A CASE STUDY OF SCIENCE, TECHNOLOGY AND INNOVATION NETWORKS: THE TRIPLE HELIX AT PONTIFICIA UNIVERSIDAD CATOLICA DEL PERU

Francisco Cuellar and Domingo Gonzalez

Postgraduate School, Pontificia Universidad Catolica del Peru, Lima, Peru

cuellar.ff@pucp.pe (corresponding); dgonzal@pucp.edu.pe

ABSTRACT

In this paper we present an exploratory research to analyze the case of the innovation networks at Pontificia Universidad Catolica del Peru (PUCP), which is a promotor of the Triple Helix Model formed by government, industry and academy. After ten years of experience with government financing instruments, and private investment, the internal research and innovation system at PUCP has been capable to generate a network based on the Triple Helix Model. The methodology used in the present research combines: i) the revision of secondary sources related to university, industry and government documentation; ii) the revision of primary sources, from interviews to stakeholders, and the management of research and innovation office at PUCP, iii) analysis of social networks of innovation at PUCP with the Graphos Method, in order to find relationships and results from the stakeholders. We analyze the results obtained from the period 2008-2016 with one of the financing instruments from the Peruvian government, where the industry associates with the university. From the results obtained, it was possible to identify the principal funding resources, the type of relationships of the innovation networks at PUCP, how the internal and external financial instruments are used by the stakeholders, and the attitude towards future developments and improvements. Finally, a proposal to improve and strengthen the management of the Triple Helix Model at PUCP is presented. The aim is to strengthen its actual network, and provide information to other institutions for replication, in order to achieve social and economic development based on science, technology and innovation (STI) in the region.

Keywords: innovation networks, triple helix, knowledge management.

INTRODUCTION

Through world history, innovation has been a critical activity for the development of countries. The main reason for the governments in developing countries to pay attention, especially in innovation, is that it is a key driver of the economy. The knowledge generated by science, technology and innovation is of particular importance from the perspective of a developing nation, due to the fact that if these countries and their industries promote and execute policies to acquire and exploit this knowledge effectively, it could be used to improve the economic and social growth in the long term (The World Bank, 2010). Nowadays the concept of the Triple Helix, which promotes interaction among academy, industry and government for the generation of innovation, has been used worldwide as an operational strategy for the generation of wealth and promote sustainable knowledge-based economies. In Peru since 2008, the government is promoting financial instruments to increase the interaction between the three stakeholders of the Triple Helix, in order to stimulate the advancement of science, technology and innovation (STI) at national level. Through a variety of public policies, the government pursues to facilitate the execution and management of topics related to STI. Some of the initiatives are: the law of tax benefits for innovation (Law 30309); the law for innovation centers for production and technology transfer (Legislative Decree 1228), the strengthen of the National Council of Science, Technology and Innovation (CONCYTEC); and financing funds from national programs such as FONDECYT and Innovate Peru.

In Peru, according to the national innovation inquiry of industrial manufacturers (INEI, 2017), it is possible to identify the interest of companies in innovation topics, with 61.2% that performed innovation activities. The most developed activities by innovative companies are acquisition of capital goods, and training in innovation, with 72.3% y 38.8% respectively. The less influential activities were technology transfer, and activities related to external research and development (R&D) with 14.6% y 8.8% respectively. It is clearly observed that activities related to development of science and technology are the less influential in the interest of industrial manufacturers. According to the national inquiry for universities and graduate students (INEI, 2015), 82.0% of research projects are financed with the budget from the university, and the rest with funding from government programs such as Innovate Peru and FONDECYT. This suggests a minor quantity of projects oriented to the real requirements of the industry. The report of science and technology projects PROCYT (CONCYTEC, 2014) during the period 2006-2011, which includes projects of applied research (52%), basic research (44%), and technology development (4%), shows that 52% of the researchers manifest they are developing projects with private companies, and 7% with public companies.

The report of technology transfer from (CONCYTEC, 2016) concludes that the principal problem identified is the limited condition for the development of technology transfer in Peru. The direct causes for this problem are: i) the limited entailment among research centers and the productive sector; ii) the limited conditions for the management of technology transfer; iii) the insufficient mechanisms and instruments for the development of an institutional structure that promotes technology transfer and intellectual property; iv) and the limited conditions for the exploitation of STI results. The final effect of the identified problem is the low competitive level of the economy.

The central objective of the present research is to evaluate with an exploratory analysis the research, development and innovation networks at PUCP, product of the relationship in projects with industry and government according to the Triple Helix model. Specifically, the experiences obtained during the period 2011-2015 with funding from Innovate Peru, with its instrument for Projects of Production Innovation for Individual Companies(PIPEI) in association with PUCP. The specific objectives are: i) collect evidence of the type of collaborative relationship among academy, industry and government for STI projects; ii) analyze and evaluate the relations generated by the innovation networks at PUCP between the different areas of engineering and industry; iii) present a proposal to improve and strengthen the management of the Triple Helix model at PUCP.

In the first section of this document, the situation of the Triple Helix model in Peru is discussed and the objectives of the research are presented. In the second section, the theoretical framework is presented, which includes: the policies of science, technology and innovation (STI) in Latin America (LATAM) during the last seventy years; the situation of STI in Peru; the basic concepts of the Triple Helix model and Analysis of Social Networks (ASN). The third section describes the methodology of research of our proposal. In the fourth section, the results are presented, analyzed and discussed. Finally, in the fifth section, the conclusion and future work are presented.

THEORETICAL FRAMEWORK

Policies of Science Technology and Innovation in LATAM

The chronology of the evolution of policies for science and technology in Latin America (LATAM) is described in detail by Sagasti (Sagasti, 2011). He proposed that in the period of 1950-2000 the policies for STI were divided in five (05) stages: promotion of science, regulations for technology transfer, instruments for policies and focus on systems, adjustment and transformation of policies for science and technology, and systems of innovation and competitiveness. The Inter-American Development Bank presents and analysis of policies of innovation in LATAM (IDB, 2010), where three (03) areas of action are recognized: policies oriented to the offer (human resources, scientific capabilities, and infrastructure), policies oriented to the demand (business sector), and policies oriented to strategies and methods for coordination. These instruments had been implemented gradually in each country, and according to the interests of each nation. The first STI institutions created in LATAM were: Concejo Nacional de Investigaciones Cientificas y Tecnologicas (CONICET) in Argentina in 1958, Consejo Nacional de Desarrollo Cientifico y Tecnologico (CNPq) in Brazil in 1951, and Consejo Nacional de Ciencia y Tecnologia (CONACYT) in México in 1970.

