

Achieving Knowledge-Creating Companies in Mexico: the Advantage of University-Industry Alliances

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ABSTRACT

In this paper we focused on developing a methodology to promote innovation through industry-university collaboration. So we analyzed two different scenarios. On one hand we have the traditional firm, that is striving to survive in the global knowledge-driven economic framework and on the other we have world class research universities that are trying to find the best way to put their knowledge in the market place, fostering spin-offs as well as promoting knowledge transfer to the traditional industry. We have analyzed the behavior of successful high-technology spin-offs, and knowledge transfer experiences worldwide. In particular, we have focused on the management paradigm of the “knowledge creating company”, proposed by Nonaka [11], since it is one of the models that best describes the organizational environment in such successful experiences. Finally, we present the methodology developed as a result of this study that is currently being applied in our State University

Keywords: scientometrics, scientifically generated innovation, knowledge management

INTRODUCTION

One of the main challenges, that emerging economies face, is the evolution from its traditional economy to a knowledge economy. It is a well-known fact that Mexico thrives to be part of a knowledge driven economy, where the capacity to support processes of innovation and learning is a key source of competitive advantage. As a matter of fact, innovation has been related to competitive advantage in firms, without regard to the type or size of the company [3,5].

Innovation has been related to competitive advantage in firms, disregarding the type or size of the company [20, 19]. Lueck and Katz [16] define innovation as “the embodiment,

combination, or synthesis of knowledge in original, relevant, valued new products, processes, or services”. Innovation literature is rich in descriptions and classifications of innovation and innovation dynamics; our main interest relies on technological innovation [18, 17].

This type of technological innovation needs a strong scientific research core, where the expertise of a scientific group provides sufficient leverage and confidence around a technological solution, allowing an extraordinary idea to transform into a successful innovation. We will call this type of technological innovation, scientifically generated innovation, and it will be the one this paper is focused on.

INNOVATION AND U-I COLLABORATION

Historically, academic research has focused on basic research [13]. Sometimes, breakthrough ideas from universities would “spill over” to industry. Little effort is being done in this field, universities are not educating industrialists, nor industrialists are tracking academic research, and worst of all, in the case of developing countries, such as Mexico, there is practically no communication between both sectors (or at least not an effective one). Almost nobody outside the academic environment knows what are the areas of research of the regional Universities or research centers. Moreover, the community knows little in general about the specific projects they are involved.

One of the main challenges faced by developing countries in their aim to implement scientifically generated innovations is detecting their thrust areas. Although the countries that are considered as technology suppliers face this challenge also, the macroeconomical framework of developing countries raises the risk of technological innovation investment. Governments, and more specifically science and technology managers (public or private), have to take decisions on a regular basis and need

reliable information on the real strengths of their scientific community, in a global environment. While developing countries investment on S&T is mainly public, since research is done by universities or public funded research centers, their entrepreneurial sectors are distant and skeptic towards the scientific community. These two issues affect negatively knowledge and technology transfer, which is necessary to trigger technological innovation.

Nevertheless, a strong academic environment fosters capacity building in local public and private universities; thus, producing human resources prone to the knowledge creation process. However, the successful cases of technology transfer are scarce. In order to overcome the underlying causes of this fact we focused on finding niches, where the strength on certain scientific area could lead to a technological development, and furthermore to the generation of wealth around it.

In order to analyze the different factors that promote (or not) innovation, we need a representative set of information. We focused our study in a small region, the State of Morelos. We chose Morelos over any other state in Mexico, because it represents the most important concentration of scientists in Mexico (per capita and per square mile). Its scientific community has established its work and family centers since 1975, reaching its most accelerated rate of growth between 1985 and 1990. Actually it is considered as a mature, prolific and high-quality scientific community. And, in the last few years, we have witnessed the success of university-business alliances. One of such cases is a very successful University spin-off.

The scientists' production is reflected on around seven hundred research papers they write each year, which represent 10% of Mexico's scientific production. Figure 1 shows the productivity of these communities in terms of number of papers published in the last eleven years. It is important to notice that Morelos has the same trend, only one order of magnitude below.

