Open Innovation in the Latin American Public University

José J. González Millán, Miryam Teresa Rodríguez Díaz, Oscar U. González Millán

[1]Ph.D. in Management from Universidad Autónoma de Querétaro, México, Professor of Bussines Administration at Universidad Pedagógica y Tecnológica de Colombia, Sogamoso, Boyacá, Colombia, javier.gonzalezmillan@uptc.edu.co
[2]Doctora en Administración Universidad Autónoma de Querétaro, Profesora/Investigadora Escuela de Administración de Empresas, Facultad Sede Sogamoso, Universidad Pedagógica y Tecnológica de Colombia, Sogamoso, Investigadora grupo Management, miryamteresa.rodriguez@uptc.edu.co
[3]M.Sc, of in health and safety at work Universidad Nacional de Colombia, Bogotá, Colombia, Professor of mining engineering at Universidad Pedagógica y Tecnológica de Colombia, oscar.gonzalez02@uptc.edu.co

Abstracts

The public University is an actor capable of energizing local ecosystems to transform the territory, and open innovation is its instrument of connection with the environment. University open innovation was studied through factor analysis by the principal components' method in Mexico and Colombia. Data were collected in 54 research groups of two public universities. The analysis showed that the first six components explain 82.479% of the variance of the university open innovation model. The coincidences were evidenced in the factors that affect the general process of open innovation in Universities of Mexico and in Colombia. It was concluded that open innovation is a relevant mechanism for linking the University with its environment.

Keywords: Open innovation; linking University with its environment; Latin American public university; Linking University-enterprise.

Introduction

Several studies highlight the relevance of linking universities with their environment to contribute to the sustainable development of their sphere of influence (Etzkowitz, 2018). This literature shows the University as a primary actor in the development processes of the territory through the generation of new knowledge which flow outwards (Eroğlu & Ekmekçioğlu, 2018; Subtil, Soares, Nogueira & Colini, 2017). The university organization is linked to the environment through the social relevance of its educational offer, the exploitation of its research results with social impact and its innovation processes with social, public and productive sectors (González & Álvarez, 2019). A construct that has contributed to the explanation of this university link with its environment is the open innovation (OI); this one was proposed by Chesbrough (2006; 2017) as the process that facilitates a community to generate innovations from a dynamic

flow of knowledge inputs and outputs between the organization and its environment. This author evidenced that organizations needed to involve different internal and external actors if they intended to accelerate their innovation processes to create value in the organization and increase their competitiveness.

The object of study in this research is open innovation in the Latin American public University, which was analysed quantitatively in the framework of the social, environmental and productive complexity of Mexico and Colombia. The University of Guanajuato was analysed in the first study site; this is an important public institution in the central-Bajio region in Mexico. This region has had a strong industrial vocation, concentrates the most dynamic automotive cluster in Latin America, and has prioritized foreign direct investment as the basis of its development policy (Álvarez, Estrada & Palacios, 2018; Pérez, 2015). In the second study site, the Pedagogical and Technological University of Colombia was analysed; this is the most prestigious state public institution in the department of Boyacá. This region has had a strong productive vocation in the primary sector, and a very important economic history in the mining sector; Boyacá is a privileged region with natural resources, so it promotes tourism as a development base (González & Álvarez, 2019).

Under the central assumption that open innovation is a viable mechanism for the Latin American public University, this document was structured in four sections; in the first, the analytical framework that supports the research is exposed; in the second, the methodology used in the investigation is described; in the third, the findings in which the most significant categories and factors for the study were identified are shown. Finally, the conclusions are presented.

Analytical Framework

OI has been adopted by several types of organizations due to the high frequency of staff turnover –scientists, engineers, knowledge managers or technicians-; the mobility of these internal actors affects the innovation processes, since it causes an imbalance in the knowledge stocks and in the structural capital of the organization (De Fátima, dos Santos & Vieira, 2018; Ramírez & García, 2018). Additionally, Issa, Schumacher, Hatiboglu, Grob & Bauernhansl (2018) show that OI has developed rapidly due to the digital transformation that the environment has undergone in recent years, which makes easier to access external knowledge generators to shorten innovation cycles, optimize resources and intensify research. According to Kenichi (2018), the University's link with the productive environment has had a strong upward trend since the early 1990s; since 2002, a second upward momentum in the University-industry collaboration is manifested under an OI model.