During the first years, the public sector had the principal role to identify the priorities and determined the activities for STI (model of linear offer). However at the end of the 70s this model was disputed due to the non-articulated policies, and absence of mechanisms to stimulate the technological demand from the productive sector. This situation generated an idle scientific-technological potential, and important results from STI in the region were underutilized. Cimolli describes how with the changes during the liberalization of the economy, also a change in the formulation, design and implementation of policies for STI occurred (Cimolli, 2006). The changes were focused in the model of lineal demand, where the private sector is supposed to be the stakeholder that demands solutions of STI.

During the 80s the projects aimed to stimulate the demand for the progress of technology with fiscal incentives and other instruments for the promotion of activities of STI. The knowledge and innovation were supposed to be originated from the government and public institutions (side of the offer) towards the productive sector (side of the demand). It was thought that the scientific progress will transform automatically into technology innovation. The public funding was the major source of resources for STI (around 80%). The scientific and academic world defined the priorities of the economic resources, with a hierarchical management style, non-flexible and pyramidal. This model did not allow a dynamic response to the private sector and its technological demands.

During the 90s the aim was to promote the regional networks of STI, define priorities and strategies to enhance the participation of women in the development of STI, break the barriers between natural sciences and social sciences, integration of STI into the general culture, the necessity of preparing a new “social contract for science and technology”, promote intellectual solidarity and moral, and orientate the agenda of researchers as a function of the demand and requirements from the society. The model of the 90s emphasizes the role of the market demands as a priority. The demand of technology turned into the principal feature to define the priority of policies and funding assignment. Emphasis was placed in technology transfer, investment in efficiency and quality, provide technological services, under a logic of commercialization of knowledge and technology.

During the new millennium the region focused on the implementation of the ideas from the "social contract for science and technology", which promotes scientific activities related to the use of STI for a sustainable development of humanity.

The National System of Science, Technology and Innovation in Peru

A summary of the evolution of Peruvian innovation policy is presented in the study by Diaz (Diaz *et al*., 2010). First, in the 60s, there was a developing stage in which an institutional framework and sectoral vision was created. During the 70s, there was a systematic order of the national science and technology system and by the end of the decade the National Council of Science and Technology (CONCYTEC) is stablished. R&D expenditures reached its maximum during 1987, year in which it accounted of 0.23% of the GDP. At the end of the 90s and coinciding with the economic crisis, investments in STI also decreased, many researchers migrated abroad, and the academic excellence of universities was neglected. These left a STI system weak and vulnerable. In the year 1997 R&D expenditures were barely 0.08% of the GDP, compared to 0.53% within the region. Along with the recovery of the Peruvian economy and the decline of STI indicators, initiatives are launched to include, once again, a comprehensive scientific and technological policy within the national political agenda. In the year 2002, CONCYTEC drafted a National Emergency Plan in Support of Science, Technology and Innovation, with the support of several government sectors, private companies, universities, scientific institutions and professional associations. At the same time, a new law for the sector is drafted, which was enacted in 2004 (Law 28303, Framework of Science Technology and Technological Innovation). In 2005, the law of the National Council of Science, Technology and Technological Innovation (Law N° 28613) was enacted, which establishes and regulates the goals, functions, and organization of CONCYTEC. In 2005, CONCYTEC is annexed to the Ministry of Education.

The National System of Science, Technology and Technological Innovation (SINACYT), created by the Law N° 28303, is responsible of directing, promoting, organizing, supervising and evaluating the actions of the government throughout the country in the field of science, technology and technological innovation; guides the actions of the private sector; and executes supporting actions that promote the scientific and technological development of the country. Its governing body is CONCYTEC. SINACYT is defined as the set of institutions and individuals in the country, dedicated to Research, Development and Technological Innovation (R+D+i) in science, technology and its advancement. The Strategic National Plan for Science Technology and Innovation for Competitiveness and Human Development 2006-2021, establishes that it is necessary to contribute to a sustainable human development, through greater competitiveness, rational use of natural resources and environmental preservation. It considers the contributions and meets the demands of the actors involved from the State, academic and research institutions, and productive sectors (CONCYTEC, 2009).

In order to support the STI policies in Peru, it is necessary to understand the current problems within science, technology and technological innovation in Peru (CONCYTEC, 2016). The following problems have been identified: i) formation of scientific-technological knowledge: two (02) main causes have been identified: technological R&D results do not respond to the need of the country and insufficient incentives for STI; ii) formation of human capital: a main cause has been identified as an insufficient critical mass of researchers and qualified human resources; iii) technological infrastructure: three

(03) main causes have been identified: low quality levels of research centers and laboratories, insufficient information on SINACYT conditions, and deficient institutional and governance of SINACYT.

The National Policy for the Development of Science, Technology and Technological Innovation contains strategic objectives and guidelines that guide the actors involved to work in an articulated manner in STI activities in order to promote the country's sustainable development. The general objective of the National Policy is to improve and strengthen the performance of science, technology and technological innovation in the country. To achieve this objective, six (06) strategic objectives have been defined: 1) promote the development and transmission of scientific and technological knowledge, aligning the research results with the needs of the country, which will be defined with the sectors involved; 2) promote and develop new incentives that stimulate and increase STI activities; 3) promote the development of qualified human capital for STI; 4) improve the quality levels of research and technological development centers; 5) generate high quality information on the performance of SINACYT's stakeholders; 6) strengthen the institutions of science, technology and technological innovation in the country.

One of the main sources of financing is the National Fund for Scientific, Technological and Technological Innovation (FONDECYT). It is a component of CONCYTEC responsible for managing, overseeing and channeling resources from national and foreign sources, destined to the activities of SINACYT in Peru. In the 2008 to 2010 period, FONDECYT had an average of 1.95 million dollars. In Peru, private companies, whose independence from the State is not discussed, in general, show little interest in the topic of STI, and maintain a historical distance with Universities and with the public organisms dedicated to the subject. In this context, innovation is certainly not a vital need for companies (Villaran, 2010). That is why in July 2006 the National Program of Science and Technology was created, which is in charge of the National Science and Technology Fund (FINCYT). This fund manages 36 million dollars (25 come from a loan from IDB, and 11 from the public treasury) with the objective of financing innovation projects in companies, research projects in universities and research centers, and the strengthening of SINACYT.

