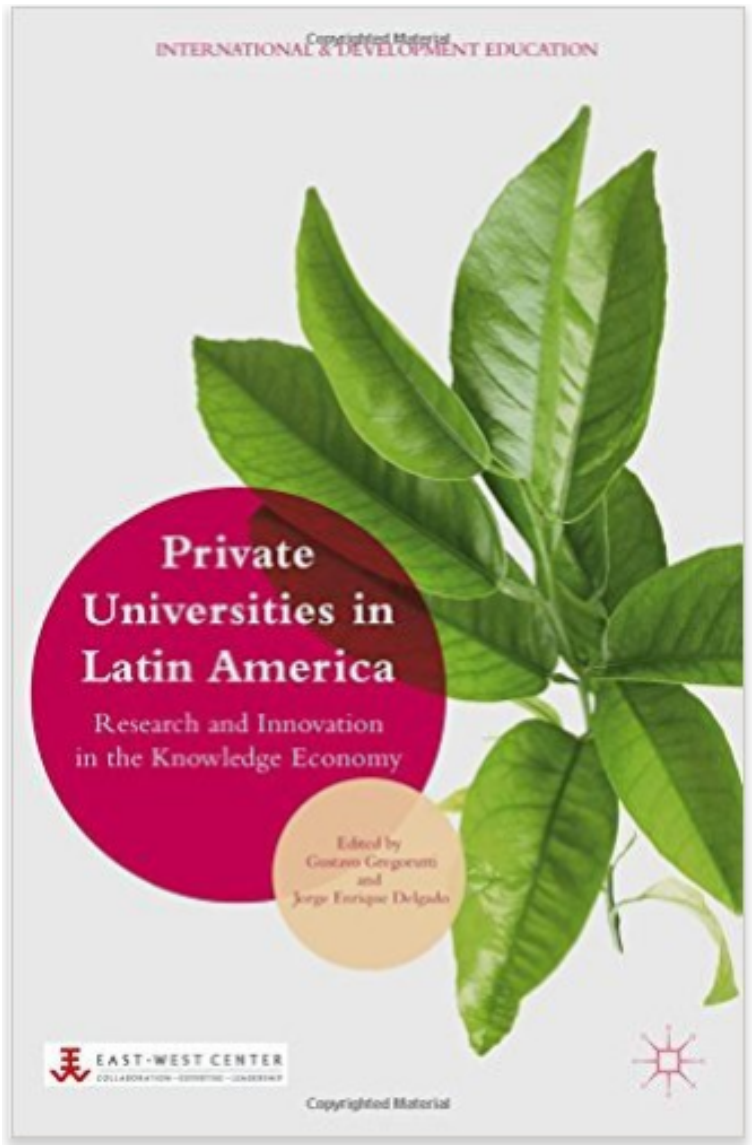

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A Research and Innovation Ecosystem Model for Private Universities: The Tecnológico de Monterrey Experience

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Introduction

European universities are centennial organizations with a well-established tradition for the generation and transmission of knowledge that goes back to, at least, the tenth century when the first universities appeared in Europe, evolving from medieval monasteries in cities like Bologna, Paris, Salamanca, and Oxford. Prior to the European-type university, even before the Christian era, other centers of studies existed in ancient Greece, China, India, Arabia, and Mesoamerica (Perkin 2006).

The word *university* comes from the Latin *universitas*, which means the gathering of masters (*magistorum*) and scholars (*scholarium*) to study, discuss, and advance knowledge in a given subject matter. The *studium generale* were monastic centers devoted to inquiry in the fields of theology, philosophy, medicine, and other disciplines known as *Trivium* (grammar, rhetoric, and dialectic) and *Cuadrivium* (arithmetic, geometry, astronomy, and music). Scholasticism, a dominant school of thought led by Thomas Aquinas (1225-1274) in the thirteenth century, emerged from those centers (Schmitt 1998). Likewise, under the influence of the philosophical movements of nominalism and voluntarism, developed by Duns Scotus (1266- 1308) and William of Ockham (1285-1349), the *stadium generale* focused on the tension between the "contingent and temporary" and the "permanent and eternal." These philosophical foundations were key for the emergence of experimental discoveries during the fifteenth and sixteenth centuries, along with the

empiricism of the British philosophers Francis Bacon (1561-1626), John Locke (1632-1704), and David Hume (1711-1776), with the contributions of scientists such as Nickolas Copernicus (1473-1543), Johan Kepler (1571-1630), Galileo Galilei (1564-1642), Rene Descartes (1596-1650), and Isaac Newton (1642-1727). These scientists and philosophers used a scientific hypothetical-deductive method of inquiry aimed at predicting and controlling nature. The industrial revolution of the eighteenth century was, to a great extent, a result of this paradigm-shift. In that context, universities adapted to the new circumstances by establishing colleges of natural science, technology and engineering, and building laboratories (Cantu Ortiz 2011, 51-57).