Nowadays, organizations incorporate their knowledge stocks into continuous interaction flows with external knowledge to maintain a high level of innovation generation (Christiansen, 2018; Marcolin, Vezzetti & Montagna, 2017; Stanko, Fisher & Bogers, 2017). According to Chesbrough (2017), OI is multidirectional and based on collaboration, since the various knowledge inputs and outputs generated by innovation are multiple. Hu, Wang & Li (2017) recognize that the environment is an intense force that pulls organizations to combine their internal knowledge with the one generated in the environment to respond faster to its demands.

However, Ollila & Yström (2017) propose that the main challenge is to select and involve the different actors in the environment to share their knowledge.

The University, as a knowledge generating organization, intentionally uses two-way knowledge flows, from the inside to the outside and from the outside to the inside of the Institution (Cruz & Gómez, 2018). According to González & Álvarez (2019), university open innovation is based on three key factors; the first one refers to the inputs to the process of linking with the environment, both soft technology –innovative culture and knowledge management- and hard technology –technological infrastructure-; the second refers to the University support processes, both administrative management and relational capital and strategic alliances; the third refers to the results of research with social impact, both goods –papers, books, prototypes, patents, spin-offs, among others- and technological services.

University open innovation is strategic to generate interdisciplinary solutions to the different problems of the social, public and productive environment (Rauter, Globocnik, Perl-Vorbach & Baumgartner, 2018); in addition, OI is an increasingly everyday mechanism in the university settings due to the digital transformation in which they are immersed (Issa et al., 2018). OI allows strengthening relational activities to share information and generate knowledge (Bueno, 2018) and increase alliances to transmit knowledge to the environment and achieve meaningful interuniversity learning (Ramírez & García, 2018). According to Chesbrough (2017), OI motivates the organization to generate interdisciplinary solutions that respond to the social demands of the environment. Thus, the first working hypothesis was raised, as follows:

H1: OI promotes interdisciplinary work and it is energized based on the profile of the academic community to socially impact the university's environment.

The OI construct incorporated the category of relational capital based on the transfer of knowledge flows outwards, and the categories of social capital and knowledge capital based on the strength of knowledge stocks within (Lenart, 2016). Ferreira & Teixeira (2018) agree with this position and add that OI has the challenge of reconciling heterogeneous interests of the different actors involved in the process of linking the University with its environment. OI as a mechanism for linking the University's environment has grown based on the combination of internal and external knowledge (Silviana, 2018), and this influences the flexible construction of knowledge networks that respond to environmental requirements (Prieto, Montes, & Taborda, 2019).

According to Al-Belushi, Stead, Gray & Burgess (2018) and Giusti, Alberti & Belfanti (2018), OI allows the organizations involved to strengthen their knowledge networks and share scientific-technological risks; in addition, collaborative learning curves are accelerated, and competitive advantages are created. Sivam, Dieguez, Pinto & Silva (2019) complement that OI facilitates the construction of active and value-generating networks for the organizations involved and that it allows the construction of valuable knowledge in the process of collaboration. According to Chen, Huang, Zhao & Ping (2019), there are two OI networks: the first is of input, because it uses the knowledge available in the environment but does not collaborate with other organizations; the second is of output, because it collaborates with other organizations that generate or use external knowledge.

Based on Álvarez-Aros & Álvarez-Herrera (2018), there are three types of networks in university open innovation: incoming, outgoing and hybrid. In the first, the direction of the flow of knowledge is from the outside to the inside of the organization; in the second, the flow is directed from the interior towards the university's environment; hybrid OI refers to two-way parallel process. In this sense, the construction of skills to create collaborative knowledge with other organizations is indispensable due to environment that demands dynamic capabilities (López, Fernández, & Edwards, 2018). Therefore, the second working hypothesis was stated, as follows:

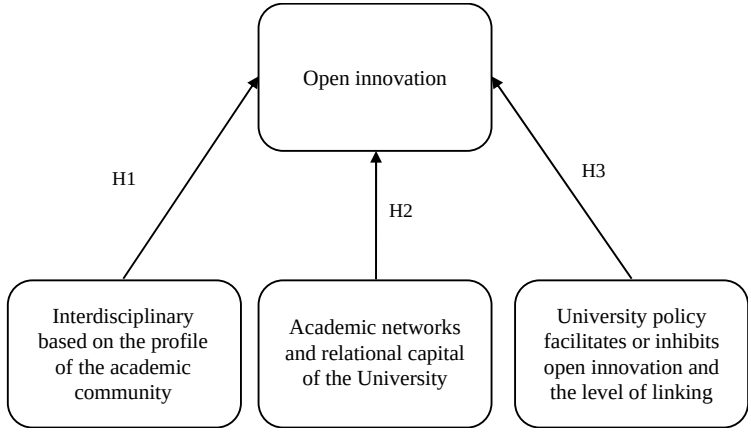
H2: OI facilitates the effectiveness of academic networks, and it strengthens the relational capital of the University to interact with its environment and meet its social demands.