In 2009, the Research and Development Fund for Competitiveness (FIDECOM), with a support of 200 million soles, was launched. The objectives of the fund are: i) to promote the productive R + D + i of the productive sector, and ii) to develop and strengthen the capacities to generate and apply technological knowledge for innovation and the development of productive capacities of workers and managers of microenterprises. An advantage of the fund is that if it is carried out in partnership with academic entities, co-financing can be up to 75% of the total amount of the projects. In July 2014 (Supreme Decree N ° 003-2014-PRODUCE), the Innovation for Competitiveness and Productivity (Innóvate Peru) program was created as the executing unit of the Ministry of Production. Its main objective is to increase business productivity by strengthening the actors of the innovation ecosystem in Peru (companies, entrepreneurs, and support entities). Currently, it manages the following funds: FINCYT 2, FIDECOM, FOMITEC and MIPYME. In 2016 a contract was signed for the project to improve the levels of productive innovation at the national level, where a loan of 40 million dollars from the IDB and a counterpart of 60 million dollars from the Treasury was obtained (INNOVATE PERU, 2017).

In the period from 2007 - 2016, Innovate Peru has co-financed approximately 2,500 projects, with 487 million soles granted. 50% of innovation projects come from within the country, and 60% are driven by MSMEs. The 70% of the projects are executed in partnership with universities. Finally, twelve (12) business incubators and accelerators have been strengthened.

The Triple Helix

Etzkowitz presents the Triple Helix Model (Etzkowitz *et al*., 1997), where the promotion of high-technology innovation is a reality whenever there are interactions among university, government and private industry. It proposes that the university assumes part of the role of companies, that it be involved with the industry and that public administrations and government intervene and provide financial resources. Due to the increase of the participation of universities in business activities, it can be concluded that the capitalization of knowledge is obtaining precedence over the disinterest in capitalization as the norm of science (Etzkowitz *et al*., 1998). This case is clearly reflected in the United States of America, where the change in the norm led to: the dynamics of entrepreneurship activities with the academia, the work of technology transfer offices, and governmental regulations which finances scientific research activities with high economic and technological potential (Leydesdorff, 2003). It concludes that, in order to promote and create an entrepreneurial environment, it is necessary to: i) establish spin-off companies as a result of developments within the university; ii) undertake knowledge-based economic development initiatives, such as science and technology parks, together with business incubators; iii) form strategic alliances with companies (large and small, in different territories, with different levels of technology); iv) create hybrid institutions that function as interfaces; v) sign research and development contracts with governmental institutions of public research and academic research groups.

In several countries the concept of the Triple Helix has been used as an operational strategy for regional development and to create a knowledge-based economy (Jacob, 2006). In Portugal, for example, the University of Coimbra has been effective in promoting the regional dynamism of innovation and entrepreneurship of the multiple innovation networks established in the region (Marques *et al*., 2006). The study presented by (Diez-Vial *et al*., 1997) confirms, with evidence collected from the Madrid Scientific Park, that long-term (formal and informal) relations between universities and firms located within the scientific park are the most relevant means to obtain a technological transfer. The most representative case in Latin America is Brazil, where the Triple Helix has become a movement that generates incubators in the university context (Almeida, 2005).

The relationships and different configurations of the Triple Helix have been studied and compared historically (Albornoz, 2006). Figure 1 shows different cases at the level of an institutional perspective and are described as follows. The first configuration reflects a statist regime where the government has the main role, limiting its capacity to generate new innovations (Russia, China, and Eastern Europe). The second configuration represents a relationship where the state has a "let-do" intervention in the economy, and the industry has the main role, with the other two support structures (United States, Western Europe). The third configuration is a balanced regime, where the three of them work together and lead joint initiatives. This last configuration allows the creation of new tri-lateral networks and hybrid organizations, which allow the creation of new technologies, new companies, and new relationships in a systemic way.

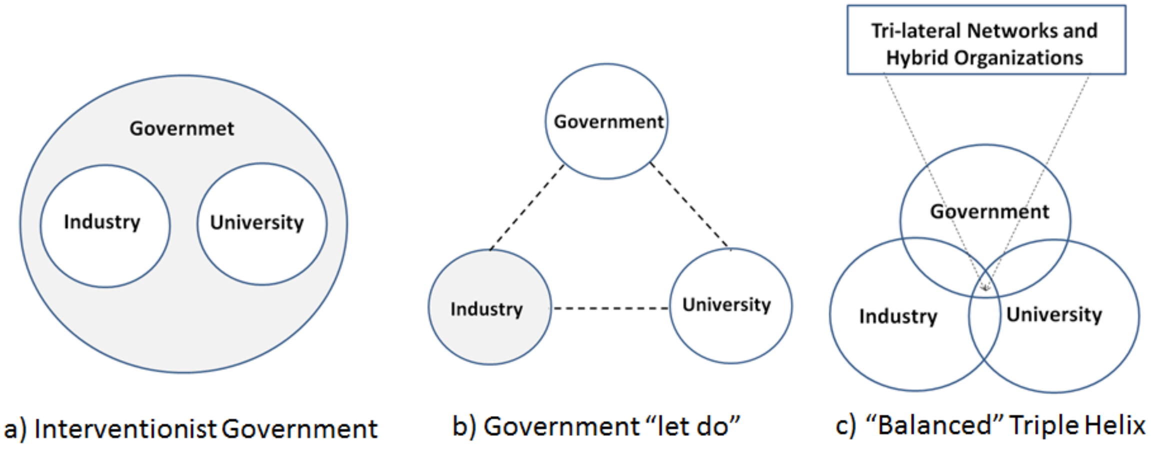


Figure 1. Configurations of the Triple Helix (Albornoz, 2006).

The Triple Helix System as an analytical construct, is defined from the perspective of systems theory, which contains: i) Components: universities, industry and government, each one with several actors; ii) Relationship between components: collaboration and moderation of conflicts, collaborative leadership, substitution and networks; iii) Functions: described as the group of specific activities of the spaces of the Triple Helix (knowledge, innovation and consensual spaces).