During the twentieth century, universities assumed a new role in society that added to the generation of fundamental theoretical knowledge for the advancement of sciences. They became engines of economic development by inserting themselves into what is called "Ecosystems of Innovation" (Etzkowitz 2001). The word ecosystem is taken from environmental and natural sciences to denote a set of individuals and groups interacting to preserve themselves using limited resources without altering their surrounding environment. An example would be a forest with trees that take rain to yield fruits that feed animals like squirrels, rabbits, or birds, which at the same time are food for predators such as wolves or eagles. In the same way, an "Innovation Ecosystem" is an analogy for natural resources that include persons, groups of people (a city, country or world region), and economic resources in constant interactions looking for balance. Thus, an innovation ecosystem is defined as "the people, institutions, policies and resources that promote the translation of new ideas into products, processes, and services" (National Science Foundation—NSF 2013). Within the context of an innovation ecosystem, the term "Triple Helix" was coined to establish a model of interaction between universities, industry, and government to foster innovation, regional development, and competitiveness in cities, countries, and even

regions (Etzkowitz and Leydesdorff 1997, 2000; Leydesdorff 2012). Universities have been forced to play an active role in this new setting by contributing with new models of knowledge and management to train professionals. Consequently, professors are constantly challenged to collaborate not just in the generation of knowledge and scientific models, but in their transference to economic and social sectors. In addition, they have to take care of intellectual property regulations through patents, brands, utility models, and other forms of copyright. This way, professors are becoming entrepreneurial researchers, a role that is actually reshaping academia (Etzkowitz 2001).

Another aspect of innovation ecosystems is their dependency on products and services designed for specific markets that result from the intersection of technological and scientific research. This way, "Technoscience" is a concept that expresses this new connection between science and technology. French philosopher Gaston Bachelard coined the term in 1953 and it was later used by Belgian philosopher Gilbert Hottois in the 1970s and popularized by various English and Spanish scholars in the 2000s and beyond. Technoscience is a type of innovation ecosystem and triple helix model. It fosters the interdisciplinary and collaborative work of industry, government, and academia to undertake multimillion dollar research and technology efforts toward national and strategic interest related to security, health, competitiveness, among others. Technoscience also refers to social contexts and historical consensus for scientific knowledge and how it has been generated throughout the last centuries (Sismondo 2010).

At this point, it is important to pinpoint some issues about the distinction usually made between public and private universities, which are relevant in governmental and academic sectors because of the role they play in modern society and from a funding standpoint (Hegde 2005). Since their creation, especially in continental Europe, major universities have been mainly

funded with public monies (from emperors, kings, governments, etc.). The United States (US) has the strongest private higher education system in the world, which can be attributed to a combination of smaller governmental structures and religious and philosophical ideologies that fueled capitalism and utilitarianism from the very beginning. Currently, both public and private universities compete for federal research funding on the basis of academic performance and scientific credentials (Levy 1986). This is not necessarily the case among Latin American higher education systems. The present chapter addresses the issue of developing research in private universities when federal funding is mainly allocated to public institutions.

Public and private universities are essential institutions for innovation ecosystems and the development of the triple helix model. In this context, the concept of world-class universities has developed to identify universities that are research-oriented, handle multi-billion dollar endowments, and attract the best students and professors from around the world. These institutions are engines of technological, economic, and social development that are reflected in world university rankings, such as the Shanghai Academic Ranking of World Universities (ARWU), the US News & World Report´s Best World Universities, the QS´s World University Rankings, and the TIMES Higher Education´s World University Rankings. Those rankings include both public and private universities. As rankings categorize institutions, they play an important role in universities' strategies to compete for the highest ranks (Samil 2009).

In order to explain the interconnection among the concepts of innovation ecosystems, triple helix, and world-class universities, the following sections introduce key elements of an original type of research and innovation ecosystem (RIE) geared toward private universities that consider both the context and situation of Latin American countries. The model is represented with the case study of a university that implemented an institutional strategy to develop research

capabilities in a teaching-oriented private university from Mexico, the *Instituto Tecnológico y de Estudios Superiores de Monterrey* (ITESM), also called Tecnológico de Monterrey (Monterrey Institute of Technology and Higher Education) (Cantu-Ortiz et al 2009, 155-156).

In the pages to come, this chapter is structured in four sections. Section one presents the key elements of a RIE for private universities. Section two introduces the ITESM case, where an institutional RIE has been in operation during the last decade. Section four discusses experiences and lessons learned from developing research strategies at ITESM. Finally, section five presents some conclusions from this analysis.