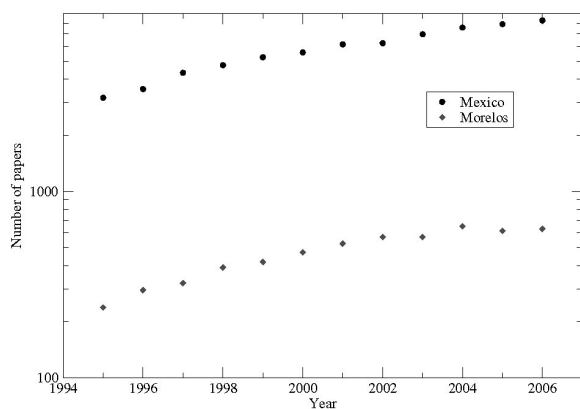


Figure 1. Research papers written from 1995 to 2006, both in Mexico (dots), and in Morelos (diamonds)

This graph seems to indicate a scale free behavior, and hence, the possibility to analyze further this set of information, searching for a power-law behavior, which is necessary to apply Paretian statistics, instead of classical Gaussian statistics. Most or the empirical studies done by the social sciences are based on Gaussian statistics, which assume normal distributions, averages, and normal confidence intervals. Such empirical

approaches are not effective for studying co-evolutionary dynamics [10] or extreme events [9] that result in Pareto distributions with fat tails, unstable averages, variance that approaches infinity and consequent wider confidence intervals. "Scale-free theories" are used to explain the foregoing dynamics and appear applicable for studying and explaining a variety of organization science phenomena. Cedano *et al.* showed that scientific production in Mexico, and in Morelos, behaves as power law phenomena [19]. Hence, we were able to apply Paretian statistical analysis to the set of scientific production in Morelos.

Methodology

As in many scientometrics analysis we used the Science Citation Index database (SCI). This database consists of selected journal records that included the fields of: authors, titles, journals, author addresses, keywords, abstracts and references cited for each paper. Data was extracted from the SCI for this study on Fall 2007, its database extracted information from approximately 8,500 of the most prestigious, high impact research journals in the world. We analyzed the key fields of the citing records: Title, Author, Category, Document Type, Cited References, and Address.

For the science production in Morelos, we downloaded all the records that satisfied the criteria: ADDRESS containing: (Mexico NOT New) AND Morelos, and dated from 1995 to 2006.

We performed the bibliometric analysis as presented by Kostoff [1] and added text mining to follow the citation mining methodology [6]. We restricted the citation mining methodology to analyze the following data: Prolific authors, Prolific institutions and/or countries, Most cited first authors, Categories most researched, as classified by the Institute of Scientific Information, Number of cites per author; and finally, Most relevant words of the abstracts.

With this data set we performed a count of each value. Furthermore, to find relevant words we use the same entropic text mining technique used in citation mining [1] to find the most relevant words occurring in the abstracts of all papers. This technique was proposed by Ortuño [14] based on the measure of the distance between different occurrences of a word in the text. So, this distance on an abstract was compared to the standard deviation of all words in all abstracts. A normalized with the mean standard deviation higher than 1 indicates that the distribution of the word within a particular abstract is not random, allowing to determine which words or string of words can be considered relevant for that particular text [7]. The reasoning behind this assumption is that the standard deviation is an indicator analogous to entropy and can sometimes play a role as a measure of order, or disorder in non-physical systems [8]. The advantage of this particular technique is that it does not require a labor-intensive revision of individual texts to extract the keywords from them, but rather provides a ready-made list of the words and strings of words whose distribution within a text is not random and, therefore, likely to be significant. Methodologies using similar steps have given good results in literature base discovery [4].

We focused then on the relevant words results that were analyzed with two different methodologies: a) through a panel of multidisciplinary human experts, and b) with a statistical approach. In previous works, such as Russell [15], the relevant

words are analyzed only by a panel of experts. The accuracy of such analysis strongly depends on the degree of expertise of the consulted team and the breadth of its multidisciplinary. In the search for an unbiased, less human-dependent approach, we found a different methodology that took advantage of the Scale-free behavior of the set.

So we applied our knowledge on Paretian statistics to rank the relevant words in an automated fashion. We formed 20 different subsets of information, collecting data from the Web of Science with each of the relevant words in the field TOPIC, whose ADDRESS contained Morelos and (Mexico Not New). Then, we obtained through our computational tool, the research categories for each of the twenty relevant words under analysis. We know that a relevant word should not be context dependent, this is, it has to be a word that has a relevant meaning in as few categories of knowledge as possible. More precisely, the majority of research papers that contain a relevant word should be concentrated in as few categories as possible. We are dealing with Paretian statistics, so we counted the different research categories that covered 80% of the research papers on each subset. Table 1 reflects the results of such analysis, ordered by number of research categories. From the results on this table we can see that the most relevant words are: STARCH, TOXIN, FILMS and CORROSION. For these four words, we searched for the most prolific authors; the results are shown in Table 2.

