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The impact of the university-enterprise linkage on scientific research, technological development and innovation in companies in the Mexican state of Aguascalientes

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Abstract: The linkage between Higher Education Institutions (HEIs) and the productive sector becomes relevant because the HEIs, as generators of knowledge, have had the task of carrying out scientific research, technological development (R&D) and innovation projects. Previous research has analyzed the university-enterprise linkage through the results of joint work or the number of contracts signed. However, research papers that measure the impact of university-enterprise in R&D and innovation in the Mexican context have not been found. Therefore, this paper analyzes and measures the impact of linkages between university and enterprise in R&D and innovation. The methodological design was based on the application of surveys to executives in 40 science and technology enterprises in the state of Aguascalientes. Finally, the results showed that such linkages had a positive and significant impact on R&D and innovation. Key words: linkage between university and enterprise, research and development (R&D), innovation..

Introduction

Knowledge has gained importance worldwide as one of the strategic resources for the economic growth of any country (OECD, 2011). In this respect, knowledge is generated through the creation of links between different agents and institutions (Amaro *et al*., 2009). The generation and accumulation of knowledge does not depend only on companies, but also oh higher education institutions (HEIs) and public and/or private research centers (PRC) (Coombs y Metcalfe, 1998).

In Mexico, the government has developed public policies that involve the productive sector and the HEIs through linkage projects with public sector support (PND, 2013; PDI, 2013; PECITI,

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2014). However, HEIs are not ranked first in the transfer of knowledge by companies, since only 0.9% of Mexican companies have signed linkage agreements with HEIs (FCCYT, 2012; PDI, 2013; CONACYT, 2014).

Likewise, the promotion of innovation has allowed enterprises to carry out projects aimed at innovation (FCCYT, 2014). Alcalá (2006) points out that the interests behind linkages for innovation are different for both actors. For companies, innovation is a major factor in their competitiveness. For HEIs, it represents a direct way of fulfilling their function of outreach towards the economic and social sectors (Alcalá *et al*., 2013).

Research background

The conceptualization of the linkage between universities and companies has evolved through their relationship with science and technology activities due to the generation, use, application and exploitation of knowledge beyond the realm of teaching, which allows it to be an essential factor for local, regional and national innovation capabilities (Amaro *et al*., 2009; Taboada, 2011; Casalet, 2012; Hernández *et al*., 2013).

Science and technology enterprises are those that carry out Scientific Research and Technological Development activities (R&D), which sometimes originate in projects carried out with HEIs and CPI that have specialized human resources and have invested on innovation (Alcalá *et al*., 2013).

Innovation requires public and private investment. For this reason, governments play an important role on the promotion of investments on R&D and innovation (OECD-FCCYT, 2012). There are different sources of financing for R&D (Dutrénit *et al*., 2006), such as governmental programs, funds and grants for innovation (FCCYT, 2014).

R&D is considered the most important channel of knowledge for science and technology enterprises. In Mexico, companies that conduct innovation projects with governmental support must belong to the Registry of Science and Technology Institutions and Enterprises (RENIECYT) in order to access any program of the National Council of Science and Technology (CONACYT) (FCCYT, 2014).

One of the objectives of the Special Program of Science and Technology (PECITI, 2014) addresses the need to build linkages between universities and enterprises with the aim of transferring knowledge. This linkage can be achieved through different linkage mechanisms or forms (Ramos, 2013; Feria, 2009; Dutrénit *et al*., 2006):

- R&D Projects.
- Joint innovation projects.

Finally, authors like Feria (2009) claim there is currently very little linkage between the scientific and the entrepreneurial sectors on R&D and innovation projects.

Theoretical perspective

The fourfold helix, a theoretical approach founded on a theory of economy based on knowledge, postulates that enterprises, HEIs, government and the civil society must collaborate in the search of benefits for all (Ezkowitz and Leydesdorff, 2000; Brundenius *et al*., 2008; Torres *et al*., 2011).

A number of researchers have discussed the need for linkage mechanisms between HEIs and the productive sector in order to achieve a linkage based on the fourfold helix approach (Casalet, 2012; Dutrénit, 2009; Feria, 2009; Ramos, 2013; Casas *et al*., 2003; Ezkowitz and Leydesdorff, 2000; Brundenius *et al*., 2008; Torres *et al*., 2011).

Based on the above, it is believed that an increase in R&D and innovation is possible through a collaborative effort of universities, the productive sector, the government, and civil society. In short, the main idea is to integrate the links among the four actors with the aim of capitalizing knowledge.

Problem and research objective

In recent years, the University-Enterprise Linkage (UEL) has been seen as a growth strategy for the productive sector (Hernández *et al*., 2013; Alvarado, 2009; Amaro *et al*., 2009; Alcalá, 2006). Other researchers consider UEL important for developed countries, but weak in Mexico (Casalet, 2012; Corona *et al*., 2011; Taboada, 2011; Dutrénit, 2009; FCCYT, 2012; PDI, 2013).