A Research and Innovation Ecosystem for Private Universities

In this chapter, the word "research" is placed before "innovation ecosystem" to emphasize the scientific and technological knowledge coming from university research teams, industrial research centers, and alliances among them. Thus, in this section, the RIE is described as part of a strategy to foster research, particularly in private universities. It describes the challenges that Latin American universities currently face and the central features of RIEs.

Private Universities in Latin America

During the last two decades, there have been concerns about the quality of private universities and governments have not implemented enough and adequate quality assurance systems to monitor these institutions. Private universities compete against each other mostly to attract students developing strategies that help them stand out as leading institutions (Byrne and O´Leary 2012). In pursuing these goals, private universities implement innovative initiatives such as student-centered learning, learning by doing, constructivist approaches, and learning technologies. Other efforts include on-line education, flexible class schedules, experience-oriented internships, opportunities to take courses abroad, and other internationalization strategies. Nonetheless, institutional advantages do not last long as competitors quickly imitate others' strategies.

Generating knowledge is not a priority among most private universities, as their focus is mainly teaching either through traditional or innovative programs. Many private universities are more concerned about developing competencies and skills to make students competent in different fields than developing their research capacity (Marmolejo 2009). However, private universities that are interested in the scientific enterprise struggle to make research programs sustainable due to the lack of a culture of science, institutional commitment, and/or government support (Sowter 2013; Levy 1986). The availability of funding and support for research is often limited, which is a challenge when considering that some types of projects are quite expensive and demand highly qualified human resources and sophisticated facilities. Several authors have analyzed some of the issues that universities experience to produce relevant research in Latin America (Altbach and Samil 2011; Enriquez 2008; Gregorutti 2011a; Marmolejo 2009). Some private universities have incorporated research as a distinctive characteristic of their institutional

models and seek to gain prestige by increasing faculty research productivity (Bustani, García, and Cantú 2006; Gregorutti 2010). There are private universities in Latin America that have been able to overcome the barriers and even to be included in major international academic rankings (Sowter 2013). In one of the contextual chapters of this book, Jorge Enrique Delgado (2014a) identifies universities included in the main academic rankings and suggests characteristics that make private universities competitive and successful.

The next section outlines the main features of a RIE that can serve as a framework for those private universities that aspire to be successful in producing and disseminating research.

Research Innovation Ecosystems

There are several terms used to denote innovation ecosystems, including knowledge cities, technology parks, and techno poles. These terms emphasize interactions in the context of the triple helix model. This section shows how a university took the steps to become a productive innovation ecosystem and passed from being a mainly teaching focused institution to become more research oriented. This case hopefully can serve as a model for other private universities in Latin America. Even though several elite universities in the region have embraced the challenge of becoming world-class universities through aggressive strategies and important investments, this is not an easy and simple goal to achieve. It requires the decided commitment of high-level administrators to developing and implementing successful strategies to produce relevant research that can impact and be transferred to the productive sector and the society in general (Salmi 2009).

For several the years, several colleagues from ITESM and I have designed and developed a model that we consider fundamental to create an innovation ecosystem in Mexico (Cantu et al. 2009). An innovation ecosystem that develops research can be represented through the following

characteristics: The *basics*, which include (1) full-time faculty, (2) professors with doctoral degrees, and (3) time dedicated to research; the *work force* that consists of (4) doctoral programs in selected fields with talented students, (5) postdoctoral positions, (6) research infrastructure, and (7) international collaboration (including student and faculty mobility); *knowledge generation,* which refers to (8) scientific publications and (9) innovation and entrepreneurship; and *management* that is determined by (10) research evaluation, (11) funding for research, and (12) research administration and support offices.

The Basics

Having full-time faculty with competitive salaries is a central starting point to develop research within a private institution. However, many productive institutions also rely upon the services of part-time professors who have full-time jobs in industries or specialized government agencies. Those professors are important to develop relationships with sectors other than the government and that can be sources of funding for research. On the other hand, in order to engage in research activities, professors should not use more than 50 percent of their workload to teaching and have no more than 10 students per course. Full-time professors should not be overloaded with teaching because they need time to conduct research in their fields, which can be varied out through research groups, publications in prestigious journals, and presenting their research in prestigious forums and conferences. In addition to having a majority of full-time professors, it is necessary that they hold doctoral degrees, hopefully obtained from a variety of local and international institutions. It is important to avoid inbreeding (Horta, Veloso, and Grediaga 2010). According to Jay Liebowitz (2004), it is highly desirable that at least 20-30 percent of the faculty

body consists of national and international professors who represent the increasingly globalized networks of researchers who have access to resources worldwide.