Theory of Analysis of Social Networks

The diffusion of innovation is a sociological theory that explains how, why and at what speed new ideas and technologies are transmitted. The research from (Rogers, 2009) defines the diffusion of innovation as a process that occurs between the members of a social system, in time and through certain channels. Christakis and Fowler (Christakis *et al*., 2009), indicate that the basic principles of a network are: the actors that shape social networks, the networks to which they belong influence what one is and what one does, the actors with whom one establishes direct links influence in the behavior and way of thinking, the actors with indirect links also influence in the behavior, and the social network is more than the sum of its parts. A complex system consists of several elementary components that interact locally with each other and with the environment. The main characteristics of a complex system are that they are: connected, interdependent, diverse, adaptable, depend on the channel, emerging (Scott, 2000). The main types of data in a social network are: i) attribute data, which are related to attitudes, opinions, behaviors of the components; ii) the data of network links, such as contacts, connections and links related to the actors. Both databases are usually collected through interviews, surveys, observation of participants and documentary sources (Hilbert, 2013).

The *analysis of social networks* (ASN) is responsible for analyzing networks through Network Theory or Graph Theory. The study focuses on the association and measurement of relationships and flows between the components. The analysis of social networks provides visual and mathematical tools for the study of human relationships. Next, some concepts and terminologies of the graph theory are described for the analysis of the structure of a network:

i) Type of Graphos:

A graph $G (N, R)$ consists of two (02) sets of information: a set of nodes $N = \{n_1, n_2, ..., n_N\}$, and a set of relations between pairs of nodes $R = \{r_1, r_2, ..., r_N\}$. In a graph each relation is a non-ordered pair of nodes $r_k = (n_i, n_j)$. The relation is non-ordered when the relation between n_i and n_j is identical, that is, $(n_i, n_j) = (n_j, n_i)$. Let R be a set of edges (non-ordered pair of nodes), and N the number of nodes, there are $N(N-1)/2$ possible edges in R. The *weighted graphs* are the appropriate representation of the weighted relationships with a numerical value, where the relationship carries a value or weight. The weighted graph consists of three (03) sets of information: nodes $N = \{n_1, n_2, ..., n_N\}$, relations $R = \{r_1, r_2, ..., r_N\}$, and values or weights $W = \{w_1, w_2, ..., w_N\}$, associated with relationships. The notation is $G_W (N, R, W)$. In an *oriented graph* the directions of the relationships are specific. These oriented relationships are called arcs (ordered pair of nodes) and reflect the direction of the link. The oriented graph $G_D (N, R, W)$ consists of a set of nodes $N = \{n_1, n_2, ..., n_N\}$, and a set of arcs $R = \{r_1, r_2, ..., r_N\}$. Each arc is an ordered pair of nodes $r_k = <n_i, n_j>$. The direction of the arc $<n_i, n_j>$ goes from n_i (the origin or emitter) to n_j (the end or receiver).

ii) Referential Concepts:

The *degree* of a node is the number of nodes adjacent to this node, or number of relations incident within it. The *out-degree* is the number of arcs originating from n_i, and the *in-degree* is the number of arcs ending in n_i. The out-degree of a node, $d_{out} (n_i)$, is the number of adjacent nodes from n_i. A *path* is a succession of nodes such that from each of its nodes there is an edge towards the successor node. The *diameter* of a graph is the largest distance between two nodes of the graph. The *intermediation* means that an actor is between two actors in the network. If the control of communication is of interest, the intermediation measure is imposed. The *proximity* is the distance between an actor and the rest of the network. If the independence of an actor is of interest, the measure based on proximity is imposed.

iii) Type of Relations:

Null is when no arc exists, when none of the arcs $<n_i, n_j>$ nor $<n_j, n_i>$ is contained in the set of oriented relations R. An *asymmetric pair* of nodes has an arc between the two nodes going in one or the other direction, but not in both directions simultaneously, this means $<n_i, n_j>$ or $<n_j, n_i>$ is contained in the set of arcs of R. It is represented as $<n_i \rightarrow n_j>$ or $<n_j \rightarrow n_i>$. The mutual or reciprocal pairs of nodes have two arcs between them, one going in one direction and the other coming in the opposite direction. That is, $<n_i, n_j>$ and $<n_j, n_i>$ are contained in the set of arcs of R. It is represented as $<n_i \rightarrow n_j>$ and $<n_j \rightarrow n_i>$.

iv) Types of Nodes:

The *isolates* nodes do not present relationships of any kind. Formally, if $d_{in} (n_i) = d_{out} (n_i) = 0$. The *transmitters* have relations originating from them only. Formally, if $d_{in} (n_i) = 0$ y $d_{out} (n_i) > 0$. The *receivers* only have relations ending in them. Formally, if $d_{in} (n_i) > 0$ y $d_{out} (n_i) = 0$. The *carriers* are those that originate and receive relations or links. Formally, if $d_{in} (n_i) > 0$ y $d_{out} (n_i) > 0$.

v) Structural Properties:

The *centrality degree* privileges the local point of view and measures the communication or exchange capacity of each node within the network, not considering its capacity to control communications. It is an index of the communication potential. It is presented in equation (1), where $a(n_j, n_i)$ is 1 only if n_j and n_i are connected by a line, 0 otherwise.

$$C_G(n_i) = \sum_{j=1}^{N} a(n_j, n_i); \quad C_G^{Nor}(n_i) = \frac{C_G(n_i)}{N-1} \qquad (1)$$

The *centrality of intermediation* refers to the frequency with which a node or actor is between a couple of other nodes in the shortest or geodesic path connected to them. This type of node exhibits a potential to control the communication. This individual can be an intermediary for the members of a network, and influence the group by filtering or distorting the information. It is presented in equation (2), where $N_{jk}(n_i)$ is the number of geodesics joining n_j and n_k that contain n_j, and N_{jk} is the number of geodesics that join n_j and n_k.

$$C_I(n_i) = \frac{\sum_{j}^{N} \sum_{<k}^{N} N_{jk}(n_i)}{N_{jk}}; \quad C_I^{Nor}(n_i) = \frac{2C_I(n_i)}{(N-1)(N-2)} \qquad (2)$$

The *centrality* of *proximity* is a more global measurement that is based not only on connections of an individual to its neighborhood, but in its proximity to all the members of the network. This centrality is also related to the control of communication, but unlike the centrality of intermediation, the node is seen as central to the extent that it can avoid the possible control of others. It is presented in equation (3), where $d(n_j, n_i)$ is the number of connections in the geodesic that join n_j and n_i.

$$C_P(n_i) = \left[\sum_{i=1}^{N} d(n_j, n_i) \right]^{-1}; \quad C_P^{Nor}(n_i) = \frac{N-1}{\sum_{i=1}^{N} d(n_j, n_i)} \qquad (3)$$

The *density* of a network is the proportion of existing links compared to the possible links. It is defined as the number of effective relations *R* between the number of possible relation that can be *N(N - 1)/2* for not oriented links and *N(N - 1)* for oriented links. This term allows to measure the relatively linked areas of the network, and to detect a neighborhood or clusters of a given node. The mathematical definition is presented in equation (4).

