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Elements that influence knowledge sharing in the university-industry-government collaboration

Case studies in Brazil

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Abstract

Purpose – The purpose of this paper is to determine the factors for an academic research project in electrical engineering to become relevant.

Design/methodology/approach – As a conceptual basis, a few theories of entrepreneurial university and triple helix were correlated, seeking to determine the main critical factors and the successful criteria of an academic research project. The research was conducted through four cases of electric engineering that succeed in generating social and economic impact.

Findings – When analyzing the available bibliography, it is clear that the connection among the companies, the market and the research that happens at the university is very important. Not only that, but also, according to the results, this is the key to generating revenue and impact on society. In addition, operational policies and competent leaders promoting this impact inside the universities are extremely important.

Originality/value – The topic was selected because of the reduced number of articles related to the identification and analyses of the main aspects that make an academic research project relevant to the society. Furthermore, the paper is significant because it analyzes the main factors that help develop a better society and country through academic research.

Keywords Knowledge sharing, Innovation, Entrepreneurial university, Entrepreneurship, Electrical engineering

Paper type Research paper

1. Introduction

It has become clear since the second half of twentieth century that society is increasingly more connected to knowledge development and its practical applications in new technologies. This way, the university assumes a central role, once it stands for three functions: education, research and extension. The first pillar, in a more practical way, looks to develop citizens to generate new knowledge, developing its nation; the second pillar focus on knowledge generation itself, by doing academic research; and the last and third pillar approaches the development of extension activities, searching for a closer connection among university, external stakeholders, society and private companies or organizations.

Technology, as a product and producer of the innovation process, reflects the degree of aggregated knowledge, the set of skills and the ability of learning an organization has in a

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certain moment. Innovation can be seen as a flow, as it is a transformational process that results from accumulated skills, knowledge and technology. Innovation and technology are gathered through unspoken and by explicit expertise, which result from collaborative learning, that were already created (Dudziak, 2007).

In this context, the Brazilian scenario is still incipient accounting for its social character of generating development through science, technology and innovation (STI). National vision is that application in science, mainly in universities, happens through education and not necessarily innovation or knowledge creation. This method of conducting science has been contested by academic research studies that proof the value of a university able to generate knowledge and actually apply it in society (Brito Cruz and Pacheco, 2004).

However, even with this indifference, it is possible to observe the importance of knowledge development in Brazil. According to data of the Organization for Economic Co-operation and Development (OECD, 2012), investment in research and development (R&D) in the country is close to great centers of research, such as UK, Canada and ahead of others, such as Italy, when comparing the share of GDP invested in R&D.

Nevertheless, more than the creation of knowledge and innovation through R&D, the Modern Age reiterates the importance of a “Third Mission”: the economic and social appreciation of knowledge produced by researchers in the universities. The definition of this mission imposes the need for strategies, structures and mechanisms to facilitate and identify knowledge transference to the private sector in many ways: licensed patents, academic spin-offs, startups and others. Therefore, universities would also need to develop a culture more oriented to entrepreneurship, with researchers engaged into this culture (Etzkowitz and Leydesdorff, 1995). Such model also spans the importance of the relationship among three stakeholders: government, universities and companies (Fayolle and Redford, 2014).

Based on this, the need for more entrepreneurial universities becomes clear. Those organizations should alter their strategies, structures, practices and culture to help students and community members to act in a more entrepreneurial way. But, in general, universities are bureaucratic institutions and, as a consequence, present low ability to adapt itself and to adopt new behaviors (Fayolle and Redford, 2014).

2. Bibliographic review

In this topic, a literature revision addressing the main topics important for this paper is presented: entrepreneurial university and collaboration among universities, companies and government. The main dimensions and topics that influence those two topics are also approached in this section.

2.1 *Entrepreneurial university*

Etzkowitz (2003) outlined the concept of entrepreneurial universities to describe a series of changes that reflect the role of universities in promoting academic research knowledge transference in a more direct and active way. However, technology transference is something challenging, once private companies and universities have, in general, distinct missions and mutual suspicion.