The Workforce

To develop research-oriented curricula, it is important to have a set of doctoral programs in several well-defined areas of study. Administrators and decision-makers need to identify specific areas of knowledge to focus on through strategic planning. Institutional resources should be committed only to those areas of research defined as a priority, since universities cannot excel in all the fields. Also, attracting talented students to graduate programs provides additional human resources and the workforce professors need to advance their projects. In order to have them more involvement in research, graduate students need to be granted some kind of internal or external financial aid (e.g., research grants, work-study modalities, scholarships from foundations or industries) because they help their professors. Budgets of private universities typically rely on tuition as the main source of revenue. However, usually doctoral students do not pay for their studies because graduate schools invest much more than what is collected through tuition. The factors mentioned above plus national and international accreditations, the capacity to attract the most talented students, and the support for research productivity contribute to build the prestige of an institution.

Another way to expand research in private universities is establishing postdoctoral programs to attract young researchers who have obtained their doctoral degrees within the last five years. Postdoctoral scholars work full time as part of research groups on specific projects. Ideally, these researchers do not have teaching responsibilities, although they may participate in theses/dissertation committees. Typically, postdocs are appointed for one or two years. Their

positions may be funded by science and technology governmental agencies, projects with the productive sector, or special funds within the university. Salaries should cover the researchers' living expenses. Postdocs should not be alumni from the same institution and it is desirable they obtained their doctoral degrees from foreign universities. It is expected that while these researchers publish their own journal articles, they can also collaborate with professors to improve manuscripts that contribute to advance disciplinary knowledge and career appointments.

Research infrastructure is necessary to develop research projects. Setting up laboratories requires an investment that has to be planned carefully. This is particularly important in experimental sciences that demand expensive equipment, such as reactors, particle accelerators, microscopies, and sequencers, as well as materials that may require special handling and storage, such as nanomaterials, biological reagents, and medicaments. Collaborative work is an effective way to increase and improve research in private institutions. Universities share facilities, degree-granting programs, and carry out complex studies with other national/international universities or research centers. Collaborations may include faculty and student exchange and participation in joint research projects and publications. In this context, mobility does not involve undergraduate students, but faculty and doctoral students who can visit partner institutions for one or more semesters. Several Latin American universities have been successful in increasing their faculty publications in high-impact journals by developing partnerships with well-established universities in other cities and countries. The Universidad de los Andes in Colombia is an example that has followed this approach.[1]

[1] Times Higher Education. 2013. Top 400 – The Times Higher Education World University Rankings 2013–2014. Retrieved: 3 October 2013.

Knowledge Generation

Peer-reviewed presentations in international conferences and publications in indexed journals are some of the outcomes of research. Publication in prestigious high-impact (based on citations) journals is greatly valued among academic communities. Indexes such as those included in the Thomson Reuters' Web of Science and Scopus of Elsevier are in general the main referents used worldwide to determine the value of a publication. The popular saying "publish or perish" is an imperative for professors, researchers, and students. However, what, where, and when to publish require a careful consideration because new discoveries are subject to intellectual property. In this regard, universities create intellectual property offices to monitor copyright of publications and patents, mainly when research outcomes are transferred to the productive sector and the society. Successful research-oriented universities must develop policies to promote high-level publication and monitor copyright (Delgado 2011, 2014b; Delgado and Weidman 2012).

A further step that private universities can take in the transfer of knowledge is the creation of spin-off companies by professors and students. This is an example of institutional ecosystems for innovation and entrepreneurship. Results of such systems include creating jobs, generating revenues for professors and students, and producing royalties for universities through licenses and patents.

Management

Assessing the quality of research outcomes is a key factor at any institution of higher education. In addition to publications and their scientific impact, there are other metrics that are used to assess research outcomes, for example, number of doctoral graduates, number of postdoctoral positions, awards and prizes received by faculty members, and external funding (in the form of

grants and contracts), patent licensing, royalties, and technical services and training (Cantu et al. 2009). Private universities should develop strategies to provide faculty members with information and even training on these indictors of productivity.

Research funding is required to develop research in private universities. As it has been pointed out, tuition fees are the main source of revenue in most private universities, which does not necessarily leave much room to invest on research facilities and fund projects. The question is how to diversify the sources of revenue to depend less on tuition income. Most successful universities generating several sources of funding have established endowments with alumni donations and extension programs and search for different types of grants and contacts, international foundations, and, in some cases, even lottery systems. Ideally, tuition fees should not represent more than 50 percent of the operating budget and the other 50 percent should come from alternative sources to strengthen and diversify university portfolios (Lombardi et al. 2011).

Finally, universities need to create specific units to support researchers. They are crucial to assist them when writing articles, grant proposals, or contracts, so researchers meet legal requirements and comply with university policies. These specialized offices can also help manage intellectual property, generate and monitor activities and the use of funding granted to research projects and programs.