Öberg & Alexander (2018) ensure that OI increases the complexity of the knowledge management process of the organizations involved; this requires greater organizational flexibility and rapid response speed in decision making. According to De Paulo, De Oliveira & Silveira (2017), the OI process is consolidated based on the strength and flexibility of the associative relationships of the management model of the organization and its innovation policy. This suggests that OI needs new models of knowledge generation and management, apart from new interaction platforms, to involve various key sectors in their processes (Robaczewska, Vanhaverbeke & Lorenz, 2019). Thus, the third working hypothesis was stated as follows:

H3: University policy facilitates or inhibits open innovation and the level of linking the University with its environment.

Bases on the three hypothesis, open innovation model is described in Figure 1.

Figure 1. Open innovation model



Source: by the authors.

Methods

The research is explanatory, and the methodological approach is quantitative. Factor analysis on previously determined variables was used to establish the relationship between them (Del Canto

& Silva, 2013), which allowed studying the factors that affect university open innovation and the relationships between them. The interpretation of the factor relationships allowed explaining some of the trends and behaviours of the variables under study (Hurtado, 2008; Méndez, 2008). The data collection instrument was designed based on the review of the literature; it was integrated of 51 questions categorized in four categories (table 1); Likert scale was used in seven points.

Table 1. General categorization of OI variables

Code	*Variable*	*Number of Items*	*Type of scale*
IE	Interaction with the environment	18	Quantitative / Ordinal
CIA	Profile of the academic community	9	Quantitative / Ordinal
GITI	Research and technology management	9	Quantitative / Ordinal
PIU	University Innovation Policy	15	Quantitative / Ordinal

Data were collected in 27 of 112 research groups of the University of Guanajuato in Mexico (UMX); 14 were randomly selected on the León campus and 13 on the Irapuato-Salamanca campus. In the Pedagogical and Technological University of Colombia (UCO) 27 of 136 research groups were randomly selected –12 in Tunja campus, 3 in Duitama, 2 in Chiquinquira y 10 in Sogamoso-.

The collected data were systematized, and these were modelled in RStudio v.1.0.153; the correlation between ungrouped data was quantified to validate the feasibility of proceeding with the principal components method; it was validated that there were no missing data and the factor analysis was continued; finally, it was proceeded with the extraction of common factors. This was complemented by the systematic observation of the university open innovation process in both institutions, which allowed enriching the interpretation of the results.

Analysis Of Results

Instrument reliability and descriptive statistical

The instrument's Cronbach alpha was calculated; its reliability was 0,927. The general descriptions were calculated (table 2). The dispersion measures were analysed to determine the level of variability of the data with respect to the average; these showed their consistency.

Table 2. General descriptions

Global descriptive		**UMX**		**UCO**	
Minimum	1,616	Minimum	1,730	Minimum	1,480
Q1	3,221	Q1	3,666	Q1	2,874
Median	4,619	Median	5,355	Median	3,881
Mean	4,340	Mean	4,797	Mean	3,946
Q3	5,745	Q3	5,777	Q3	5,234
Maximum	6,601	Maximum	6,629	Maximum	6,560

The global average was found to be 4,34 with a standard deviation of 1,92; this implies a high level of assertiveness in the responses. UMX reported an average of 4,79 and UCO of 3,94. This allows to visualize a more favourable trend towards university open innovation at UMX. The Q1 was 3,22; this means that only 25% of the research groups do not carry out direct activities related

to the environment. The Q1 for UMX was 3,66 and for UCO 2,87. This allows to visualize greater heterogeneity in the research groups in Colombia. The Q3 resulted in 5,74 –Q3 for UMX was 5,77 and for UCO it was 5,23-. Therefore, the proximity of this 25% to the maximum value of seven points on the scale shows the potential development of university open innovation practices.