Oriented Graph (G_o) $$D(G_o) = \frac{R}{N(N-1)} \qquad (4)$$

METHODOLOGY

Context at PUCP

In Peru, the university primarily has an academic mission, but is currently adopting a function of generator of knowledge, and is evolving to become an entity that directly contributes to the economic and social development. The Institutional Strategic Plan of 2011-2017 of PUCP assumes its commitment to human development through the generation of knowledge and promotion of research, which is reflected in its scientific production at the national level. PUCP has a Vice-Rectorate of Research (VRI), created in 2009, which has the task of encouraging, financing, coordinating and disseminating the research efforts carried out at the university. The Direction of Research Management (DGI) is a dependent instance of the VRI responsible of designing, formulating, and implementing the policies of the VRI, as well as to offer operative support to all its initiatives. Some of the tasks of the DGI are to centralize the information on the research production of PUCP, administer the financing of research projects that the university supports with internal and external resources, and perform a qualitative follow-up that guarantees the quality of the results.

In 2011 within the DGI, the Office of Innovation (OFIN) was created, with the function of acting as a hinge between the researches developed in the university, public funds and the private sector. It seeks to foster an association between researchers and the industrial sector for a reciprocal and lasting exchange of knowledge. The OFIN supports researchers and industrial sector to present the projects in practical terms of supply and demand, determine feasibility, and establish the innovative qualities of a research and development project. This is achieved with the support of procedures and methodologies for the valorization of the technology, promotion of technological transfer packages, dissemination of projects, and management of innovation networks. With more than 9 years of experience in the field of research with public funds, PUCP has been able to generate an innovation network that is the result of relations between university, industry and government, the three principal actors of the Triple Helix.

Methodology of Research

The central objective of this study is to evaluate with an exploratory analysis the results obtained by the PUCP in R&D and Innovation projects product of the Triple Helix relationship, specifically the experiences obtained in the period 2008-2016 with innovation funds PIPEI (Projects of Pruduction Innovation of Individual Companies) where the companies were associated with PUCP. The specific objectives will be: i) Collect evidence of the type of collaborative relationship that exists between university, industry and state for STI projects; ii) Analyze and evaluate the interrelations generated by the innovation networks in PUCP, between the companies and the engineering specialties of the university; iii) Present a proposal to improve and strengthen the current management system for innovation and technology transfer at PUCP. The tools to be used in the present exploratory research are described as follows:

- Information from secondary sources will be analyzed, such as: the National Survey of Innovation in the Manufacturing Industry 2015 from INEI (National Institute of Statistics and Informatics), the report of Technological Innovation in the Manufacturing Sector 2013 from CONCYTEC, the National Survey to University Graduates and Universities 2014 from INEI, the Characterization of the Science and Technology Projects PROCYT 2011 of CONCYTEC, and the Book of the Special Program of Technology Transfer 2016 from CONCYTEC, which will allow to obtain evidence on university, industry and state relations.
- In order to analyze and evaluate the innovation networks generated in PUCP, indicators of the Direction of Innovation Management of PUCP will be reviewed, and it will be complemented with primary information analysis through information provided directly by inquiries to the actors involved.
- Analysis of social networks (ASN) will be used through the Graphos Method, together with the network visualization tool Gephi (https://gephi.org/), in order to study and describe the relationships established between PUCP, industry and government.

Data Collection and Variables of Study

The information of the innovation network with companies and researchers is provided by the Office of Innovation from PUCP and through surveys to researchers and companies that have worked directly with the university. The actors considered were the researchers from the faculty of Science and Engineering that work in association with companies that received funding form the government program “Innovate Peru”, specifically the PIPEI instrument (Production Innovation for Individual Companies), during the period 2011-2015. The population of researchers that meet these characteristics are 26. It was estimated that the minimum sample size with a confidence ratio of 95% and a margin of error of 5% is 19 researchers.

The surveys pursue to answer questions such as who, what, where and how much, with respect to the habits and characteristics of the collaboration among researchers (Ponce, 2015). For the structure of the survey of the researchers at PUCP, the researcher's profile, research experience, scientific collaboration, opinion on the university-company relationship were included. Regarding the type of collaboration, two extremes were proposed according to the study by Hara et al. (Hara, 2003). It identifies the most basic type of collaboration called "consultations or exchange of information" that require complementary knowledge or skills among researchers; and the other extreme is that of "Research Groups", where, according to the authors, it is required, in addition to the compatibility of personalities, to participate actively, refine ideas and analyze results. The table of scores to assign weights to the type of relationship is shown in Table 1.

The metrics for the Analysis Social Network (ARS) theory will be used to understand the interaction of networks. The interactions will be considered asymmetric, that is, if n_i considers n_j as a source of information, not necessarily n_j considers n_i in the same way, $<n_i \rightarrow n_j> \neq <n_j \rightarrow n_i>$. Once the network is formed, the following parameters will be analyzed: *network size, out-degree and in-degree, geodesic, centrality of degree, centrality of intermediation, proximity centrality, and density* of the network. Finally, the link with the productive sector is analyzed from the perception of the researchers with respect to the expected results of joint work and the limitations to achieve them.

Type of collaboration	Consultancy/ Exchange of information	Course, workshop, symposium	Services	Research Project	Conference Publication	Indexed Publication	Research Group
weight	1	2	3	4	5	6	7

Table 1: Distribution of weights according to the type of relationship.

ANALYSIS AND DISCUSSION OF RESULTS

Analysis from Secondary Sources

According to the National Innovation Inquiry of Industrial Manufacturers (INEI, 2017), from the expenses and investments executed by the companies in activities of innovation 73.8% was invested in acquisition of capital gods, and only 3.3% and 0.7% in technology transfer and external R&D. The financial sources are own resources (83.4%), private resources (64.8%), and government funding (4.0%). The principal agents that collaborate with the innovative private sector are suppliers (43.6%), clients (41.3%), and in a minor proportion technical institutes (18.7%), universities (6.9%), private research institutes (3.6%), and public research institutes (2.3%). From the analysis it is observed that the expenses in capital gods surpass by far the expenses in technology transfer and R&D, this situation could be a great disadvantage, due to the fact that the last mentioned activities could generated mayor added value to the companies. The slight of use of financial instruments from the government could be attributed to a reduced diffusion and lack of confidence in the government. There is not enough collaboration with institutions of scientific and technological base, and this could be attributed to the elevated costs of innovation (38.9%) and economic liquidity (33.6%), which were mentioned by the industrial sector as the principal obstacles for innovation.