Although, not only Etzkowitz approached the concept of entrepreneurial universities, but also different scholars, such as Chrisman *et al.* (1995), Clark (1998a, b) and many others. Even though there is no unique concept about what is an entrepreneurial university, there is a consensus that it is related to knowledge transference with the purpose of causing economic and social development. In other words, every research project and knowledge produced in a lab should aim, somehow, to benefit society, by its economic and social results.

Not only academic researchers, but also OECD approached the theme, synthesizing every concept and knowledge developed by research projects about the topic and created a framework defining what is an entrepreneurial university. The frame describes seven

functions: “Leadership and governance,” “Organizational capability, people and incentives,” “Development of entrepreneurship in the education,” “Paths to entrepreneurs,” “University company,” “External relations for knowledge sharing,” “Universities while international institutions” and “Measurement of university impact.”

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2.2 Critical factors in an entrepreneurial university

Many factors influence the success of an entrepreneurial university strategy implementation. Blok *et al.* (2014) identified, in their study, five macro factors with huge influence: “Strategy,” “Resources,” “Infrastructure,” “Reach” and “Development.” Each of those factors is composed by activities and tangible actions, so it is possible to reach a higher level of granularity to design the better strategy to become an entrepreneurial university.

Strategy. The macro factor “Strategy” involves how universities introduce an entrepreneurial education program in their strategy (Niras, 2009). The activities related to this factor are: mission and strategic objective of universities, and operational politics that are unfolded of such objectives in order to improve the strategic program of the entrepreneurial university. The mission and strategy are important to demonstrate an agility to adapt to rapid changes that should present in that kind of organization (Sporn, 2001). Those strategic objectives, previously described, need to be present in every and each level of leadership of the organization and present in the politics of every department (Potter, 2008).

According to Sotirakou (2004), not only the structure of the governance, but also the style of the leadership in the universities should create a scenario where entrepreneurship programs might prosper. It implies programs should be supported by the university employees, and by directors.

Resources. Another crucial factor for the development of an entrepreneurial program is the availability of finance it (Niras, 2009). Specific activities regard the amount of resources, the type of resources available and own income generation to the university, through patents, consulting or even product selling. Many researchers mentioned the importance of finance to develop and execute activities related to entrepreneurship, stating that it is impossible to implement those practices without dedicated funds.

Not only the size of the budget matters, it is also important to understand the availability of resources during a constant period of time, maintaining programs’ sustainability (Potter, 2008). Sporn (2001) alerts about the dependence of resources from the government, as it reduces the capacity to adapt to changes in the university environment. Diversification of revenue streams diminishes considerably universities vulnerability (Clark 1998a, b) and increases programs’ sustainability (Potter, 2008).

Infrastructure. The third factor influencing on building an entrepreneurial university is the infrastructure offered by the institution, which not only structures to support the education (Niras, 2009), but also ensures specific actions to develop and improve: structures such as incubators or entrepreneurial centers; and structures for research, and study of entrepreneurship. Garavan and O’Cinneide (1994) showed the importance of a space to conduct an entrepreneurship education, while Etzkowitz (2003) also recognized the importance of such structures (Siegel and Phan, 2005). Glas and Menzies (1998), in addition, showed that entrepreneurial centers help to develop an entrepreneurial mindset, and improve the transfer of knowledge between university and society.

Just as the education and the research about entrepreneurship would be multidisciplinary by nature (Coduras Martínez *et al.*, 2010), it would need to have structures and programs to encourage multidisciplinary contacts. These programs should not be only different courses offered by the university (Potter, 2008); instead, these should act as incentive to reduce institutional barriers and to build bridges between ideas and knowledge among students, professors, researchers and other community members (Wiese and Sherman, 2011).