Factor analysis by the principal components' method

The analysis of common factors was carried out by the principal components method to extract the most relevant ones to explain the model (Díaz, 2002). The relevance of the factorial analysis was assessed by the test of Kaiser-Meyer-Olkin (KMO) and Bartlett's sphericity test (Méndez & Macias, 2007). The KMO test gave a result of 0,974 with a significance level of 0,000, and Bartlett's sphericity test reported 25565,232; therefore, it is assumed that it is possible to process the data by factor analysis.

The proportions of the variance were calculated for each of the factors and for the total scale; according to the Kaizen's principle, if the variability of the original data is 1, then the variability of the main components will be 1; this is detailed in the appendix 1, where the variance of all components is displayed. The first fourteen components accumulate 99,0% of the variance; however, the first three components have greater variance, and the next eleven do not provide further explanation. Table 3 displays only the first nine components; it shows that the first six components explain 82,479% of the variance in the model of university open innovation.

Table 3. Importance of the principal components

	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9
Standard deviation	7.8432	4.2139	3.62389	2.94311	2.91964	2.43202	2.30274	2.07287	2.01627
Proportion of Variance	0.4393	0.1268	0.09378	0.06185	0.06087	0.04224	0.03786	0.03068	0.02903
Cumulative Proportion	0.4393	0.5661	0.65983	0.72168	0.78255	0.82479	0.86265	0.89333	0.92236

The global boxplot was analysed; the missing data were validated in main components, and it is confirmed that the components with greater variance are the first three. Table 4 shows what defines each of the first six components and their variance (82,479% of the variability). The decision was made to work with the first four components to lose as little information as possible (72,17% of the variance).

Table 4. Definition of the first six components

Component	ID	VAR	Description
PC1	CIA01	43, 93%	The research group uses outside ideas and knowledge, intensively.
PC2	GITI03	12,68%	The members of the research group are invited to listen proposals of project from the productive, social and public sectors.
PC3	IE04	9.38%	In collective academic products, one or more authors are from other national universities.
PC4	IE12	6,18%	Members of the research group participate in technology networks.
PC5	PIU03	6,08%	Open innovation and the linking with the environment are promoted, and it are motivated by some researchers (individual interest).
PC6	PIU13	4,22%	The university organization has been modified, in recent years, to facilitate the management of knowledge (copyright, patents, utility models, among others).

According to these results, a tendency to strengthen interdisciplinary work with sectors of the University's environment and with external academic institutions is highlighted; this coincides with Ramírez & García (2018), they ensure that the collaborative construction of knowledge makes OI possible, while suggesting that relational capital is a relevant factor in the development of OI to boost the flows and stocks of technological, social or academic knowledge.

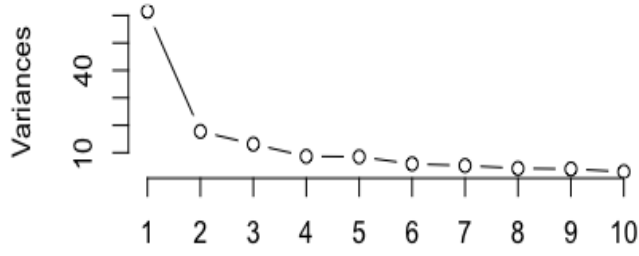
Components five and six exhibit the individual effort of researchers and the challenges of intellectual property management. Likewise, these highlight the relevance of the ways of linking to the environment and university policies that facilitate or inhibit OI through dynamic knowledge flows and organizational capital.

This agrees with Gimenez & Beukel (2018), because they propose that OI is a strategic axis in the organization, which is implemented through a policy and management that combines closed and open innovation with external and internal knowledge flows to accelerate its linking with its environment; likewise, the relevance of the intellectual property management between involved actors in the OI process is confirmed (Da Silva, 2017).

Confirmatory Factor Analysis

Based on the above, the confirmatory factor analysis was made through the main axis factorization method with varimax rotation; this model sediments the variables that most explain each of the components of the OI model. Graphically, figure 2 confirms that the first four components are the ones that contribute most to the explanation of the model; approximately 75,0% of the variability is explained by them.

Figure 2. Sedimentation of main components



Source: by the authors based on data collected in the fieldwork.