Figure 1 summarizes the twelve features described above to develop research through an innovation ecosystem. These elements combined should help private universities creating a research culture, establishing the organizational arrangements, and providing the physical infrastructure necessary to consolidate the scientific work.

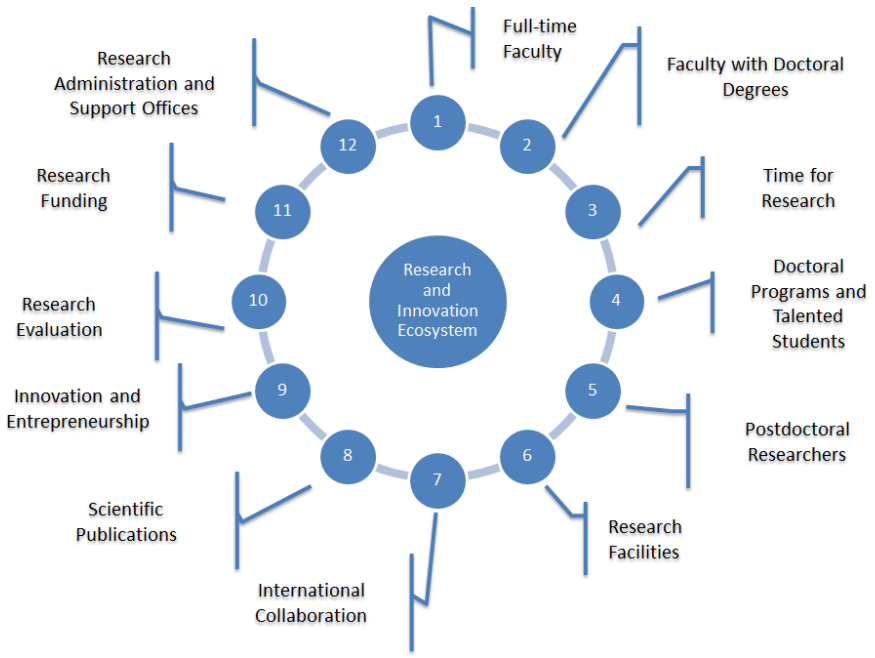

Figure 1. Components of a research and innovation ecosystem for private universities

The twelve categories of the RIE model can be applied to both public and private universities. Perhaps, the main difference between public and private universities in Latin America could be associated with category 11, funding for research. A great portion of public university budgets in most higher education systems in the region comes from government funding. On the contrary, as it was mentioned above, the main source of revenue in most private universities is tuition. Public funding for research is usually available for public universities (where most research is originated) and a few elite universities. However, there is so much variation throughout the region that even public universities are pressed to broaden their sources of revenue to develop the research enterprise (Bernasconi 2007; Riveros et al. 2008).

In the following section, the ITESM is used to illustrate how the RIE model can be successfully used in a private institution. In 2002, ITESM started a transformation where research has a central role in the institution's mission in order to become a world-class university.

A case study: The Instituto Tecnológico de Monterrey

ITESM is a private, multi-campus university headquartered in the city of Monterrey, Mexico. A group of entrepreneurs led by the MIT graduate Eugenio Garza Sada founded ITESM in 1943. This institution was aimed at preparing professionals with the highest standards for the growing industry in Mexico. ITESM is a comprehensive university with a flagship campus in Monterrey, where most of the research is conducted. Having undergraduate and graduate programs, enrollment at the Monterrey campus consists of about 15,000 undergraduate students and more than 3,500 graduate students, including 673 doctoral students and 50 postdoctoral positions. This university also has research groups in the Mexico City, Puebla, and Guadalajara campuses that constitute what is called the *TEC Research Group*. The Monterrey campus includes schools of engineering, information technology, biotechnology and food sciences, architecture, business, social sciences, the humanities, and medicine. ITESM is proud of having 31 campuses throughout the country that enroll more than 100,000 students. The ITESM system also comprises a second university called *TEC Milenio*, which is a teaching-oriented university with 35 campuses country-wide with near 50,000 students. *TEC Milenio* is set to provide regional industries and businesses with well-trained practitioners.

ITESM developed a successful undergraduate education system that gained international recognition. As part of its innovative leadership, the ITESM Management created in 2002 a unique program to advance research; it was called Research Chairs. Its objective is to strengthen research and development as a way to achieve the institutional goal of becoming a world-class university. Cantu, et al. (2009) described extensively the chair model. This program is structured to provide seed money to a principal researcher who works in association with adjunct faculty,

postdoctoral researchers, and graduate students to conduct research within a specific field, creating a cluster. As a distinctive feature, Research Chairs also seeks to identify potential researchers among undergraduate students who become involved through internships that emphasize research skill development (Galeano et al. 2012). Seed money is guaranteed to each research chair for at least five years and it can be renewed after a cyclical assessment method that considers quantitative indicators and a qualitative peer-evaluation. This rigorous assessment system has been applied to all research chairs and is a main procedure to advance research among those chairs (Cantu and Moreira 2009; Gregorutti 2011b).