Reach. The factor “Reach” is essential to understand the mutual influence among the program of entrepreneurial university, local environment, community and business around the institution. Connections with local corporate environment grant to students, professors and researchers the opportunity to have practical entrepreneurial experience, and develop a more entrepreneurial mindset (Niras, 2009). Specific activities related to this factor are: involvement with external stakeholders, and alumni programs. Pittaway and Cope (2007) presented the importance of external stakeholders such as entrepreneurs, employees, governmental and industry representatives, and possible clients to facilitate the development of entrepreneurial skills.

The value added by these connections relies on the possibility to promote technical support related to business administration and on the development of skills by the university community (Hynes and Richardson, 2007). University alumni can be useful in the development of entrepreneurial activities (Niras, 2009), offering, for instance, classes as guests or even offering internships (Matlay, 2011). Besides the stakeholders already presented before, it is also important to be involved and engaged with local community, seeking knowledge transference and society development (Etzkowitz, 2003).

Development. The factor “Development” is related to the continuous improvement of programs and activities related to entrepreneurship, based on monitoring and changing to meet stakeholders’ expectations. With an ongoing improvement of those programs it is possible to meet the desire of everyone involved (Niras, 2009). The activities connected to this factor are: measurement of frequent programs with internal and external stakeholders, and improvement toward needs identified by the measurement previously done. Using this method of continuous improvement, the university can achieve a better entrepreneurial environment.

2.3 Success criteria of an entrepreneurial university

Blok *et al.* (2014) combined the results of the research of Niras (2009) with the purpose to identify which are the best performance indicators and the dimensions connected to entrepreneurial programs.

Those performance indicators are divided in three macro groups of entrepreneurial university impact measurement: “Education,” “Knowledge Transference, and “Practical Study” (Blok *et al.*, 2014).

Education: representation of students enrolled in entrepreneurship courses and classes. This indicator measures the extension of entrepreneurial mindset and how it is widespread in the university as a whole.

Knowledge transference: number of patents, external financing and studies revised by others researchers. This indicator measures how the knowledge transference actually happens in the entrepreneurial university and what are the consequences of this knowledge previously developed.

Practical study: representation of students enrolled in extracurricular activities. This indicator measures whether the entrepreneurial university is being able to create mechanisms of practical education and not only theoretical classes.

3. Research method

The research method is to understand the main factors to develop an academic project that brings economic and social development. In other words, a project that fits in the concept of entrepreneurial university was based in four electrical engineering case studies.

With the objective of doing so, a research instrument was used to measure which factors influence the development of each project. The factors researched were previously presented in the bibliographic review and proposed by Blok *et al.* (2014): “Strategy,” “Resources,” “Infrastructure,” “Reach” and “Development.”

After applying the research instrument to determine the main critical factors for each project, the results were weighted according to the performance indicators proposed by Blok *et al.* (2014). The group of indicators used was “Knowledge transference,” as the goal is to measure only the performance of a specific academic project and not necessarily of the university as a whole. Therefore, to calculate the performance indicator of each project (π_i), the following factors were considered: number of patents (NP), number of external financing (FE) and number of peers’ review (RC). Those factors were weighted by the formula below, once peers’ review is a secondary impact, supporting other’s research and not directly the society:

$$\pi_i = \frac{2 \times NP + 2 \times FE + RC}{5}.$$

After that, the ponderation of each factor is made using the formula below. The importance of each factor for each academic project (f_i) is weighted by that project’s results (π_i), according to the performance indicators:

$$\sum_i^n (f_i \times \pi_i) / (\pi_i)$$

4. Case studies

The four cases studied are academic projects in electrical engineering and were developed in different educational institutions.

4.1 *Measurement of suitability of sunglasses to the norm of ultraviolet and luminous transmittance*

The research project developed at the São Carlos School of Engineering expected to build a simple equipment for measuring ultraviolet and luminous transmittance of sunglasses. The purpose was to get a device in which a regular citizen could easily and intuitively measure his own glasses and get the answer whether he should use it or not, according to the ultraviolet transmittance. Until then the measurement of the ultraviolet transmittance was carried out from the spectrophotometry, which needed specialized professionals for measurement and presented high purchase and maintenance cost.

