadian dollars)

Year	2000	2001	2002	2003	2004	2005	2006
Canada	20,600	23,200	23,531	24,719	26,833	28,142	28,715
Federal Government	2,000	2,100	2,190	2,083	2,084	2414	2496
Provincial Government	260	300	282	278	290	303	333
Business Enterprises	12,400	14,300	13,540	14,123	15,299	15791	16137
Higher Education	6,000	6,000	7,455	8,143	9,058	9518	9624
Private Non-Profit	57	60	63	92	103	117	125
Total	41,317	45,960	47,061	49,438	53,667	56,285	57,430

Source: Statistics Canada. Canada's National Statistical Agency. (March, 2007).

Figure 3 Domestic spending on research and development (GERD), performing sector, by province. Canada.



Source: Statistics Canada. Canada's National Statistical Agency. (March, 2007)

During the World War II, the American federal government began to provide significant funds for university research (Dill 1990); University-industry collaborations have occurred successfully in the US in big extent because of the existence of an excellent relationship between government and higher education, mainly since World War II" (Dill 1990). When the war was over the government continued investing important resources in university research (Atkinson 2002), and this has continued systematically, obtaining significant results in the American scientific and technological development. By the 1960s, R&D in the United States had achieved world - wide leadership status. International competition started to grow as of 1960, becoming a threat for the USA. Hence, the competitive pressures brought to bear on industry and the financial pressure on universities, made these two dissimilar cultures produce closer relationships (Fusfeld 1994)[10].

By the 1970s the effects of industrial research were evident to all segments of society and during 1980s the most significant changes in the university-industry relationship came up (Geiger 2004). Thus, "universities saw a source of technical progress, scientific stimulation, and funds. The general public observed the output of industrial research as an important source of economic growth. Industrial research was still unfamiliar and not well understood, but it had become a recognized and appreciated activity" (Fusfeld 1994). Figures 4 and 5 show the in detail the academic spending in R&D in the United States in which the basic research share grew from two-thirds to three-quarter in 10 years, what shows a growing interest for basic research.

Figure 4 Academic R & D Spending in the United States (Millions of US dollars)

Year	1992	1993	1994	1995	1996	1997	1999	1998	2000	2001	2002
Basic Research	$12,516	$13,303	$13,986	$14,808	$15,478	$16,598	$18,789	$20,350	$22,243	$24,273	$26,959
Applied R & D	6,302	6,648	7,041	7,362	7,567	7,771	7,065	7,178	7,820	8,494	9,374
Total	$18,818	$19,951	$21,027	$22,170	$23,045	$24,369	$25,854	$27,528	$30,063	$32,767	$36,333

Source: Chemical & Engineering News. Character of Academic R&D spending in the United States (November 15, Vol.82 No.46 pp.37-41)

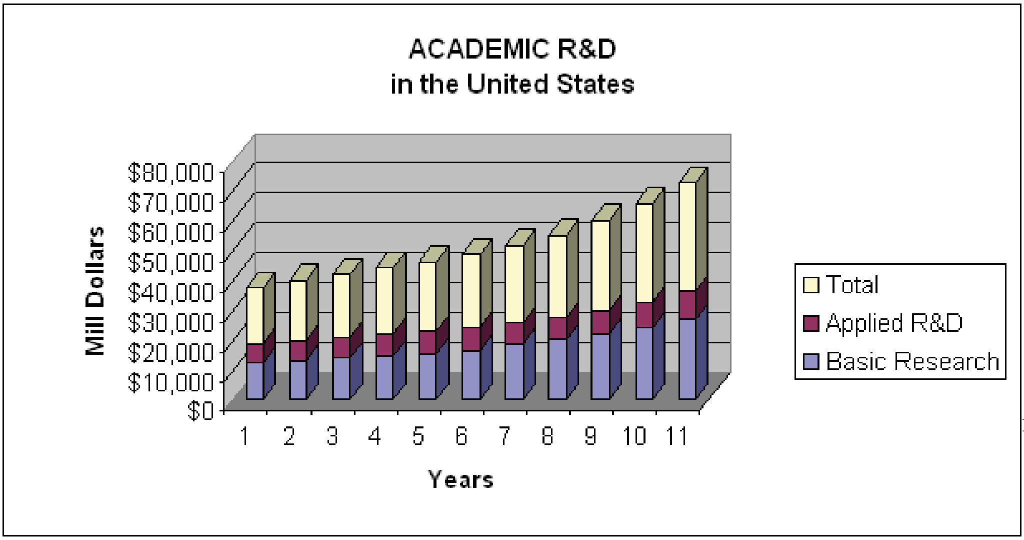
Moreover, "industry's investment in research experienced a great increase, almost all of the additional research funds went to universities; these increases suggested important developments on both sides of this relationship, in the needs of industry as well as with the receptivity of universities" (Peters and Fusfeld 1982)[11].