Table 5 shows the results of breaking down the incident variables into the first four main components. In PC1 (intensive use of ideas and external knowledge), the first variable that has a significant impact is the one which refers to the participation of researchers in projects in collaboration with organizations of its environment; the second refers to academic productivity in collaboration with external institutions, and the relational capital of the University. In PC2 (interest in projects of the productive, social and public environment), the first significant variable is the perception of OI as a valuable university mechanism; the second is the

involvement of the university community with civil society and the public sector; in addition to university policies that facilitate collaboration with the environment.

According to Cruz & Gómez (2018), open innovation processes should strengthen collaboration, cooperation, co-creation and co-innovation schemes with the university's environment to impact economic, social, cultural and environmental development, since the university is the key to energize ecosystems and strengthen local and regional development (Álvarez & Palacios, 2018; Robaczewska, et al., 2019).

Table 5. Explanatory variables by main component

Component	Code	*Description*
PC1	CIA02	The research group participates in project with organizations from the productive, social or public sectors.
	CIA07	Relevance of collective academic production.
	IE06	Internal projects funded by sources outside the university with external participants.
	IE09	External projects funded by sources outside the university with external participants.
PC2	GITI05	Non-monetary academic benefits of open innovation and the link with the environment.
	IE16	Research group participates in activities with associations, business chambers or civil society organizations.
	IE17	Research group participates in activities with public sector.
	PIU05	The university organization facilitates the collaboration with other universities or research centres.
PC3	CIA02	The research group participates in project with organizations from the productive, social or public sectors.
	CIA07	Relevance of collective academic production.
	IE07	Internal projects funded by sources inside the university with external participants.
	IE13	The research group participates in interdisciplinary projects with industrial sector, it funded by public resources.
	IE14	The research group participates in disciplinary projects with industrial sector, it funded by public resources.
PC4	GITI07	Competences about knowledge valuation to manage open innovation and linkage with the environment.
	GITI09	Competences about protection mechanisms of knowledge to manage open innovation and linkage with the environment.
	IE08	Participation of the research group in projects as guests by internal groups of university.
	IE09	Participation of the research group in projects as guests by groups of external universities.

PIU12	The university organization facilitates the open innovation and linking the University with its environment.
PIU13	The university organization facilitates the management of knowledge (copyright, patents, utility models, among others).

In PC3 (collective academic productivity with external institutions) the participation of researchers in projects and the generation of products with external collaborators stands out; these are linked to mechanisms of motivation and institutional stimulation. PC4 (dynamic participation in knowledge networks) was explained by three dimensions: the valuation of knowledge, the competences for its valuation and the university policies that facilitate or inhibit the management of intellectual property.

Discussion Of Results

According to Marquerie, Castaño & Piedrahita (2018), the work of research groups to develop innovation processes is linked to university policies; if physical, economic and technological resources are provided, then these policies will stimulate collaborative work in networks with other organizations and institutions to strengthen relational capital of the University (Lenart, 2016; Sivam et al., 2019).

Based on the findings, the first working hypothesis is confirmed; university OI promotes interdisciplinary work and it is energized based on the profile of the academic community to socially impact the university's environment. Likewise, evidence was found not to reject the second hypothesis; OI facilitates the effectiveness of academic networks and strengthens the relational capital of the University to interact with its environment. Finally, university policy does facilitate or inhibit open innovation and the level of linking the University with the environment; therefore, the third hypothesis is not rejected.

Based on the pattern of responses, the heterogeneity of the observations was analysed (Wang & Hanges, 2011; Muthén, 2001). From the level of centrality and variability of the responses, it is inferred that both institutions have similar potential behaviours; the differences were found in their way of linking with the environment by areas of knowledge. In UMX its strength in the areas of engineering and health was evidenced. In UCO its dynamism in economic-administrative sciences and electronic engineering was highlighted.

Conclusions

It is concluded that OI is a relevant mechanism for linking the University with its environment because it causes the generation and application of interdisciplinary knowledge with social, productive, academic and technological impact. In addition, OI affects the relational capital of the University, and the creation and strength of its knowledge networks. However, university OI will work if and only if there is an operational innovation policy that strengthens the link with the environment to respond to its social demands.

The research findings showed coincidences in the factors that influence the general process of university OI in Mexico and in Colombia; however, there are differences in the paths to build their relationship capital with the environment. The sectors with the greatest impact in UMX are engineering and health sciences; in UCO are electronics and economic-administrative sciences.

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