Earlier research has concluded that UEL can be promoted in Mexico by providing economic support through the access to public funding (PECITI, 2014; PND, 2013; PDI, 2013). An example of such funding is the existence of programs, funds and grants to promote innovation (FCCYT, 2014).

However, no research has been found which studies the influence of UEL on R&D and innovation in the Mexican context. The general objective of our research is therefore to analyze and measure the impact of UEL on R&D and innovation in science and technology enterprises in the Mexican state of Aguascalientes.

University-enterprise linkage, scientific research, technological development and innovation

As a part of the analysis of the UEL variable, scientific research is considered one of a number of scientific and technological activities, defined as the systematic actions related to the generation, divulgation, and application of scientific and technological knowledge (PECITI, 2014).

Most basic research is conducted at universities and public research organizations. The support of the public sector for such research is fundamental, because it is essential to develop

scientific and technological knowledge, as well as the human capital that can make innovation benefit society and the economy (OECD-FCCYT, 2012).

The knowledge that is transferred, transmitted or exchanged, and that becomes the foundation on which improvements on products and processes are generated, creates new technological developments, promotes innovative activities, and produces new knowledge through networks, which have repercussions on productive activities and the generation of knowledge (Casas, 2003).

R&D is generated both in enterprises and in HEIs. Innovation, however, is developed and applied directly in enterprises (Stezano, 2012; Torres *et al*., 2011). The OECD (2011) defines innovation as the introduction in the market of a new or improved product or process, or the development of new organizational or commercialization techniques.

For companies, innovation is one of the main factors of their competitiveness, since it has an economic value. However, "for HEIs it represents a direct way of fulfilling their third substantial function of outreach towards the social and economic sectors which are relevant for national, regional and local development" (Alcalá, 2006: 23).

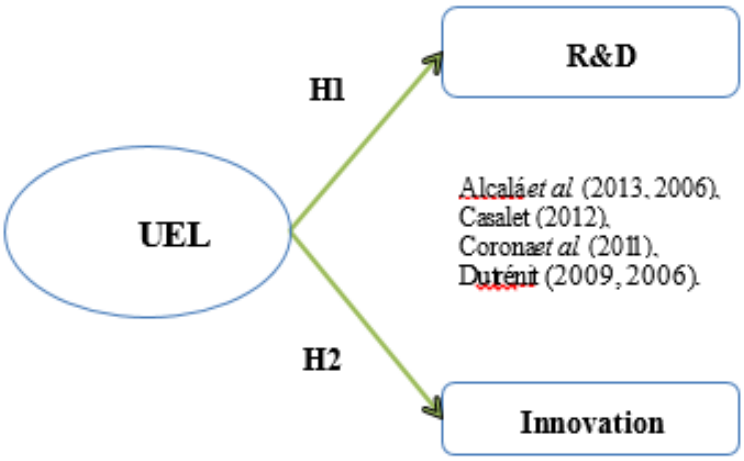
Thus, the study of the UEL becomes especially relevant for the study of R&D and innovation activities.

Methodology

Our research was explanatory and causal. It was conducted using quantitative methodology by correlating the independent variable UEL with dependent variables R&D and innovation. The theoretical relationship between such variables can be appreciated in the works of authors such as Ramos (2013), Feria (2009), and Dutrénit *et al*. (2006).

Based on earlier research, a conceptual model proposal was created to represent the variables and their relationships. Figure 1 shows variables UEL, R&D, and innovation.

Figure 1. Conceptual Research Model Proposal



Source: Based on the authors mentioned above.

Figure 1 presents the independent variable UEL and the dependent variables R&D and innovation. In order to formulate the research hypotheses it is necessary to verify first which are the research questions, since "research can address a part of the problem descriptively, and another part in an explanatory way" (Hernández *et al*., 2010: 107).

Based on the formulation of the problem, the general research question is a causal question: "What is the impact of the UEL on R&D and innovation?" Thus, a causal hypothesis is formulated for that question.

Causal hypotheses

> do not only postulate one or more relationships between two or more variables and the way in which they are manifested, but also propose a sense of understanding of the relationships. This sense may be more or less complete, depending on the number of variables included, but all these hypotheses establish cause-and-effect relationships (Hernández *et al*., 2010: 100).

The following are the research hypotheses based on earlier research, which postulate there is a relationship between the UEL and R&D and innovation (Alcalá *et al*., 2013, 2006; Casalet, 2012; Corona *et al*., 2011; Dutrénit, 2009, 2006).