The 12-category RIE Model was built based on experiences learned from designing and implementing the Research Chair Program. The following sections show the main results of this program for the 2003-2013 year interval.

The Basics

ITESM has approximately 3,200 full-time faculty members in all the schools, of which near 1,000 hold doctoral degrees. The following indicators represent research outcomes of *TEC Research* (Monterrey Campus and the research groups in other campus). The number of professors accredited by the *Consejo Nacional de Ciencia y Tecnología* (CONACYT, National Council for Science and Technology) through the *Sistema Nacional de Investigadores* (SNI, National Researcher System) grew from 72 in 2002 to 257 in 2013. The number of research chairs in the 2003-2013 year period increased from 22 in 2003 to 144 in 2013. The areas of knowledge and the number of research chairs per area in 2014 are:

- Engineering: 36
- Social sciences: 33

- Business: 30
- Information technologies: 22
- Life sciences: 10
- Humanities: 8
- Medicine: 5

It is important to note that faculty members can use a chair's budget to reduce their teaching load up to 50 percent of the required teaching in order to conduct more research. The same budget can be used to support postdoctoral scholars, graduate and undergraduate students, some travel, and operating expenses.

The Workforce

The doctoral programs offered at ITESM are discipline oriented and had in 2012 the following indicators, totaling and enrollment of 673 students:

- Science of engineering: 170
- Management science: 115
- Information and communication technologies: 113
- Humanities: 95
- Public policy and management: 80
- Biotechnology: 55
- Social sciences: 38
- Clinical sciences: 7

All these programs have been accredited by CONACYT through the *Programa Nacional de Programas de Calidad* (PNPC, National Program of Quality Programs). The only exception is the PhD in clinical science, which is a brand new program currently under evaluation for PNPC accreditation. This certification qualify students to receive federal scholarship for living and traveling expenses throughout their doctoral studies, even if they need to visit a research center for a whole year. As a consequence of this extra funding, the number of doctoral students grew from 265 in 2002 to 673 in 2012.

The number of postdoctoral researcher positions has grown steadily since 2005. Most of these positions have been funded by CONACYT through the postdoctoral scholarship program, which is open annually. The number of doctoral positions in research chairs is about 50, and this number will grow to about 10 new doctoral positions per year in the next five years, using other sources of funding.

International collaboration is also important for scholars to gain research and publication experience by working with well-established research groups at partner universities. ITESM partners include the following universities in the United States and Canada: Texas at Austin, Texas A&M, Carnegie Mellon, Cornell, Johns Hopkins, Houston, British Columbia, and Toronto. There are also university partners in Europe and Asia.[2]

As a result of strategic facility development, professors and students have access to an improved environment to carry out complex projects. For instance, in the last years, research infrastructure has grown in areas such as biotechnology, manufacturing, mechatronics and robotics, optics, information technologies, electronics, industrial engineering, sustainable development, including laboratories for solar energy, water studies, construction, and civil

[2] For further details, see a book chapter published by Cantu and Ceballos on the patterns of international collaboration within research chairs (Cantu and Ceballos 2012).

engineering. In order to increase sources of income, the university created endowments, increased donations, implemented lotteries, and expanded consulting services. Even though alumni donations are not yet significant when compared with United States standards, contributions have become more regular. This is an important breakthrough for this institution.

Knowledge Generation

As a result of the Research Chair Program, publications and citations have changed drastically. For instance, the Scopus database shows how publications, citations, and citations per paper have increased since 2002 (Table 1).

Table 1. ITESM publications and citations in Scopus since 2002

Year	Articles	Citations	Cites/Articles
2002	63	334	5.3
2003	95	385	4.1
2004	190	572	3.0
2005	247	748	3.0
2006	245	923	3.8
2007	260	1000	3.8
2008	265	1336	5.0
2009	285	1481	5.2
2010	295	2005	6.8
2011	279	2233	8.0
2012	318	2580	8.1