Relevant Word	Categories
STARCH	6
TOXIN	8
FILMS	8
CORROSION	8
WOMEN	11
ISOLATES	12
STRAINS	12
CI	14
CHILDREN	15
HEALTH	15
PREVALENCE	16
CANCER	17
PATIENTS	19
BLOOD	20
Q	22
WATER	23
MORTALITY	23
LEAD	28
DEGREES	30
MU	32

Table 1: Relevant Words ordered by the number of categories that cover 80% of the papers written in Morelos that contain them as topic

Relevant Words	Most Prolific Authors
STARCH	BELLOPEREZ, LA
	AGAMAACEVEDO, E
TOXIN	POSSANI, LD
	BRAVO, A
FILMS	SEBASTIAN, PJ
	NAIR, PK
CORROSION	GONZALEZRODRIGUEZ, JG
	MARTINEZ, L

Table 2: Most Relevant Words with its most prolific authors in Morelos

Now, we can narrow our search to the pairs (Starch, BELLOPEREZ), (Toxin, POSSANI), (Toxin, BRAVO), (Films, SEBASTIAN), (Films, NAIR), (Corrosion, GONZALEZRODRIGUEZ), (Corrosion, MARTINEZ). In these pairs we could identify Lorenzo MARTINEZ, founder of CPI, the successful university spin-off; as well as Gonzalo GONZALESRODRIGUEZ, one of the research collaborators and consultants of CPI.

Results

As shown earlier, CORROSION is one of the most relevant words detected with our methodology. So, we analyzed the papers published under the following criteria: TOPIC: corrosion* OR corrosive*; and ADDRESS: Mexico NOT New AND Morelos, aiming to find the scientific production of the last 10 years, done in Morelos, on corrosion. This led us to discover not only that Martinez is one of the most prolific authors in Morelos.

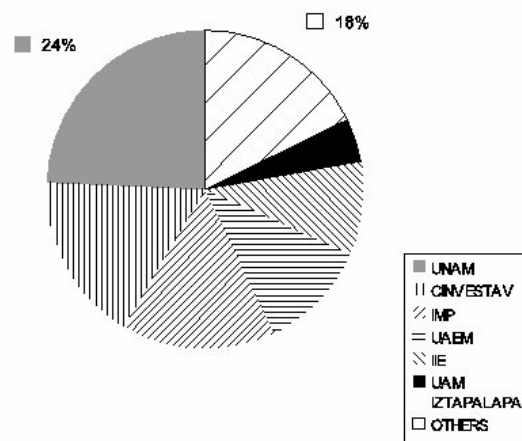


Figure 2: Mexican institutions conducting research on corrosion. This results were obtained with the search criteria: TOPIC: corrosion* OR corrosive*; and ADDRESS: Mexico AND Morelos NOT New.

In figure 2 we can see the Mexican institutions that conduct research in corrosion. Once again, UNAM, the institution where Martinez conducts his research, as well as UAEM, where GonzalezRodriguez's group is in close relation with Martinez's,

appear in the top places, accounting for almost 40% of the research done in Mexico on this field. Moreover, this graph shows us possible competitors (or strategic alliances, as well) in the marketplace, since CINVESTAV, IMP, IIE and UAM are all prestigious universities or research centers that are entering successfully the innovation scenario.

THE KNOWLEDGE CREATING SPIN-OFF

Martinez founded several years ago CPI, a firm that provides services of highly specialized technology in anti-corrosion protection. It also coordinates training and certification programs on corrosion, due to his partnership agreement with NACE International (National Association of Corrosion Engineers). His company represents one of the most successful technology transfer ventures in the region, with strong strategic alliances with several universities, mainly with Universidad Autonoma del Estado de Morelos (UAEM).