> H1: UEL projects have an impact on R&D in science and technology enterprises in Aguascalientes, Mexico.
>
> H2: UEL projects have an impact on innovation in science and technology enterprises in Aguascalientes, Mexico.

The case of Aguascalientes

The Mexican state of Aguascalientes has experienced significant growth in the amounts of government support programs to which it has had access. The Scientific and Technological Advisory Forum (FCCYT), both in its Reports (2010) and in the National Ranking of Science, Technology and Innovation (2013), points out that Aguascalientes is placed above the national median regarding funds and programs for innovation (FCCYT, 2014; 2012).

The unit of analysis is the number of science and technology companies found in Aguascalientes' RENIECYT. We also took into account micro, small, medium-sized and big enterprises in different sectors of the economy.

We took into account the companies registered in RENIECYT in 2016, since they are the ones that have access to governmental programs and funds through CONACYT. The total number of companies in the productive sector was 140 (SIICYT, 2016).

Table 1. Companies in Aguascalientes' RENIECYT

Sector of the economy	Number of companies	Percentage
Agriculture, livestock, forestry, fishing and hunting	4	2.86%
Wholesale and retail commerce	3	2.14%
Construction	6	4.29%
Electricity, water and gas supply through ducts to the end consumer	1	0.71%
Generation, transmission and distribution of electricity	4	2.86%
Food, tobacco, beverages and textile processing and manufacturing industry	9	6.43%
Wood, paper and oil derivate manufacturing industry	6	4.29%
Machinery and equipment manufacturing industry	23	16.43%
Manufacturing industries	21	15.00%
Mass media information	4	2.86%
Other services, except for government activities	2	1.43%
Support to businesses and waste disposal services	4	2.86%
Health and social welfare services	1	0.71%
Educational services	2	1.43%
Professional, scientific and technical services	49	35.00%
Transportation, mail and storage	1	0.71%
TOTAL	**140**	**100%**

Source: Based on SIICYT (2016).

Table 1 shows the total number of enterprises in Aguascalientes' RENIECYT, according to the sector of the economy to which they belong. From these companies, the professional, scientific and technical service sector accounted for 35% of the total number, followed by the machinery and equipment manufacturing industry (16.43%) and the manufacturing industries (15%).

The empirical study was conducted through questionnaires applied to those in charge of scientific and technological activities in the companies. The information was collected on a single occasion from a specific group of companies, so this study may be defined as a transversal one.

Our methodological design allowed us to apply questionnaires in a non-probabilistic sampling that was convenient due to the practical impossibility of locating all of the companies registered in the RENIECYT. The search and location of the companies was done using the directories of the National Institute of Statistics, Geography and Information Technology (INEGI), web browsers, and the local press.

The field work was conducted under some restrictions, some of them due to the location of the companies listed in Aguascalientes' RENIECYT, since 20% of the companies could not be located in the directories of INEGI, web browsers, or local press.

The remaining companies were contacted by e-mail, telephone calls or in the addresses given. We were able to contact 40 companies throughout the state in the following industrial parks: Parque Industrial de Valle de Aguascalientes, Parque Industrial San Francisco de los Romo, Parque Industrial El Chichimeco en Jesús María, Ciudad Industrial, Pabellón de Arteaga, and the north and center of Aguascalientes City.

The questionnaire applied was based on the OECD and FCCYT reports (2014), as well as the INEGI's Survey on Technological Research and Development (ESIDET) (ESIDET, 2012). After all the information was collected, the results were analyzed.

Results

From the 40 enterprises we obtained, first of all, their general information: name or business name, number of employees, name of the person who answered the questionnaire and his/her position in the company, as well as the registration number in the RENIECYT. Table 2 shows the distribution of the 40 companies according to size and sector of the economy.

Table 2. Companies by size and sector of the economy

Sector of the economy	Size of company	Number of companies
Machinery and equipment manufacturing industry	Big	4
Machinery and equipment manufacturing industry	Medium-sized	5
Machinery and equipment manufacturing industry	Small	2
Food, tobacco, beverages and textile processing and manufacturing industry	Medium-sized	8
Wood, paper and oil derivate manufacturing and chemical industry	Medium-sized	1
Wood, paper and oil derivate manufacturing and chemical industry	Small	3
Agriculture, livestock, forestry, fishing and hunting	Medium-sized	1
Agriculture, livestock, forestry, fishing and hunting	Small	2
Construction	Medium-sized	1
Construction	Small	3
Professional, scientific and technical services	Big	1
Professional, scientific and technical services	Small	5
Support to businesses, waste disposal and remedial services	Small	1
Mining	Big	1
Transportation, mail and storage	Big	1
Other services except for government activities	Small	1
TOTAL		**40**

Source: Based on the information obtained in the questionnaires.

Table 2 shows the participation of different kinds of manufacturing industry: machinery and equipment, food, tobacco, beverages and textiles, as well as wood, paper, oil derivates and chemical industry.