[10] "In the early 1970s the United States was still the leader in the manufacture and sale of high technology, and for this reason it showed strong interest to retake the World leadership in R&D" (Carboni 1992).

[11] The top 200 universities which conduct 96 percent of university research, and particularly the top which conduct 58 percent, possess well-equipped research facilities and conduct major programs that involve faculty from different departments working through research centers. They form an important part of the national research enterprise" (Fusfeld and Haklisch 1984). In the United States, federal funds have successfully supported the university-industry collaboration, while overall support of university R&D by industry is just over seven percent; industrial support of these research centers alone is in approximately 31 per cent (Doutriaux and Barker 1995) (see appendix 4).

In figures 6 and 7 we show the expenses made on research and development in the United States, in which you may appreciate that the largest expenditure is done by industries, whose investments are dedicated to applied research.

Figure 5 Character of Academic R&D spending in the United States from 1992 to 2002



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7. CONCLUSIONS

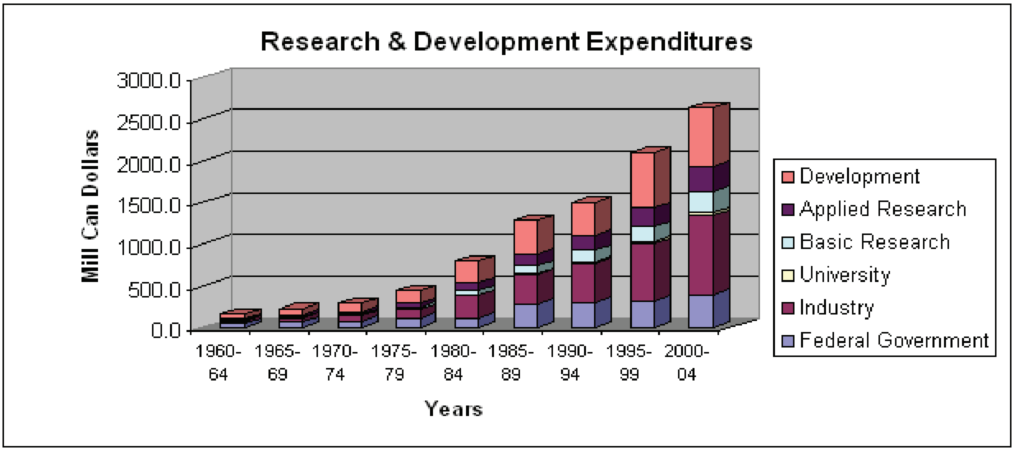
As this broad overview demonstrates, American and Canadian investment in R&D as a whole, tended to improve and strengthen their ties to universities. Hence, the growth of leading companies in the world market can be substantially explained as a consequence of technological and scientific developments accomplished jointly by academic centers and industry partners. In turn, applied science has been frequently produced by the engineering departments of many American corporations, Bell laboratories and other think tanks are good examples of the corporate interest into establishing long term partnerships with academic entities.

Figure 6 Research and Development Expenditures in the United States by source and objectives; 1960-2004 (Millions of Canadian Dollars)

	Federal Government	Industry	University	Basic Research	Applied Research
1960-64	52.9	25.8	0.4	9.1	17.8
1965-69	72.2	41	1	15.7	24.5
1970-74	80.1	61.1	1.6	19.8	31.7
1975-79	112.5	101.7	3	31.1	49.5
1980-84	119	263	6.1	55	91.2
1985-89	286.5	350	11.3	92.2	142.4
1990-94	304.6	467.3	18	136	185.5
1995-99	324.4	684.3	25	173.4	229.2
2000-04	397	940	36.3	254.6	301

Source: National Science Foundation. Research and Development Expenditures. (2005)

Figure 7 Spending in Research and development in the United States



Source: National Science Foundation. Research and Development Expenditures (2005)

During the industrial and technological development and the incipient relation with universities in the first half of the twentieth century, some barriers and constraints discouraged the achievement of productive and stable agreements between universities and corporations. Consequently, the American Council of Education, as well as some other specialists, proposed a series of recommendations for both corporations and academic institutions in order to regulate and improve the results of partnerships.