The issue of intellectual property protection was also analyzed in the case of Martinez. CPI is a university spin-off, that in its beginning relied on the expertise of its major stockholder, Martinez. As time passed by, and the need for more experts grew (along with the sales of the company), Martinez registered his methodology and analysis procedures, protecting from others the most important asset of his company: knowledge. Furthermore, he has two patents pending in Mexico, for engineering innovations developed entirely by CPI's group of engineers (all of them graduate students at UAEM, also).

Financially, CPI has proven to be successful not only by the gross income it has had in the past 5 years; but also because it has generated a couple more of firms in this recent period. Hence, conforming a small consortium dedicated to different market shares. The consortium's gross income is represented in Figure 6.

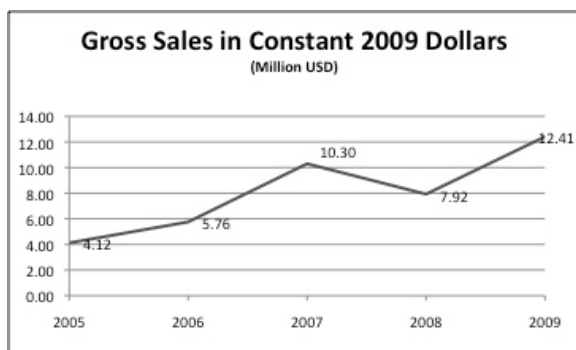


Figure 6. Gross Sales (in millions of Mexican pesos) over the past 4 years (2009 is estimated)

CPI's growth is also measured by the size of the company. On 2004, it had 6 full time employees, and worked with 11 independent consultants from 2 state universities. On 2008, 46 people work full time, it has strategic alliances with 5 state universities in Mexico, and it hired the services of more than 50 independent consultants from all over the world. Also last year 30% of its sales were made to other countries in Latin America.

A growth at this rate, both in the economic and scientific arenas, clearly shows the relevance of this study.

The external forces that fostered the spin-off

While analyzing CPI's creation, we were able to pinpoint a specific moment where the external conditions aided and promoted Martinez's venture: The acknowledgement that CONACyT (National Council of Science and Technology in Mexico), gave him as a National Investigator of Excellence, valid from January 2003 through December 2012. The recognition was given only to 50 scientists. It rewarded Martinez's overall work, not only in the scientific community, but also in the technology transfer arena. This, on one hand, set a standard on how important it was for Mexican authorities to develop technology transfer experiences, since the acknowledgement includes a monetary prize. But most importantly, the financial security it represents, over a period of 10 years, relieves scientists of the burden related to increase their impact in the short term, giving enough latitude to articulate medium and long term ventures. When Martinez received this recognition, the research center authorities had the vision of fostering this attitude towards entrepreneurial activities. This openness from the academic authorities is what we have named "External force 1". Since it is a new input to the normal scientific community environment, where the number of papers published in respected journals is mostly, the only activity recognized as productive.

So, even though Martinez worked as an independent consultant some time ago, the academic and productive sector dynamics were out of sync. This lack of timing translated on a fairly good productive relationship, but limited in time to the research university agenda and in scope to the legal university framework. It was not until the manifestation of the "External force 1" that this small group of scientists and managers were driven to enable the generation of a spin-off that could provide services to the industry, without the disadvantages of the academic dynamics. As the company grew, they kept on fulfilling the increasing need for innovation that the market had, in their area of expertise.

Then we followed the history of this spin-off as it began to grow, and how a second external force led this company to develop a knowledge-creating environment. Moreover, as this spin-off faced the need to increase its market share, we pinpointed its influence in other research universities, as an external force to them, to foster a knowledge creating ambient in those universities as well. While analyzing the organizational culture at CPI, we clearly found a direct association between Nonaka's proposal of "knowledge creating company" [11] and the operation at CPI. Furthermore, this organizational culture was shared with their customers (oil transport Mexican industry) as well as their providers (state universities and research centers).

Nonaka identifies three elements in his model [12]:

- The SECI (Socialization, Externalization, Combination and Internalization) process, that stands for the conversion of tacit and explicit knowledge in different moments of the knowledge creating process.
 - Socialization: transformation of tacit to tacit knowledge, by empathizing among peers.
 - Externalization: transformation of tacit to explicit knowledge, by articulation while producing drafts,
 - Combination: transformation of explicit to explicit knowledge, by connecting different organization areas and levels.
 - Internalization: transformation of explicit to tacit knowledge, by embodying knowledge, making it

“personal”.