First we analyze the descriptive statistics of the results obtained between UEL R&D and innovation. The data base was processed using the SPSS statistics software version 21 and analyzed.

Table 3. Contingency UEL, R&D and innovation

	R&D		Innovation		Total
	No	Yes	No	Yes	
UEL No	14	0	14	0	**14**
UEL Yes	12	14	12	14	**26**
Total	**26**	**14**	**26**	**14**	**40**

Source: Based on the results obtained using SPSS software.

Table 3 shows the relationship between the variables, where 14 companies that conducted linkage activities had an impact on R&D and innovation. 14 companies that did not conduct such activities saw no results, and 12 companies conducted linkage activities but observed no impact on their R&D and innovation activities.

Table 4. Chi-squared test

	Value	gl	Asymptotic Significance (bilateral)	Exact Significance (bilateral)	Exact Significance (unilateral)
Pearson's chi squared	22,969	1	0,000		
Correction for continuity	19,588	1	0,000		
Likelihood ratio	29,399	1	0,000		
Fisher's exact test				0,000	0,000
Linear-by-linear association	22, 203	1	0,000		
N of valid cases	40				

Source: Based on the results obtained using SPSS software.

The aim of Table 4 is to test the null hypothesis. Since the frequency distribution was homogeneous and the level of significance lower than 0.001, we rejected the hypothesis that UEL projects have no influence on R&D and innovation I science and technology companies in Aguascalientes.

Thus, since the null hypothesis was rejected, we looked for a measurement that allowed us to quantify the degree of dependence of the variables. A possible mechanism is simple linear regression, which helps to explore further the research hypothesis presented in the general objective of this research.

Based on a review of the literature,

> simple regression is another procedure to predict data … the minimum ratio is 5 to 1, the desirable level is between 15 and 20 observations for each independent variable. When this level is reached, results should be generalizable if the sample size is representative. In cases where the sample available fails to meet these criteria, the researcher must ensure the validation of the generalization of the results (Hair *et al.*, 1999: 160; Aldás *et al.*, 2004: 78).

Hence, a simple linear regression analysis was made:

Table 5. Simple linear regression

Models	R	R squared	R square corrected	Typical estimation error
1 – 2	0,875	0,766	0,757	0,250

Source: Based on the results obtained using SPSS software.

Table 5 shows the correlation coefficient, which shows that UEL explains up to 75.7% the R&D and innovation activities.

Table 6. ANOVA

Models	Sum of squares	gl	Root mean square	F	Significance
Regression	5,717	1	5,717	91,467	0,000
Residual	1,750	28	0,063		
Total	7,467	29			

Source: Based on the results obtained using SPSS software.

Table 6 ANOVA, or analysis of variance, shows that the whole of variables UEL and R&D and innovation activities show no significant differences, since they all have a lower than 0.01 significance. The quality of the analysis is therefore confirmed.

Based on the analysis of the results, the following section presents the conclusions and some final thoughts on our research.

Conclusions

Our research aimed to analyze and measure the impact of UEL on R&D and innovation in science and technology companies of the state of Aguascalientes. Based on the results of our statistical analysis, we conclude that UEL explains up to 75.7% the R&D and innovation in these companies.

This can be understood as an effect of the fact that most companies that sought to establish linkages with HEIs did so in order to develop an innovative project with government support. This resulted in the improvement of a process, product, organization or market through innovation, with most participants coming from the manufacturing industry.

Our contact with entrepreneurs also provided information on specific features of the UEL environment in Aguascalientes. Overall, some answers stand out regarding issues related to the state government policies, the lack of promotion and divulgation of linkage by HEIs, the availability of research professors to work on projects according to industry timetables, as well as the interest of HEIs in meeting deadlines.

The following are some recommendations for both government and HEIs.

- Government:
  - More support of the state government to UEL.
  - Creating of a state policy to obtain funds for R&D and innovation.
  - Creating funds for research professors to work on UEL projects.
  - Promoting the participation and initiatives of society at large.

- HEIs:
  - Proposing measures to speed up administrative procedures and paperwork.
  - Providing incentives for all the actors involved in UEL projects.
  - Promoting especially the UEL on R&D and innovation activities.
  - Participation and initiatives of students and research professors to conduct UEL projects.

In this respect, it would be convenient to have closer collaboration and work among the four helixes: government, enterprise, HEIs and society at large in order to find mechanisms that enable local, regional and national economic growth and development.

Finally, our research points to future lines of research, since our findings were limited to statistical analysis to measure the impact of UEL on R&D and innovation. Such research could rely on qualitative methods to provide further information on key variables and actors. It would also be useful to design a method for the organizational analysis of linkage, by analyzing UEL models as a whole.

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