According to the National Inquiry for Universities and Graduate Students (INEI, 2015), from 82 universities, 82.0% of research projects are financed with the budget from the university, and 20% with funding from government programs such as Innovate Peru (FIDECOM, FINCYT) and FONDECYT. This suggests a minor quantity of projects oriented to the real requirements of the industry, and that a strong relationship with the productive sector is not promoted. It is necessary to promote the investment of the business sector, so that the knowledge generated by universities attends the requirements of the market demands.

The report of Science and Technology Projects PROCYT (CONCYTEC, 2014) during the period 2006-2011 and a population of 67 researchers, which includes projects of applied research (52%), basic research (44%), and technology development (4%), shows that 52% of the researchers manifest they are developing projects with private companies, and 7% with public companies. From that group 86% declared that they are satisfied with the relationship. This is an indicator of the positive attitude towards collaboration with the productive sector. The main reasons to be involved with the industry are: demand of research, find technical solutions, and provide human resources highly qualified. From the group 80% of researchers obtained as results publications in indexed journals, national and international congresses, posters, and specialized manuals. However, 86% reveals that no intellectual property results were obtained, and 46% of them declare to ignore intellectual property instruments. These results demonstrate that there is a gap between knowledge generated, intellectual property, and technology transfer.

The report of Technology Transfer from (CONCYTEC, 2016) concludes that the principal problem identified is the limited condition for the development of technology transfer in Peru. The final effect of the identified problem is the low competitive level of the economy. The direct causes for this problem are:

i. *The limited entailment among research centers and the productive sector*. It is necessary to strengthen the link between offer and demand of science, technology and innovation, a key activity for this is the Technology Transfer. It is necessary to promote spaces for interaction for industry sector, the academy, and the government (conferences exhibitions, forums, others). All the information about events has to be visible and systematized (virtual platforms of Technology Transfer, portfolio of technology demand, portfolio of technology transfer).

ii. *The limited conditions for the management of technology transfer*. There are eighteen (18) diplomat and five (05) master programs oriented to management of innovation, however, only one (01) master program is specialized in intellectual property, but none of the group in transfer of technology.

iii. *The insufficient mechanisms and instruments for the development of an institutional structure that promotes technology transfer and intellectual property*. At national level, from 142, only 10 count with a policy for intellectual property and 4 with procedures for technology transfer. About public research institutes only 3 count with a policy for intellectual property and 1 with procedures for technology transfer

iv. *The limited conditions for the exploitation of STI results*. It is mainly due to the limited funding for technology transfer, and limited incentives for the creation of university spinoffs. The financed entrepreneurships with the programs “Ideas Audaces”, support ideas with high social impact, but not necessarily with impact in the market demand. The program “StartUp Peru” had supported 172 entrepreneurships until 2016, however, the financial amount (USD 15000) and time (1 year max.) to accomplish the ideas do not respond to the requirements of entrepreneurships with scientific and technology base.

The Special Program of Technology Transfer defines the general and specific objectives until 2021. The general objective is to generate the conditions for the development of Technology Transfer in Peru. The specific objectives to achieve this goal are: promote the adequate mechanisms for the link between academy and industry, generate sufficient conditions for exploitation of STI results, generate capabilities for human resources related to management of technology transfer, and promote mechanisms and instruments for the institutional development of the technology transfer.

Analysis from Primary Sources at PUCP

The funding obtained from the government programs are: FINCYT with 34.527 million soles (USD 10.46 million) in the period 2007-2015, FONDECYT with 14.969 million soles (USD 4.54 million) in the period 2013-2015, and FIDECOM with 31.741 million soles (USD 9.62 million) in the period 2010-2015.

The FIDECOM program is the most representative in terms of projects that involve association with the productive sector, and has the following instruments: Projects of Production Innovation for Individual Companies (PIPEI), Projects of Production Innovation for Associated Companies (PIPEA), Projects of Innovation for Individual Companies (PITEI), Minor Projects for Production Innovation (PIMEN), Associative Projects for Technology Transfer in Microbusiness (PATTEM), Projects for Validation and Packaging of Innovation (PVEI), Projects of Technology Innovation of High Impact. The instruments obtained from FIDECOM are: 38 PIPEI projects, 23 PIPEA projects, 18 PIMEN Projects, 06 PITEI projects, 02 PATTEM projects. Due to the amount of Projects of Production Innovation for Individual Companies (PIPEI), in the following section of analysis of social networks (ASN), this group will be analyzed.

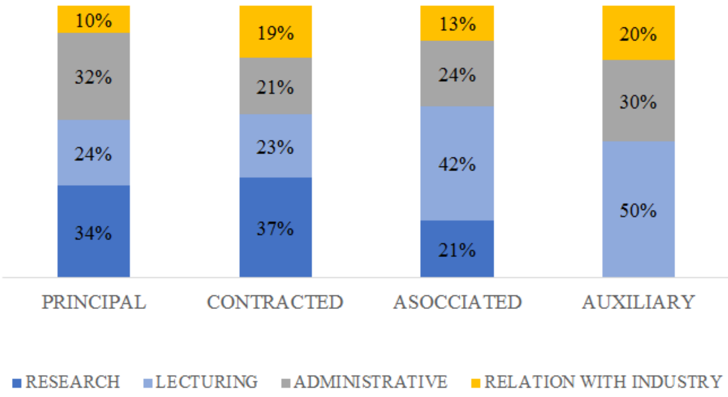


Figure 2: Distribution in % of activities from researchers.

A disadvantage of the funding obtained from the government, is that they depend from public policies and the current government. If there is a significant reduction in this budget, there will be a negative impact in the external funding for STI projects. It is necessary to promote the support with financing from the productive sector, in order to guarantee the sustainability in the long term of science, technology and innovation projects. Therefore it is highly important to obtain positive results to strengthen the link between industry and academy.