- 'Ba', the context also known as the time and space where SECI occurs. The research center infrastructure (physical and virtual).
- The knowledge assets, the set of inputs, outputs and moderators of the knowledge creating process.

The way these three elements interact and conform a knowledge-creating platform resembled clearly the way scientific research is done in our culture. Several studies have shown the relevance of culture as well as the individuals' capacity to communicate, this being critical in the processing of tacit knowledge. Our academic community relies strongly on the continuous transformation of tacit and explicit knowledge. Socialization, Externalization, Combination and Internalization are common processes that take place on our research centers daily, while interacting among peers; communicating findings and protocols; elaborating research papers; on internal and external congresses and seminars; and while learning from the latest breakthroughs as well as the reference literature; respectively.

When Martinez began the process of spinning off, he was able to do by himself the basic management of the small firm. His experience as former director of the Center of Physic Sciences (the research center he's been working for, during the last 20 years, now Institute) was a valuable asset in the process. So, when Martinez changed of scenario, he followed his years of training as a lead researcher and replicated this well known organizational culture in his company.

He fostered a well-balanced *ba*, where employees, consultants, customers and providers were free to interact, comfortably and openly. Since he started as the sole moderator of a very small company, he managed to maintain the perfect environment for knowledge creating. Also, he began working for former research collaborators that had left the scientific scenario, to be part of the productive sector, thus being able to maintain the climate of trust, openness and communication, indispensable for knowledge creation to take place. Moreover, he did not hire the experts but, sensible to the academic dynamics and legal restrictions, he formed strategic alliances with the state universities as a whole, promoting the development of qualified human resources (graduate students), as well as promoting specific research areas that were pertinent and closely related with the customers problematic at hand.

However, as CPI began to grow; and hence, the complexity of the relationships with its costumers, employees and providers, it faced one of the most crucial challenges that companies face, the definition of its organizational culture. He hired a management consultant to organize the growing company he had been managing by himself. The consultant had never faced a high-technology company, where the most valuable asset is knowledge. He tried to impose a more restrictive, traditional managerial style. Attention was paid to expenses, income, hours spent in the working place or with customers; disregarding the friendly, trustworthy environment CPI used to have. Excessive regulation on everyone's time and whereabouts at the firm promoted a negative working climate.

Fortunately enough, the trust, care and commitment of most of the employees at CPI, as well as the continuous communication between them and Martinez, stopped the transformation of the knowledge-creating environment to a traditional, rigid, over-controlled one. At the same time this crisis was starting, CPI was investing on a research project on knowledge and

technology transfer. So Martinez received continuous input about different management methodologies. In particular, the project focused on Nonaka's knowledge creating company, due to the similarities found with CPI. Once Nonaka's theory was presented to Martinez, he decided to reinstall the former way of doing things at his company, with a clearer framework in mind. We identify this as “External force 2”. He reoriented the management consultant towards the accounting and tax departments, and established clearly the roles and functions of everyone in the company, in a non-restrictive way. Special attention was put to promoting a better *ba*, both physical and virtual. Today, CPI's headquarters are nicely decorated, open, comfortable and foster spaces where interaction between all employees is promoted. All managers are convinced that CPI is a knowledge creating company, and their main concern is to keep communication flowing. The elaboration of manuals, reports, web pages, and logbooks is a process that involves several individuals, since every piece of information is produced by the expert technician, revised by a couple of his peers, edited by communication experts, and stored in the general repository which everyone is encouraged to consult and improve.

BIOTECHNOLOGY AND IT

As we stated before, another important target of this research was to propose a methodology to promote innovation for established firms. First of all, to find thrust areas in Morelos, we applied data mining techniques to the scientific production of our state research centers, finding that Biotechnology and IT are two such areas. So we searched worldwide for successful high-tech companies in the biotechnology and IT sector that were focusing their attention on the knowledge-creating company model.

In the Biotechnology area, its knowledge intensiveness has driven different industries towards a knowledge-nurturing scheme. For instance, the Finnish food industry [20], realizing the need to innovate, has turned its attention to functional foods. The external forces that drove this initiative are both technological and market-based. On one side, there is a market demanding better healthier and more nutritious food (also known as functional food), this market need has to be met by a food industry that didn't use to focus on such detailed information regarding their products. On the other hand, biotechnology is turning low-technology industries into high-technology industries rapidly. These two of factors act together as an external force or driver of change. The success of this strategic change depends mostly on the ability to take necessary actions for creating new knowledge. These changes have implications for both strategic decision-making and knowledge management processes. Since this industry's best course of action is to enable partnerships with biotechnology companies, instead of investing heavily on R&D (which has not been done in the past), knowledge needs to be well managed not only inside each firm, but also between biotechnology companies and research centers, among others.