In Canada, there were similar measures taken, among which some of the most relevant were tax incentives for joint R&D industry – university partnerships. In turn, the greater demand for graduate education in the post-war period favored the growth of universities, as well as scientific and technological progress. This helps to support the idea that universities played a fundamental role in the growth of the Canadian economy in terms of functioning as a strategic support base for industrial development, meeting particularly the needs of high-technology for small and medium enterprises.

The universities were very careful of not losing the origin of their existence which was to preserve their more valuable principles and at the same time to preserve their academic freedom even when collaborating with industry. The industry due to its own nature has needed universities, professionals who are dedicated to applied research with the objective of successfully and profitably surviving on the long run, in even more competitive markets.

The high international levels of competitiveness that arose, especially in the last decades of the XX century, provoked an important transition towards a rapid change industrial technology supported on basic research activities, in which universities played a relevant role.

Thus, by 2004 university-industry cooperative programs in the United States and Canada had helped to improve advanced technology at economic level and the standards of living in society. In the XXI century the industry depends on industrial research which was consolidated after many years of continuous effort, in which notable advances were carried out in many areas. The universities and the industry in the emerging countries could develop U-ICP when they acknowledge and accept their strengths and weaknesses are different, but at the same time can be complimentary and obtain benefits and values for both parties.

8. RECOMMENDATIONS

The challenge to maintain the U-ICP for the following years, in the United States as well as in Canada, will be to take into account that since 1990 there has been a technological development without precedents in most of the developed countries, as well as in some emerging countries such as China, India, Argentina, Brazil, Chile and Korea, which are performing a transcendental role in the scientific and technological development.

In the case of Mexico, one factor which can accelerate the development of the U-ICP is the increase in patents and licenses at the universities, supported by CONACyT whom since its beginnings has promoted support programs for the UICP, even though until 2004 they were not relevant programs, they eventually continued to be presented. The Mexican government offers fiscal incentives to the industries that carry out agreements with universities, granting 30% to R&D over the total investment. This incentive is granted throughout a fiscal credit, which means that companies may deduce their investment in R&D Turing the following fiscal period.

Both universities and industry should continue their scientific and technological programs with a future-based vision in order to confront the huge challenges of competition and world growth. The consolidation in university and industrial research will only be achieved respecting each others position and trying to solve the complexity area that scientists of the middle of the XXI Century will represent.

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ANNEXES

Annex 1

U-ICP Benefits for the Industry

- "A supply of better qualified graduates having more relevant training because the industry's needs have been identified. Obtain access to manpower (students and professors).
- Obtain a window on science and technology.
- Solve a problem or get specific information unavailable elsewhere.
- Obtain prestige or enhance the company's image.
- Access to a variety of post-experience training facilities it has helped to design, and also to access expertise not available in corporate laboratories.
- Access to the university's physical facilities and the expertise of its staff.
- Access to the research, consulting and data collection of the university.
- Provide general support of technical excellence.
- An improved public image in the society in which it operates, which means that more talented students will be attracted to the industrial sector" (APO 2001).

Annex 2

U-ICP Benefits for the Universities

Fulfill the Universities' service mission.
- "The opportunity to assess the needs of the economy and to develop its activities accordingly. Help diversify the university's funding base, providing new sources of funds not only from government" (APO 2001).
- "The opportunity to place students in industry so that classroom learning can be related to practical experience. Professors and researchers are exposed to real industrial problems and needs" (Gu and Whewell; UN 1974).
- "Provides better training for the increasing number of graduates going to industry".
- Assistance from industry in curriculum development to ensure that curricula shall be relevant to local conditions.
- Strengthening staff development by giving faculty members opportunities to gain practical experience, identifying new and relevant programs.
- Provides a chance to work on an intellectually challenging research program which may be of immediate importance to society.
- Access to industry for both fundamental and applied research" (UN 1974; IRI 1995).

Annex 3

Benefits for the Society

- “An improved return on investment in higher education.
- A more effective educational contribution to economic development.
- Better utilization of human and physical resources.
- Less social and political stress that accompany unemployment of university graduates” (UN 1974; Geisler and Rubenstein 1989;B-HEF 1988).