The company was opened with the support of the Small Business Innovation Research Program (PIPE) of the São Paulo Research Promotion Agency, FAPESP (São Paulo Research Foundation). The first two products of the company were the ultraviolet transmittance meter previously developed in the laboratory, and the display used for the construction of such devices. In the development of the company, the entrepreneurs were incubated for some time in ParqTec, a local incubator, and received three financing scholarships by the PIPE of FAPESP (2010) and got to have a registered patent.

Entrepreneurs and researchers attribute much of its success to the great leaders they have had in their journeys. In addition, the will and tenacity to undertake was also pointed out as very important characteristics.

4.2 *Diagnosis of dermatological diseases via optical techniques*

A researcher developed his doctoral thesis in the Department of Electrical Engineering of the School of Engineering of São Carlos and his goal was to develop a portable device that, through the use of light patterns, could detect changes in the epithelium of patients. The equipment measured the change of chemical components after the application of aminolevulinic acid and application of light.

The researcher realized this technique also possessed the ability to perform dental diagnoses, since when applied to the teeth, the system also had the capacity to find caries.

With the products developed, in 2011 the team opened a company. Their aim was to market such innovative diagnostic techniques. In the development of the project, the company was incubated in the ParqTec and received support from PIPE, through three different financing. Currently, the company focuses more on the commercialization of test equipment for medical equipment due to the strong Brazilian regulation on medical equipment.

Like the previous case, the entrepreneur attributes a significant value to the leaders who contributed to the project. The encouragement given by his advisors was essential to think outside of common sense and bring the solution to the market.

4.3 New method of locomotion for people with physical disabilities

A graduate in Biomedical Engineering from the National Institute of Telecommunications (INATEL), during his course approached the development of technologies in the area of electrical engineering from projects of scientific initiation. One of the main projects conducted by the student was a mobile device capable of allowing the physically disabled in an upright position and allowing them to move. Such equipment was denominated Dynamic Orthostatic Chair. The Orthostatic Dynamic Chair seeks to overcome the difficulties faced by people with modular injury, helping in the erect locomotion. The user, by standing up, can perform habitual activities, within the limits imposed by the disability. The equipment moves from motion sensors attached to the user's head or from remote control.

The researcher also developed several other projects that seek to impact society, such as a hydrocephalus diagnostic method, which is currently being tested and used by the Medical School of the University of São Paulo.

The entrepreneur, unlike the other researched in this paper, studied and developed all his research in a private education institution and stated that the encouragement of entrepreneurship and of the development of solutions for social and economic impact was very natural, different from the cases of public educational institutions.

4.4 New method of virtual reality execution using clusters

In his master's thesis, a researcher focused on developing a method of execution of virtual reality from clusters that allowed a greater speed for the method. The main innovation was a new algorithm to increase the speed of the tracing technique, which until then was very slow, despite the very superior quality. Such technique is widely used in films and special effects.

After developing such algorithm, the researcher had as objective to take what he developed in laboratory to the market. Initially a PIPE project was opened by FAPESP to fund and develop the company. While the project was not approved, the entrepreneur did specific projects in the area to generate his own income.

Once the funding was approved by FAPESP, the company was opened and began to develop projects in the area of virtual reality and image processing. Today, the company develops projects for several clients and has six specific products in the area.

In the opinion of the entrepreneur in this case, the main success factor was his resilience and willingness, since he obtained very little support to take his project to the market and open his own company. He testified that in many situations he was widely criticized for not wanting to pursue a purely academic career.

5. Results

The results evaluated in the case studies were based on interviews conducted using the "Data collection instrument." Those results were divided into two sections, "Quantitative results" and "Qualitative results."

5.1 Quantitative results

The quantitative results were based on direct questions based on bibliographical research. The five factors analyzed were: strategy, resources, infrastructure, reach and development.