Analysis of Social Networks (ASN) at PUCP

The present result is based on the interview of twenty (20) researchers, being the minimum of the sample nineteen (19) of the total population, in order for the results to be considered reliable. From the interview 50% of the researchers are younger than 50 years, and an important 35% are younger than 40 years. According to a study from CONCYTEC the media for Peruvian researchers is 51 years, which is considered as a late start for a career in research, due to the fact that there will be only a few years for scientific productivity.

The department of engineering is divided in sections, and from the analysis it was obtained that from the majority, eight (08) are from mechanical engineering (40%), and six (06) are from electronic engineering (30%). A question to identify how their time is distributed was applied (activities of research, lecturing, administrative, relation with industry). Additionally the hierarchy for the position of professor as PUCP is as follows (ascendant order): Contracted, Auxiliary, Associated, and Principal. The results are presented in Figure 2, Principals and Contracted dedicate more than a third of their time to research activities; Contracted and Auxiliaries dedicate around 20% to activities related to relations with the industry in different modalities.

From the results of collaboration with industry, 95% of researchers confirmed that they collaborated with productive sector in the last 5 years. This is an important result, as it shows a high level of relationship with the industry. The three (03) principal reasons for the relationship are: advice and technology support, collaborative research, and external research. However, business training and mixed centers were not mentioned as mechanisms of collaboration. In 73% of the cases, the researchers manifested that the relationship with their respective industry collaborator was “good or very good”. However, 53% of the cases did not maintain contact with the company after their respective project was finished. The three (03) principal achievements mentioned were: motivation to develop new projects with industry, patents, and scientific publications.

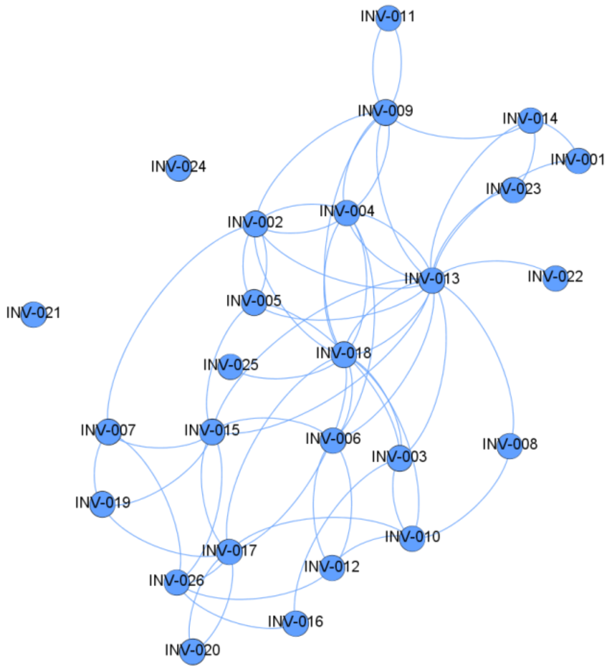


Figure 3: General ASN Graph of researchers from PUCP (related to PIPEI projects)

The sections from the Department of Engineering at PUCP, and number of researchers that integrate this network are: mechanics (08), electronics (06), industrial engineering (02), informatics (02), mechatronics (01), and telecommunications (01). It is important to mention that this network is not formally constituted. However, the revealed information in the present study, allows measuring the collaboration and identifying the principal characteristics of the actors that conform the network.

The information obtained not only allowed to determine the link between the participants, but the type of relationship among the actors. The information was entered to Gephi (https://gephi.org/), with the objective to build the network and be able to analyze according to the indicators proposed in the methodology (*network size, out-degree and in-degree, geodesic, centrality of degree, centrality of intermediation, proximity centrality, and density of the network*).

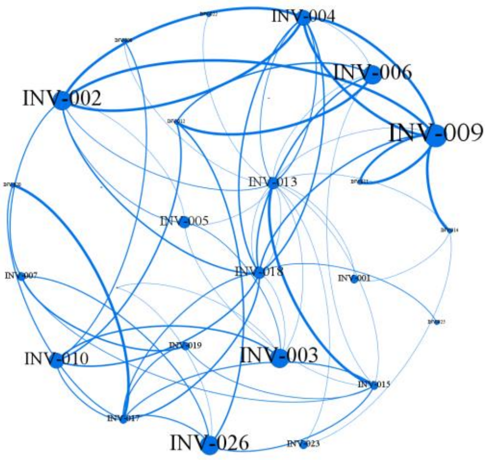
Previous to discuss the results from the ASN, it is interesting to compare the perception and the reality about the level of *real scientific collaboration* among the actors. From the Likert scale about collaboration with pairs, 75% of the researchers declared that they have a high to medium level of collaboration with the others. However, this perception does not correspond to the reality if we just observe the total network presented in Figure 3. Although there are some articulated nodes in the network, two (02) of them (10%) are not connected to the group, and work completely isolated. The measurements, that will be discussed further, corroborate this observation to conclude that the Research Network at PUCP with projects in collaboration with industry (PIPEI) is still incipient. This not only due to the amount of links, but the strength of each link as well.

Next, an analysis about the measurements obtained is presented. For each indicator a network graph is presented and the results are interpreted from the point of view of the theory of Analysis of Social Networks.

In-degree: the links entering to a node are the referrals from the members of the network about a specific actor on the analyzed network. Figure 4 presents the graph result and its respective table with the five (05) researchers with the highest in-degree or d_{in} (n_i). The explanation of the table is that a total of six (06) researchers mentioned a type of collaboration with INV-009; three (03) of them are form the same section (Electronic Engineering).

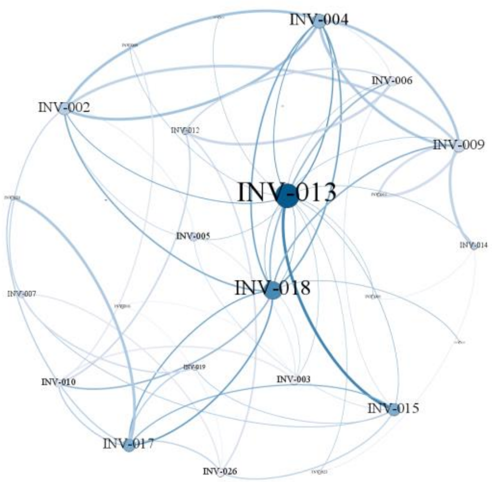
Out-degree: when a researcher responds to the question: which researchers did you collaborate in the las 5 years? The answer is the output links to other nodes or actors. Figure 5 presents the graph result and its respective table with the five (05) researchers with the highest out-degree or d_{out} (n_i).