Another example can be found in the pharmaceutical industry [21], since it is knowledge intensive sector. In this industry, innovation is the key element for success, not only in the biotechnology area, but also in the communications one. As a matter of fact, virtual networks have recently been the only feasible alternative to encourage new product development. Hence, careful management of information, robust information

systems, collaborative virtual environments, and secure communication channels, are some knowledge assets necessary to take into consideration while establishing a knowledge management framework. Once more, the market pressure for better, harmless, more specific drugs; as well as the competitors' ability to foster in-house innovation, has led smaller pharmaceutical companies to engage in strategic alliances with university research centers. Thus, emphasizing the importance of establishing knowledge-creating frameworks that hold this type of collaboration.

The IT industry poses a greater challenge. Information is the only asset of this industry. Notwithstanding the different sector it attends, this industry needs a strong, robust and sturdy relationship with its customers. It is through intensive communication with them and with the latest breakthroughs that better, more competitive products are developed. Dayasindhu [22] pinpoints the productivity increase that the Indian software industry achieves by focusing on innovation and growth. Thus, there is a pressure (external force) from a market that demands more flexibility and specificity. This pressure is driving the IT Indian industry towards creating trust and encouraging intra and inter organization relationships. So, the faster they adopt knowledge creating environments the better they will face the challenge this more demanding market represents.

In this case, we highlight two external forces as well; one that accounts for the decision to modify the company's environment, and another that determines the need to adopt a knowledge-creation environment, in the sense described by Nonaka. We believe that the more this environment follows the model proposed by Nonaka, the better these companies will foster knowledge sharing, the most important process for the knowledge-creating company.

FINAL RESULTS

The analysis of these experiences led us to develop a methodology to help both traditional industries and universities' spin-offs to achieve an organizational culture of knowledge management, through the establishment of strategic alliances with the universities where the experts of their fields of interest do their research. Our methodology includes the application of data mining and bibliometrics on scientific paper databases for the detection of both experts and scientific thrust areas that might have a higher chance to generate successful high-technology spin-offs.

Our Methodology

To promote spin-offs from the University or Research Center:

1. Application of scientometric analysis over the region of interest (geographic, institutional, thematic, etc.) to identify opportunity niches.
2. Implementation of institutional stimuli as "external force 1" events that promote entrepreneurial activity in the niches identified in 1.
3. Training on knowledge-creating organizational culture to the entrepreneurial team.
4. Unlimited access to technology transfer specialists on management, marketing, intellectual property, accounting, legal, and any other matter not related to the expertise of the entrepreneurial team.

To promote innovation in established firms:

1. Training on knowledge-creating organizational culture

by experts in technology/knowledge transfer in the firm's area of expertise.

2. Articulation of thematic meetings with experts from the academic sector, where tacit and explicit knowledge is shared. These experts have to be trained in knowledge-creating organizational culture as well.
3. Depending on the relative size and managerial style of the company, two possible scenarios can be drawn:
 - a. Large or more isolated companies will hire the experts to work as their consultants. In this case, the continuous assistance of a technology/knowledge transfer specialist is recommended at least in the initial stages, to ensure the best implementation of knowledge-creating organizational culture tools and practices.
 - b. Smaller or more open companies will form a strategic alliance with the Universities or Research Centers hosting the experts they are interested in. In this case, the university will appoint a technology/knowledge transfer consultant to create and manage the best consultant team possible, under the knowledge-creating paradigm.

Our state university is already applying this methodology to promote spin-offs and knowledge transfer alliances in the high-technological niches that are highlighted by it. On one hand, it is promoting a series of workshops that focus on developing a technology/knowledge transfer team. This team will be responsible for the establishment of a knowledge-creating organizational culture in each research center; as well as for the implementation of the methodology in the potential spin-offs throughout the university. On the other hand, this team will offer conferences and small workshops to the industry, in order to identify potential allies, and perform the follow-up of these ventures.

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