Of the five macro factors analyzed, two stood out with an average above four points. “Resources” stood out, with 4.47 points, as the main factor that influences a research project to generate impact in society. This factor accounts which financial resources are available and how they are allocated. These financial resources do not necessarily come from university programs and research entities, but from own revenue generation.

The second macro factor that influences the impact of research projects is “Reach.” This includes how the research project, the laboratory and the university relate to external stakeholders. In other words, it assesses how the reach and relationship with clients, companies, society, alumni and others is given (Figure 1).

As presented in the research method, the macro factor of “Strategy” consists of three factors. The highlighted factor, with 4.52 points, is how the strategic objectives of the organization are presented in the leadership of the university. That is, in what concerns the impact on society of a research project, it is essential that there are figures of leaderships that influence and direct the researchers. Such leadership figures can be research coordinators, teachers, mentors or even departmental leaders. It can be observed that the mission and strategy of the university are not presented as essential factors (Figure 2).

The main factor related to “Resources” would be the own generation of income by the laboratory or the research project. This is due to the fact that for a project to have an impact on society, it must generate value and, thus, be able to generate its own resources.

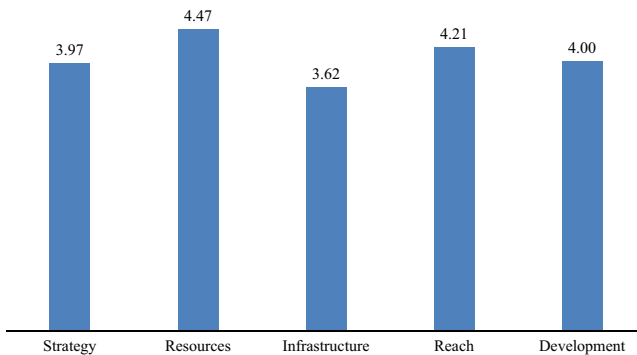


Figure 1. Result by macro factor

Source: Prepared by the author

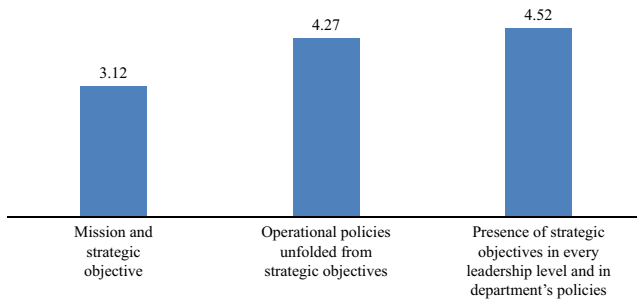


Figure 2. Result by factor related to strategy

Source: Prepared by the author

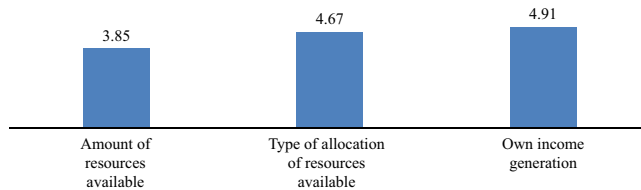
The government, the university and research promotion agencies will not be able to maintain the research project in the long term if there is no financial sustainability. In addition, it can be noted the amount of resources allocated by the university is not a relevant factor, with only 3.85 points, as it depends very much on how resources are allocated. That is, it is not enough to invest a huge amount of financial resources if it is not applied in a proper and useful way for the researchers and the research project (Figure 3).

Meanwhile, the macro factor “Infrastructure” highlights how structures for research and study of entrepreneurship affect projects. The relevance of this factor is due to the fact that the electrical engineering course is extremely technical and theoretical, so students and teachers do not have as much knowledge of the step by step to take to market, besides having few incentives to do so. Therefore, structures such as subjects, research and entrepreneurship clubs appear to be extremely relevant to the development of research that impacts society (Figure 4).

The macro factor of “Reach” would be the second most important to provide the practical application of the research project. This is mainly due to the involvement of the university and the research project with external stakeholders. Therefore, the relationship with the market, other companies, clients and investors is very important (Figure 5).