It is interesting to mention that none of the top in-degree researchers are coincident with the top out-degree researchers. This occurs due to the fact that an actor that mentions collaboration with other, not necessarily will be mentioned by the latter. During the interview to each participant, the list of the 26 researchers from the network was shown. And then, it is not possible to attribute the response to a memory aspect.



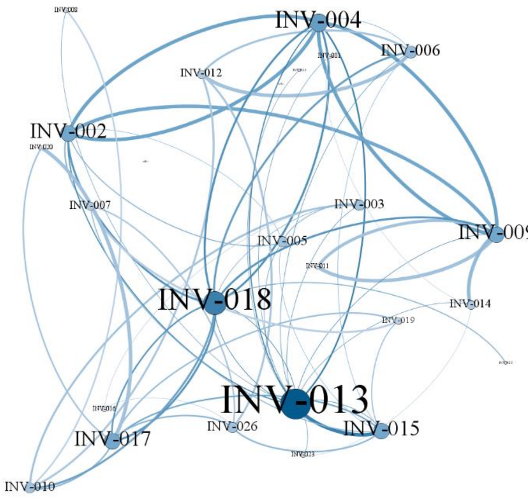
Label	Section	indegree
INV-009	ING. MECHATRONICS	6
INV-002	ING. ELECTRONICS	5
INV-006	ING. MECHANICS	5
INV-003	ING. ELECTRONICS	5
INV-026	ING. MECHANICS	5

Figure 4: Graph of the network based on the in-degree.



Label	Section	outdegree
INV-013	ING. INDUSTRIAL	13
INV-018	ING. MECHANICS	9
INV-015	ING. MECHANICS	6
INV-017	ING. ELECTRONICS	6
INV-004	ING. ELECTRONICS	5

Figure 5: Graph of the network based on the out-degree.



Label	Secion	degree
INV-013	ING. INDUSTRIAL	16
INV-018	ING. MECHANICS	12
INV-004	ING. ELECTRONICS	9
INV-015	ING. MECHANICS	8
INV-017	ING. ELECTRONICS	8
INV-002	ING. ELECTRONICS	8
INV-009	ING. MECHATRONICS	8

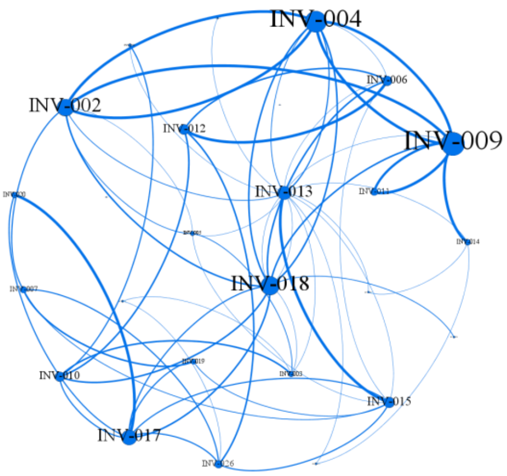
Figure 6: Graph of the network based on its centrality degree.

Centrality degree: represents the total number of links to a node or actor. In Figure 6 it is possible to observe a graph of each node with different size depending on their degree. The media of the degree is 4.8, which implies that each node from this network has at least three (03) links. This is a low value considering that the total number of links for 26 nodes could maximum 100. The comparative analysis of the degree of each node allows identifying the actors that have a better position in the network. In this sense, the respective table of Figure 6 shows the nodes with highest degree (in-degree + out-degree).

Geodesic distance: a distance of 2.7 was founded. This implies that in average a researcher is positioned three (03) researchers away from any colleague. In practical terms, due to the low level of integration of the network, a researcher will require to contact at least two intermediaries in order to reach a colleague of his interest. If we consider that the researchers from the different sections are physically near and in the same campus, this result is obtrusive.

Density: the value obtained is 9.5%. From the 650 possible relations between researchers, there are only 62. This is a network with a low level of connectivity. It is important to mention that at this level the type of relation is not evaluated, but only the existence. Then, there is an opportunity to execute a plan for the development of the network.

Weighted Graph: it is important to differentiate between the type of relations that require only a consultancy or exchange of information, and the relations that require a higher level of integration such as being part of a research group. Figure 7 presents the graph result and its respective table with the five (05) researchers with the highest weighted value in the network. This means strong links based on research projects together, scientific publications and relationship in a research group at PUCP.



Label	Section	weighted degree
INV-009	ING. MECHATRONICS	46
INV-004	ING. ELECTRONICS	42
INV-018	ING. MECHANICS	36
INV-002	ING. ELECTRONICS	33
INV-017	ING. ELECTRONICS	29

Figure 7: Graph of the network based on the weights.

CONCLUSIONS

From the numbers presented in the analysis of secondary information, it is possible to observe that it is of high importance to strengthen the links between offer (academy) and demand (industry) of science, technology and innovation. A key activity to achieve this goal is the Technology Transfer. The government is already offering financial instruments for this, but the industry sector still do not use this opportunity. It is necessary to promote spaces for interaction, such as workshops, technology fairs, and symposiums of STU; and systematize and present the information through appropriate virtual platforms.

The principal external funding for research in science, technology and innovation in PUCP is provided by the government. Specifically, the funding for collaboration with industry represents 43% (USD 9.62 million) of the total, and is represented by the instruments from FIDECOM program. The disadvantage on depending in this funding is that it depends on public policies and the current government. It is necessary to promote private financing from the productive sector, in order to guarantee the sustainability in STI projects.

The analysis of social network concludes that the level of connectivity of the PIPEI network (non-formal) of researchers from the Engineering Department at PUCP is incipient, with a density of 9.5% of the total possible relations between researchers. This is opposite to the perception of the 75% of researchers that consider having a high or medium level of collaboration. About the relation with industry, 73% of the researchers manifest to have at least a good experience with industry, however 53% did not continue in contact with the companies once the project was finished. It is possible to identify a potential opportunity to strengthen the network of the Triple Helix, in order have a long term relationship and promote further collaboration to bring new investments in projects of STI.

Future work will consist to analyze the network of companies that worked with the interviewed researchers, in order to find a cross correlation between the two groups. The work could be expanded not only to the total projects under the PIPEI funding, but include other financial instruments from FIDECOM, which is related to the association industry-academy funded partially by the government.

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