In addition, ITESM has developed an Innovation Program through a network of patents and technology transfer offices (TTO) to help researchers protect discoveries and engage in commercialization initiatives. For instance, in 2004, ITESM signed an agreement with the *Instituto Mexicano de la Propiedad Intelectual* (IMPI, Mexican Institute for Industrial Property) to conduct workshops intended to raise awareness among professors and students regarding

patents and industrial property practices. These workshops concluded with annual certification equivalent to patent experts. More than 200 scholars have been trained in the last few years. As a result, a culture of invention, patenting, and intellectual property has helped propel a growing number of patent registrations. For instance, in 2002, professors reported zero patents, whereas in 2012 this number rose to 61, for a total portfolio of 342 patents in the 10-year period, in Mexico and abroad, in areas such as biotechnology, engineering, medicine, and informational technology. Some of these patents have been licensed to companies and government agencies, generating incipient royalties to professors and the institution. Regarding entrepreneurship, some of those patents have been licensed to professors to start spin-off companies. Between 2005 and 2009 there were about 10 companies founded by professors. In 2010, the strategic leadership started the Incubation Cell Program to help doctoral students develop technology-based spin-off companies from their own research. Between 2010 and 2012, graduate students created close to 50 of those companies, of which 35 were still active in 2013. The university provides doctoral students with services that include incubation, access to funding, angel capital, investor networks, and legal, fiscal, and financial counseling to set up companies.[3]

Management

The support offices at ITESM offer a set of services that address three important issues to facilitate research: evaluation, funding, and administration.

Research evaluation considers both a quantitative and a qualitative assessment. The first one is based on a set of indicators and a grading system that assigns scores for publications, impact factor, SNI recognition and prizes, graduated doctoral students, postdoctoral positions, external funding, undergraduate teaching, and consulting and academic service (e.g., being part of

[3] There is a description of the incubation cell model for technology-based entrepreneurship by Cantu-Ortiz et al. (2013).

editorial boards, special program committees, and organizing conferences or workshops). As part of the quantitative assessment, a Research Chair Group must obtain at least 1000 points per year to be able to maintain steady funding from the university. In addition, a committee made up of internal and external members assesses activities and projects based on qualitative indicators. The principal investigator, or leader of the Research Chair, gives an oral presentation about the group's achievements and answers questions from the referees. Finally, the quantitative and qualitative scores are combined to yield a final evaluation that may recommend continuation, cancellation, or the need to implement improvements in weak areas. Over the last ten years, more than one hundred Research Chairs have been assessed in 3-to-5 year periods. About 20 percent of them were canceled for not achieving the expected performance.

Through this methodology, a private university can obtain sustainable research funding. To do so, this institution has set apart a certain percentage of tuition income, as seed money, to support Research Chairs. Chairs, for instance, use seed money to attract external funding. For instance, they have been successful to attract USD$1.3 for each seed dollar. In addition to encouraging research with new sources of money, external funding has been used to upgrade facilities and research equipment, a factor that is essential to continue starting new projects. Also, the ITESM has established a research endowment that grows through consulting services, continuing education, and strategic alumni and companies' donations. This endowment is still in an embryonic stage and it has not contributed significantly to the advancement of complex projects. In 2012, the total income for research, including internal and external sources, reached USD$50 million. This is a significant landmark for a private university in Latin America.

Finally, research administration and support offices are important units that make things happen. Thus, as a strategic move to support and guide researchers, the following offices were created to leave scholars with more time to conduct research:

- Writing papers, revising style and grammar, and selecting conferences and journals to communicate and publish research.
- Grant and contract writing for external funding that meets legal and university policy requirements.
- Managing intellectual property when there are paper presentations in conferences or and publication of journal articles.
- Generating and auditing financial statements for externally funded projects.

In short, this case study illustrates how a private university like the ITESM is transforming with the purpose of joining the select group of world-class universities. This is the result of a clear leadership combined with a system that supports research and innovation as part of its educational model.

Discussion

With about 15 percent of the world population, Latin America accounts for less than 2.5 percent of scientific publications, according to the SCImago 2013 ranking of research universities. The region also has less that 2 percent of the world's 500 best universities, as reported by US News & World Report in 2012 (Marginson 2012; Sowter 2013). The latter percentage corresponds to 10 Latin American universities in Brazil, Chile, Colombia, and Mexico. Three out of the ten

universities can be regarded as private research universities, namely, Pontificia Universidad Católica de Chile (PUCC), Universidad de los Andes (Uniandes) from Colombia and ITESM. A close analysis of their profiles reveals that these three institutions meet the twelve characteristics of the RIE, in various degrees of development. For instance, PUCC has close ties with the central government, receiving grants and important state support for their research program in a competitive basis. Uniandes has developed international collaborations with scholars from top-ranked European and North American universities, in order to boost research outcomes such as co-authorship of scholarly publications. The ITESM is known for its close linkages with industries and the private sector that sponsor applied research programs with active student participation. Employers worldwide consider graduates from the ITESM among the best in Latin America (Sowter 2013). These three institutions have demonstrated a clear strategy with abundant results.