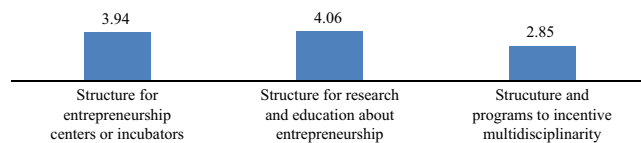
“Development” would be the macro factor that refers to the continuous improvement of research support programs by the university by the development agencies. It is noticed that in the same way, the measurement and the implementation of improvements appear as relevant (Figure 6).

Figure 3.
Result by factor
related to resources



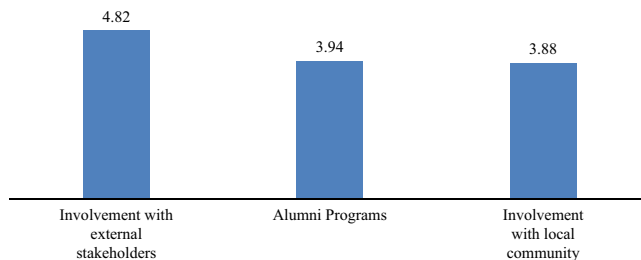
Source: Prepared by the author

Figure 4.
Result by factor
related to
infrastructure



Source: Prepared by the author

Figure 5.
Result by factor
related to reach



Source: Prepared by the author

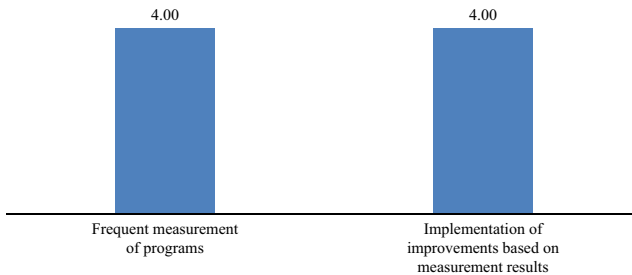
In order to understand the factors that most influence the impact on society of a research project, five items stood out. For the project to succeed, it should be able to have its own income generation, resources should be allocated in the right way, with a good involvement with the market, other companies and with customers. It is also necessary that such a scenario presents a background with university leaderships prepared to encourage and assists the researchers and students to undertake, in addition to clear operational policies from the Universities that allow such incentives (Figure 7).

5.2 Qualitative results

Of the four cases studied, three used the PIPE program of FAPESP to create their companies from research projects, highlighting the importance of structures and mechanisms. Thus, having promotion research agencies and the university concerned about society impact is extremely important to ensure that research conducted in laboratories generates social and economic development, as long as such concern is accompanied by clear operational mechanisms.

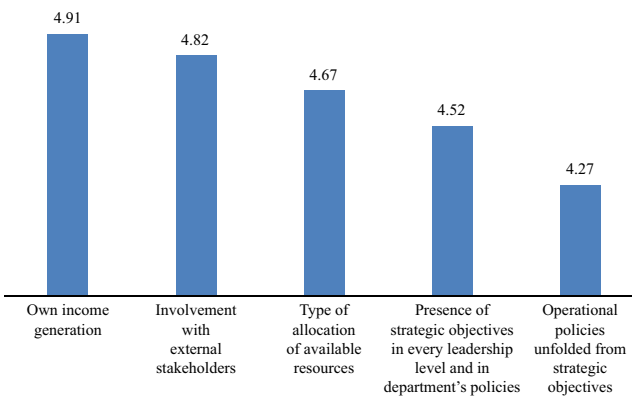
Development programs must also adapt to the real needs of researchers. All the cases studied emphasized the importance of programs that approach researchers and students and do not have large bureaucracies. PIPE, for example, is a program little known within the university and requires high level of bureaucracy.