The whole concept of innovation ecosystem the ITESM has implemented to convey the triple helix interaction in a real and practical way, is resulting in sustained advancement of research in multiple forms. This also means that a private university, very much oriented to teaching and training professionals, can redirect resources and institutional missions to make it happen. Although this complex system has shown a very positive impact, it has come through many adjustments over the years, since its initial launch in 2002. Moreover, the system still faces important challenges to reach full potential. One of them is related to people and their culture, motivation, expectations, and leadership. In other words, everything boils down to people, so the ITESM requires better scholar recruitment selection methods to guarantee new academics fit the institutional mission to develop high productivity research. In addition, this university, like most private universities in Mexico, faces challenges to partner with the government to strengthen a

type of relationship that is promoted through the triple helix model. Mechanisms of public funding do not tend to promote entrepreneurial venture with private education; actually, the government spends most resources on public universities that already have productive scholars.

Considering research productivity alone, ten years ago, ITESM was not even ranked among the top 100 universities in the region. The fact that the institution is now ranked among the top 10 in Latin America is a direct consequence of the policies implemented with the RIE program. This growth is the result of the combination of internal and external factors within the ecosystem. The teaching load is one of the most crucial components of the RIE program, since it constitutes the biggest obstacle for professors to engage in research. This, in turn, is related to university financial constraints and mainly strategic decisions by upper level administrators to establish and support research tracks for professors pursuing research careers in their home institutions. Even though the publications; outcome has improved in the last ten years as a consequence of the Research Chairs model (from 30 to 300 indexed publications approximately), publications need to grow from 300 to around 3,000 in the next few years in order to reach the level of leading public universities in Latin America. This requires a critical mass of researchers including professors, graduate students, and postdoctoral researchers.

A second strategy to improve research performance is focusing research on few disciplines and subjects, so the resources available are invested wisely. Having too many areas of research leads to dispersed efforts and results. The ITESM has chosen to concentrate on information technologies, mechatronics and robotics, biotechnology, and sustainable technologies to increase its research performance.

A third factor is attracting the best possible talent to research programs, particularly doctoral students and postdoctoral fellows in selected disciplines and research subjects. Talent should be

organized in research groups specialized in particular subjects and be provided access to the infrastructure and facilities necessary to develop the research enterprise. This also demands a strong commitment from administrators to provide funding to support and expand research capacity. In order to do so, the ITESM created an endowment to sponsor research that feeds from alumni donations, industrial partner funding, local government projects, and continuing education programs.

A fourth strategy is the incubation of technology-based companies to commercialize research and innovation outcomes by students, professors, and industrial partners that license university technologies. In the last three years, more than 50 spin-out companies have been established and this number is expected to grow in the near future. Key elements of this aspect are the commercialization of value-added products and services and the creation of better-paid jobs.

Keeping an international competitive level for universities is especially difficult in the social, political, and economic instability Mexico has been immersed over the last years. Those problems also create a very unpredictable future that threatens stability and the probability of succeed on the long term. However, there are signs of positive regaining that allow optimism in the near future and Mexico can regain some momentum. In short, important challenges still remain, particularly those that have to do with cultural issues within institutions of higher education, and their sustainability in a global context of rapid technological change and academic competitiveness and collaboration worldwide. Private institutions that will implement the strategies presented here may be more successful to compete for more resources.

Conclusion

This chapter has described a RIE model that could be used to develop research among private universities in Latin America. This model has been developed over the last 10 years by observation, benchmarking, and experimentation, but also as a direct result of strategies implemented to transform a teaching-oriented university into one that would be among the best institutions in the region. The RIE includes twelve parameters that are grouped in four categories (basics, workforce, knowledge generation, and management) and has been instrumental to make the dream of having a world-class university a reality. Faculty members and their qualifications constitute the basics; the workforce is made up of graduate students, postdoctoral researchers, and outstanding professors; knowledge generation is the core of all this process of knowledge creation and transfer; and management is necessary to successfully implement strategies that would lead to continuous and improved productivity.

This model of research productivity has shown that private universities can compete globally to attract the best talent (professors and students) to play a relevant role worldwide. Successful research and innovation programs seem to be a magnet to attract key human resources. Perhaps, this is one of the main reasons why world-class universities have embraced a strong leadership to consolidate ecosystems. In this context, collaboration among institutions and researchers has become essential for growth. For the ITESM, this is also an important factor that has contributed to link research productivity with indicators of successful economic and social impact (Lancho et al 2011).

In short, the RIE model described here may be implemented and helpful for similar institutions elsewhere. Even though the model needs to continue evolving, it can be used as a roadmap and checklist to start research and innovation programs in Latin American private universities. This model is useful to be competitive in the globally growing higher education.

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