Another factor pointed out as important by the researchers studied are the leaders who influenced their paths. They all pointed out a few people who were essential to the success of



Source: Prepared by the author

Figure 6. Result by development related factor



Source: Prepared by the author

Figure 7. Five factors with higher scores

their projects, usually the advisor or leaders of the research laboratory. Such leadership has the function of facilitating the research project path through market contacts or previous step-by-step experience.

Parallel to the incentive of laboratory leaders, incubator structures of companies also appear in a relevant way. In general, such structures are places in which entrepreneurs connect and form a network to support their companies' growth. Additionally, these structures are spaces more connected to the market and that usually help in a route of going to the market.

Finally, the most important point indicated by the researchers was their own will to undertake. In general, they were people with different life experiences and who at some point had incentives to go in that entrepreneurial direction. All pointed out that this type of experience does not happen in the traditional classroom, since the general culture that permeates these means is extremely academic.

6. Final considerations

This paper presented as main objective the understanding of what are the critical factors that lead an academic research project to achieve significant social and economic impacts. The importance of this theme comes from the significant Brazilian investment in R&D, about 1.3 percent of GDP in 2016. From a precise definition of such factors, it is possible to define the best way to allocate such investment, seeking the greater technological and economic return to the country in a practical way.

To reach this objective, the work focused on the concept of Entrepreneurial Universities in the bibliographic review. This concept accurately predicts which are the main factors that guarantee an efficient transfer of knowledge between the academic environment and the private sector, generating social and economic impact. The concept predicts that five key factors are key to success: strategy, resources, infrastructure, reach and development. They influence how the university prioritizes the incentive to entrepreneurship and helps to identify what needs to be done in order to the university achieve the title of "entrepreneurial university."

With such factors defined, there was also a search for the understanding of how the Brazilian situation is in this sense. It is noticed that in general the academic knowledge developed in the country comes from universities and public research agencies, which makes it difficult to transfer knowledge to private sector in many cases. Therefore, in this context, it is extremely important to create mechanisms to ensure that the university does not become an isolated environment. As an important step in the way of creating such mechanisms, a new framework for supporting technology and innovation was approved in 2018. The new science and technology decree deals mainly with stimuli for the scientific and technological development of the country. Among many other advances for the country's technological development, the mechanism allows public institutions to give space for business use, focusing on the construction of environments that promote innovation.

The paper also sought to focus on the concept of what is a successful research project within the context of university entrepreneurs. That is, what are the objectives and simple measurement criteria that prove its success, in terms of social and economic impact, of an electrical engineering thesis developed in the laboratory. From the bibliographic review, it was possible to identify three major milestones that should highlight this: number of patents developed, number of external financing and number of knowledge review by colleagues.

After such definitions, the research methodology was defined. It intended to understand what are the main factors, in the opinion of successful cases, that influence a successful research project. For this purpose, four cases of success were defined, which answered the interview guided by the research instrument developed. Based on the answers of each question, a weighting factor was applied according to the success obtained by such a project according to previously defined success criteria. In this way, it was possible to understand

quantitatively the main factors for the social and economic success of such projects. In addition, the interview also sought to understand qualitative success factors.

In the quantitative results, the importance of own generation of income from the research project is perceptible and to succeed in this criteria, the company also needs to be able to have a good relationship and contact with external stakeholders, such as customers and other companies. In addition to understanding the market and being able to generate its own revenue, a successful project also depends on good operational policies on the part of the university and of the development agencies (CNPq, FAPESP and others), since they are extremely relevant to put in practice the desire of the university to become an entrepreneurial one. Finally, another factor of extreme importance is the presence of strong leaders who influence and encourage students and researchers to have contact with the market and develop solutions that can be applied in a context larger than the academic environment.

It is interesting to note that although important, both allocated resources and university mission, appeared as secondary factors. According to the researchers, the main driver for success is the organization's culture and the factors previously cited. Therefore, it can be inferred that simply increasing investment in innovation in Brazil should not be enough for an efficient technological development, since there are many other factors and mechanisms that need to be rethought and addressed previously.

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